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Cornelius Herstatt
Rajnish Tiwari *Editors*

Lead Market India

Key Elements and Corporate Perspectives for Frugal Innovations

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यस्तु सर्वाणि भूतानि आत्मन्येवानुपश्यति
सर्वभूतेषु चात्मानं ततो न विजुगुप्सते ॥

"He who sees all living beings in self; and the self in all beings and forms; feels no hatred for anyone."
(Wisdom from ancient India; sutra attributed to the Ishaavsashya Upanishad)

Preface

Our interest in India goes back to our early research on Research and Development (R&D) offshoring, a topic which moved many companies in the early years of the new millennium. In those days, firms primarily looked at India as an extended workbench for developing and manufacturing products or parts thereof. We started to travel frequently to India and interviewed many decision-makers in German and Indian firms, government agencies, representatives of chambers of commerce, and other industry associations. These discussions showed us quickly that to consider India merely as an extended workbench was incomplete. To fully realize the potential of India, companies would instead need to enter with a much stronger commitment. This could only be achieved through an intensive presence in the country, a deep understanding of the specific context through intensive local market research, and collaborative product development on-site.

This broader understanding was the trigger to start our research program "Global Innovation" in 2006. Since then, we have been fortunate enough to have kept on discovering new insights and developments with a high socioeconomic relevance for relevant stakeholders. The phenomenon of "frugal innovation" was one such discovery that we made early on and decided to go deeper into it. In 2013, we set up a Center for Frugal Innovation (CFI) at our institute with the purpose of "conducting and promoting research, consulting, and education in the field of affordable and sustainable innovations." Today, we have research partners in academia, government, and the corporate world spread across many nations. Germany's Federal Ministry of Education and Research (BMBF) has included the topic of frugal innovations in its current round of funding program called "Innovations- und Technikanalyse" (English: Innovation and Technology Analysis) and CFI partners with BMBF in this. Our engagement with India and frugal innovations has produced several publications, also in book form with Springer.

It is, therefore, a very special occasion to be placing our institute's fourth book on a topic explicitly related to India, all of them with Springer, to our prospective readers. For this, we wish to thank all people who have directly or indirectly contributed to the successful completion of this work. First and foremost, our

sincere thanks go to all coauthors of contributed chapters. All colleagues at the institute and CFI have supported the efforts involved with this publication and have motivated us whenever needed. Due to space constraints, it is not possible to mention all of them, but special thanks are due to Dr. Katharina Kalogerakis, who is, and has been, not only a part of several projects at CFI and has coauthored two of the book sections but has also chipped in with readings and corrections whenever needed, and to Dr. Stephan Buse, who has been involved in different capacities in many studies presented here. Sincere thanks are also due to our student assistants Mithun Kumaar Jayavarthanavelu and Vinoth Mathimaran, who have provided absolutely valuable assistance with all manuscript-related tasks with great enthusiasm. Carola Tiedemann and Andreas Kühl have provided wonderful support with administrative and IT-related issues, respectively. The list would remain incomplete without mentioning the persistent support of Prashanth Mahagaonkar, friend and editor at Springer Verlag, who was throughout this project (and also beyond it) available for a thought-provoking and motivating discussion. We would also like to express our sincere thanks to Ms. Kalpana Balaraman, project coordinator, at Springer for bearing with us patiently and providing a dignified and excellent professional support in the face of all challenges.

Rajnish Tiwari would also like to sincerely thank Claussen Simon Foundation for supporting his research at TUHH with a generous grant. Finally, family members and personal friends have, of course, been a constant and the most important source of motivation and inspiration. We would like to express our deep felt gratefulness for their unwavering, continuous, and unconditional support. Thank you for being there!

Notwithstanding the fabulous support granted by a great number of people to the successful completion of this project, any errors and omissions, needless to say, remain entirely ours.

Hamburg, Germany — Cornelius Herstatt
Hamburg, Germany — Rajnish Tiwari
July 2016

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India's Emergence as a Lead Market for Frugal Innovations: An Introduction to the Theme and to the Contributed Volume

Cornelius Herstatt and Rajnish Tiwari

The present work "Lead Market India: Key Elements and Corporate Perspectives for Frugal Innovations" in a way, documents the evolution of the research on globalization of innovation not only at our institute but also at a macro level. In 2006, when we decided to set up a research project "global innovation" to investigate internationalization of research and development (R&D) and its transcendence towards globalization of innovation, the world still looked a little different. Even if India was registering impressive growth in gross domestic product (GDP) and attracting large amounts of foreign direct investments (FDI), considerable skepticism remained with regard to India's potential to create innovations to cater to the rising demand and aspirations of its people. The dominant logic then was still that "lead markets"—markets that provide key impetuses for globally successful innovations in an industry or industry segment over a sustained period of time—can only emerge and exist in the economically developed world (Beise, 2001; Beise & Cleff, 2004; Beise & Gemünden, 2004; Gerybadze & Reger, 1999; Ghoshal & Bartlett, 1990; Jänicke, 2005; Porter, 1990). A country in the developing world, such as India, was therefore not seen as a lead market or even having the potential to become one in near future.

This presumption was also perfectly logical. After all, there must be certain affluence and the corresponding purchasing power to pay for the newest and best technologies. Products and services that result from high-cost R&D efforts are expensive at the beginning of the product lifecycle. Innovations in a lead market would attempt to cater to the anticipatory needs of a "sophisticated" customer base under the presumption that these needs would diffuse globally and the lead market—an industrialized nation with high international visibility such as the United States of America, Germany or Japan—would act as a role model for customers

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elsewhere. So, in a sense, innovations, to a good extent, were driven by technological development intending to induce demand from affluent customers and aimed to serve the top of the economic pyramid.

This logic could be traced back to the theory of international product lifecycle (Vernon, 1966). However, the late C.K. Prahalad and Kenneth Lieberthal in a Harvard Business Review article once compared such practices to "corporate imperialism" (Prahalad & Lieberthal, 1998) and advised firms to develop products that would better suit the demand conditions of the masses in the emerging economies. Later, Prahalad and some other well-known researchers postulated the concept of the "Bottom of the Pyramid" (Hart & Christensen, 2002; Prahalad, 2004; Prahalad & Hart, 2002), which—despite some shortcomings (see, e.g., Karnani, 2007; Karamchandani, Kubzansky, and Lalwani, 2011; Tiwari & Herstatt, 2012b)—acted as an eye-opener for many a manager and academic, for it forcefully illustrated the vast opportunities that lied unattended in exactly those segments that many big corporates had considered absolutely unattractive till then.

However, much water has flowed down the Ganges and other rivers since then. As our present book is set in the context of India, let us stick to the subcontinent, though. Our early research brought to our notice some very interesting cases of constraints-induced, low-cost innovations from India such as the *Gramateller*, solar-powered cash-dispensers (IBEF, n.d.), the *Tata Nano*, the world's cheapest car (van den Waeyenberg & Hens, 2008), high-quality and low-cost open-heart surgeries (Economist, 2009) or self-generating power supply systems (Gulyani, 1999). Business press coined a specific term "indovation" (Lamont, 2010; Menon, 2011; Mitra, 2011) to refer to such cost-effective and efficient solutions coming from the land of many paradoxes, such as high poverty contrasted with a growing, big middle class; often poor public infrastructure coupled with the world-class facilities of many individual firms and institutions; and illiteracy in the face of a large skilled workforce. A survey of foreign firms engaged in R&D activities conducted by us in collaboration with the Hawaii-based East-West Center in 2007 revealed that the "unsaturated, emerging middle-class consumer market of India is growing into the role of 'lead market' for certain products especially electronic goods and automotives with basic functionality, less over-engineering, durability and affordable prices" (Herstatt, Tiwari, Ernst, & Buse, 2008).

Then, price-sensitivity of the Indian market, all of a sudden, turned from a liability to a key asset. In a globalized world there was an increasing demand for low-cost, "good enough" innovations even if they came from an emerging economy such as India; notwithstanding the negative "country of origin" effects which a classic, marketing text-book would have probably prophesized (cf. Johansson, Douglas, & Nonaka, 1985; Kotler & Gertner, 2002; Shimp, Samiee, & Madden, 1993). There were far too-many similarities in the demand- and supply-side structures in many other parts of the developing world, largely neglected by big multinational companies (MNCs) in their product planning, to cause a snob effect and reject such cost-effective, charming solutions to the day-to-day problems. On the other hand, significant cost pressures and lack of skilled manpower have made MNCs more open to integrating emerging economies, such as India, into their

innovation value chains. Kumar and Puranam (2012) have documented several "invisible" component-level innovations that have enabled a broader, successful innovation without coming into limelight. These findings were, thus, early precursors of a phenomenon which came to be known as "reverse innovation" in due course (Govindarajan & Ramamurti, 2011; Sarkar, 2011).

Our own studies (see, e.g., Buse, Tiwari, & Herstatt, 2010; Herstatt et al., 2008; Tiwari & Herstatt, 2010, 2011, 2012a, 2012b; Tiwari, Buse, & Herstatt, 2007; Tiwari, Herstatt, & Ranawat, 2011) continued studying the interplay of the forces of globalization in India, a large, emerging economy. By 2014 we had published results that indicated that a lead market had emerged there for a particular category of innovations. This lead market was for products that, in principle, enabled "affordable excellence" and came into existence primarily on account of three reasons (Tiwari & Herstatt, 2014):

(a) The size of the potential demand in the domestic market was enough to overcompensate the negative effects of lower per-capita income.
(b) The country's eco-system was endowed with significant technological capabilities (both domestic and MNC-owned) that enabled large chunks of product development to be performed in Open Global Innovation Networks (OGINs) reducing development costs as well as market and technological uncertainty.
(c) The country had become a part of the global village. On account of its membership in multilateral organizations such as World Trade Organization (WTO), companies producing in India could export their products and services to the wider world.

Based on these studies we have proposed certain changes to the lead market model and have defined them as follows (Tiwari & Herstatt, 2014: 205):

> A lead market is a national market, which primarily on account of the size of its domestic demand, its access to technological capabilities and its embeddedness in the global economy provides key innovation impetus to a particular category of products.

This modified understanding of lead markets has already found application in the relevant research community (Jänicke, 2014; Quitzow, Walz, Köhler, & Rennings, 2014) and builds the basis of our understanding for lead markets in this work.

As regards innovations, we discovered that there has been a multitude of terms to define those cost-effective, good-enough solutions which enable affordable excellence. Some scholars have called them "Jugaad" (e.g., Holtbrügge, 2013; Radjou, Prabhu, & Ahuja, 2012), but this term has been prone to criticism on account of its focus on "make-do" solutions (Birtchnell, 2011; Krishnan, 2010; Tiwari, Fischer, & Kalogerakis, 2016). Other terms such as "Indovation", "Grassroot Innovation", "Bottom of the Pyramid" or "Inclusive Innovation" have emphasized certain aspects of such solutions but have not given a comprehensive definition (Tiwari & Herstatt, 2014). The term "reverse innovation" too presupposes that these products or services will *necessarily* move in due course from east to west. Nevertheless, there has to be no such theoretical, binding requirement for a cost-effective product from an emerging economy to succeed worldwide, especially in

the industrialized world. It may be entirely sufficient for it to succeed in certain countries or maybe just in its home market. Moreover, frugal innovations do not have to take place in the context of developing economies. There is no reason why a firm in an industrialised nation cannot come up with a frugal solution for the needs of its customers at home or abroad. We, therefore, differentiate between these two concepts. Solutions that enable affordable excellence while being focused on core functionalities are referred to as "frugal innovations" (Agarwal & Brem, 2012; Brem & Ivens, 2013; Zeschky, Winterhalter, & Gassmann, 2014). These can overlap in their scope with any or all of the terms mentioned above. For the purpose of this work we use the following definition proposed by Tiwari et al. (2016: 17):

> "Frugal innovations seek to create attractive value propositions for their targeted customer groups by focusing on core functionalities and thus minimizing the use of material and financial resources in the complete value chain. They substantially reduce the cost of usage and/or ownership while fulfilling or even exceeding prescribed quality standards."

In this work we present results of 10 selected studies that have been conducted at our institute in relation to India, its lead market-potential for certain innovations and its penchant for frugal innovations. The volume has four sections. Section A consists of the chapters, "Frugal Innovation: An Assessment of Scholarly Discourse, Trends and Potential Societal Implications", and "Frugality in Indian Context: What Makes India a Lead Market for Affordable Excellence?". Thereby, it lays the foundation for the present volume by connecting India to the themes of frugal innovations and lead markets. Section B connects frugality to innovations at grassroots and for the "Bottom of the Pyramid" (BOP). It comprises of chapters "Emerging Patterns of Grassroots Innovations", "Consumer Innovation at the Bottom of the Indian Economic Pyramid" and "Lessons from Low-Cost Healthcare Innovations for the Base-of the Pyramid Markets: How Incumbents Can Systematically Create Disruptive Innovations". Theme of section C is to connect frugal innovations with inventive analogies and disruption. Chapters "Developing Frugal Innovations with Inventive Analogies: Preliminary Evidence from Innovations in India" and "Made in India for the World: An Empirical Investigation into Novelty and Nature of Innovations", which comprise this section, provide the reader with a larger perspective on the making of frugal innovations. The final section D, containing chapters "India's Electronic Voting Machines (EVMs): Social Construction of a 'Frugal' Innovation"', "Renewable Energy in India: Policies, Trends and Foreign Direct Investments in Research and Development", and "Commercial Vehicle Industry in India: An Investigation of the Innovation and Business Trends (2000–2015)", introduces the reader to actual practices of frugal innovations in three selected industrial fields, i.e. voting machines, renewable energies, and commercial vehicles. Individual chapters, based on their abstracts, are described below.

After this brief introduction, the second chapter by Rajnish Tiwari, Luise Fischer and Katharina Kalogerakis deals with the topic "Frugal Innovation: An Assessment of Scholarly Discourse, Trends and Potential Societal Implications". This paper follows a two-fold objective: (a) It seeks to establish the theoretical antecedents of frugal innovation by examining the scholarly discourse; and (b) It attempts to

generate hypotheses about its long-term relevance by examining historical trends of frugality and their disappearance. Based upon an extensive literature review and some preliminary primary data the authors propose a new definition for frugal innovation and hypothesize that frugality was a key social value with positive associations before the era of unprecedented prosperity in the industrialized world led to saturated markets and inter alia to feature-driven competition and over-consumption of resources. They posit that the new ground realities, e.g., economic downturn in the industrialized world and the rapidly rising consumption in the economically developing world, are expected to turn frugality, once again, into an important societal value and frugal innovation into a critical success factor in mid-term future.

Third chapter by Rajnish Tiwari is concerned with "Frugality in Indian Context: What Makes India a Lead Market for Affordable Excellence?". The author posits that, India, apparently, has acquired the role of a pioneer for innovations that aim at combining affordability with excellence, cutting across sectoral boundaries and poses the question: what is it that makes India a forerunner for an innovation paradigm with increasing global relevance? He then goes on propose that the "lead market" theory can explain to a quite large extent the attractiveness of India for frugal solutions. This paper, apart from dwelling on the concept of lead markets and its application in the context of frugal innovations in India, also presents some qualitative results of an empirical survey conducted by the author with Indian students that underscore the role of culture as a key determinant for the acceptance of frugal innovation by relevant stakeholders.

Fourth chapter by Anup Nair, Rajnish Tiwari and Stephan Buse investigates the "Emerging Patterns of Grassroots Innovations". The study examines the dimensions and trends which make Grassroot Innovations unique, factors which govern and influence them and then suggests how these innovations can be commercialized. It is based on in-depth case studies which were gathered during field work with the National Innovation Foundation in India. The data illustrates how factors like education, age, occupation and sector influence the triggers and the outcomes of Grassroot Innovations. It also demonstrates how individuals, institutions and firms could collaborate to commercialize these products and solutions.

Fifth chapter by Sarah Praceus and Cornelius Herstatt takes a closer look at "Consumer Innovation at the Bottom of the Indian Economic Pyramid". They specifically address the question whether user innovation exists at the Bottom of the Economic Pyramid (BOP) and at what quality levels. They analyze patterns and characteristics of a large sample of innovations developed by people living at the Indian BOP collected by the Indian National Innovation Foundation. They compare these innovations to consumer innovations in the developed world and examine effects of demographic, knowledge and context factors on innovation activity and the outcome. The authors find similarities with consumer innovation in the developed world and at the same time adaptations to the BOP context, e.g. fulfillment of rather basic necessities than hobby-related needs. The study further shows that consumer innovations are a good starting point for firms seeking solutions for BOP markets. It provides insights on identifying promising consumer innovators at the BOP.

Sixth chapter by Aditi Ramdorai and Cornelius Herstatt addresses the topic "Lessons from Low-Cost Healthcare Innovations for the Base-of the Pyramid Markets: How Incumbents Can Systematically Create Disruptive Innovations". The authors analyze firms' ability to successfully drive disruptive innovations from within the organization through the lens of organizational ambidexterity. While consensus exists on the need for ambidexterity, the underlying mechanisms remain under-theorized. The authors seek to address this general gap in the research of organizational ambidexterity. This work looks at the mechanisms of ambidexterity at GE Healthcare to help explain its ability in successfully hosting sustaining and disruptive innovations from within its boundaries.

Seventh chapter by Rajnish Tiwari, Katharina Kalogerakis and Cornelius Herstatt deals with the issue of "Developing Frugal Innovations with Inventive Analogies: Preliminary Evidence from Innovations in India". The aim of this paper is to examine the use of inventive analogies in creating frugal solutions and their impact on project results. Based on three explorative case studies from India, the authors generate preliminary evidence that analogies can have a significant impact on the successful development of innovations in environments characterized by severe resource constraints and high price-sensitivity. Besides, useful insights for companies that want to exploit market opportunities in the emerging economies are generated.

Eighth chapter by Daniel Tobias Hagenau and Rajnish Tiwari is titled "Made in India for the World: An Empirical Investigation into Novelty and Nature of Innovations". The study develops a consistent innovation typology for categorizing large data samples from a variety of existing literature. It then describes and finally evaluates a sample of 178 innovations for the Indian market based on 38 different criteria. The results show a considerable amount of radical innovations and innovations with disruptive potential among the sample and a special concentration on small- and micro-sized innovators from India. It confirms previous suggestions that India is especially focused on innovations within the software and electronics engineering sectors. The results also support the importance of local knowledge and 'social capital' for successful disruptive innovation. Finally, a perceivable increase in the technology orientation of innovations by foreign companies suggests a continuous build-up of local technology-competence and foreign trust in the same.

Ninth chapter by Maximilian Herstatt and Cornelius Herstatt is concerned with "India's Electronic Voting Machines (EVMs): Social Construction of a 'Frugal' Innovation'". This paper takes a closer look at the Indian voting technology and the discussions around alleged security holes. Using a theoretical model called Social Construction of Technology (SCOT), the authors argue that after the EVM was adopted in India, different social groups interpreted the EVM in diverse ways. They show the SCOT model to be helpful for structuring the controversy in a fruitful manner. The research questions addressed here are: How did the ECI and EVM manufacturers react to allegations that EVMs are vulnerable to manipulation? How was the election practice affected?

Tenth chapter by Aditya Prasad Bhagwat and Rajnish Tiwari is titled "Renewable Energy in India: Policies, Trends and Foreign Direct Investments in Research and Development". Properly utilizing the potential of renewable energy (RE) is necessary for achieving sustainable development in a fast growing and demographically young country like India. They argue that intensified research and development (R&D) and business activity in the domestic sector is required to ensure the spread, affordability and efficacy of RE according to local needs. At the same time, collaborative activities on an international level are important to finance growth, gain technical knowledge and promote cost effective manufacturing in a rapidly connecting and increasingly inter-dependent world. They study different types of collaborations, e.g. in manufacturing and R&D, to understand the trends in India's RE sector, while capturing a larger picture.

Eleventh chapter by Bhimsen Dattatraya Phadnis and Rajnish Tiwari takes a closer look at the "Commercial Vehicle Industry in India: An Investigation of the Innovation and Business Trends (2000–2015)". India has advanced to the position of the fifth largest commercial vehicle (CV) producer in the world. The CV industry has grown significantly since the turn of the new millennium increasing its sales more than fourfolds in the process, despite suffering some external shocks in this period. In this study the authors analyze the innovation and business profile of India's CV industry. The study is based on indicators such as sales and revenues, R&D expenditure, types of innovations and their impact, open innovation activities, product portfolio and product selling points. The study reveals that Indian CV manufacturers have relied mainly on product innovations compared to other types of innovations for growth, and most of these product innovations have resulted in incremental improvements of products. In addition, firms made various open innovation moves which helped them to acquire new markets and increase their revenue.

We hope that this book will be useful not only for those wishing to study India and her economic prospects but also for a large section of relevant stakeholders in India and abroad. The diverse studies in this contributed volume address multiple dimensions like innovations, economic growth, social welfare, and sustainability. These dimensions have high relevance for businesses, academia, policymakers and other stakeholders. By showcasing developments in India we also hope to make a humble contribution to the social and scholarly discourse on the role of frugality and resource-efficiency in a world where available natural resources are finite, but innovation policies, at least in the industrialized world, have been more input- than output-oriented in the recent past. Developing nations need to chalk their own course and do not necessarily have to emulate this dominant model.

If this work can showcase that excellence can be connected to affordability; that it is possible to place the interests of the end-consumer in the forefront during product development; and if we can contribute a small spark to ignite a social debate on whether and how the frugal approach can be *re*-incorporated in the business and innovation strategies of firms and organizations worldwide, then we would consider our research to have been fruitful.

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References

Agarwal, N., & Brem, A. (2012). Frugal and reverse innovation – Literature overview and case study insights from a German MNC in India and China. In B. Katzi, T. Holzmann, K. Sailer, & K. D. Thoben (Eds.), *Proceedings of the 2012 18th international conference on Engineering, Technology and Innovation*. IEEE: Munich.

Beise, M. (2001). *Lead markets: Country-specific success factors of the global diffusion of innovations*. Heidelberg: Physica-Verlag.

Beise, M., & Cleff, T. (2004). Assessing the lead market potential of countries for innovation projects. *Journal of International Management, 10*, 453–477.

Beise, M., & Gemünden, H. G. (2004). Lead markets: A new framework for the international diffusion of innovation. *Management International Review, 44*(Special Issue 2004/03), 83–102.

Birtchnell, T. (2011). Jugaad as systemic risk and disruptive innovation in India. *Contemporary South Asia, 19*(4), 357–372.

Brem, A., & Ivens, B. (2013). Do frugal and reverse innovation foster sustainability? Introduction of a conceptual framework. *Journal of Technology Management for Growing Economies, 4*(2), 31–50.

Buse, S., Tiwari, R., & Herstatt, C. (2010). Global innovation: An answer to mitigate barriers to innovation in small and medium-sized enterprises. *International Journal of Innovation and Technology Management, 7*(3), 215–227.

Economist. (2009, April 18). Health care in India: Lessons from a frugal innovator. *The Economist*, pp. 67–68.

Gerybadze, A., & Reger, G. (1999). Globalization of R&D: Recent changes in the management of innovation in transnational corporations. *Research Policy, 28*(2–3), 251–274.

Ghoshal, S., & Bartlett, C. A. (1990). The multinational corporation as an interorganizational network. *Academy of Management Review, 15*(4), 603–625.

Govindarajan, V., & Ramamurti, R. (2011). Reverse innovation, emerging markets, and global strategy. *Global Strategy Journal, 1*(3/4), 191–205.

Gulyani, S. (1999). Innovating with infrastructure: How India's largest carmaker copes with poor electricity supply. *World Development, 27*(10), 1749–1768.

Hart, S. L., & Christensen, C. M. (2002). The great leap: Driving innovation from the base of the pyramid. *MIT Sloan Management Review, 44*(1), 51–56.

Herstatt, C., Tiwari, R., Ernst, D., & Buse, S. (2008). *India's national innovation system: Key elements and corporate perspectives*. Economics Series, Working Paper No. 96, Honolulu, Hawaii, East-West Center.

Holtbrügge, D. (2013). Indigenous management research. *Management International Review, 53*, 1–11.

IBEF. (n.d.). *Solar powered ATM to increase banking penetration*. Retrieved February 22, 2012, from http://www.india-at-davos.ibef.org/download/Solar-powered-ATM-to-increase-banking-penetration.pdf

Jänicke, M. (2005). Trend-setters in environmental policy: the character and role of pioneer countries. *European Environment, 15*, 129–142.

Jänicke, M. (2014). Entwicklungsländer als Vorreiter der Nachhaltigkeit? Frugale Technik. *Ökologisches Wirtschaften, 29*(1), 30–36.

Johansson, J. K., Douglas, S. P., & Nonaka, I. (1985). Assessing the impact of country of origin on product evaluations: A new methodological perspective. *Journal of Marketing Research, 22* (4), 388–396.

Karnani, A. (2007). The mirage of marketing to the bottom of the pyramid: How the private sector can help alleviate poverty. *California Management Review, 49*(4), 90–111.

Karamchandani, A., Kubzansky, M., & Lalwani, N. (2011). Is the bottom of the pyramid really for you. *Harvard Business Review, 89*(3), 107–111.

Kotler, P., & Gertner, D. (2002). Country as brand, products, and beyond: A place marketing and brand management perspective. *Journal of Brand Management, 9*(4/5), 249–261.

Krishnan, R. T. (2010). *From Jugaad to systematic innovation: The challenge for India*. Bangalore: Utpreraka Foundation.

Kumar, N., & Puranam, P. (2012). *India inside: The emerging innovation challenge to the West*. Boston: Harvard Business Review Press.

Lamont, J. (2010, June 14). The age of 'Indovation' dawns. *The Financial Times*, London.

Menon, N. (2011, November 26). Indovation or Indian Jugaad goes abroad. *Economic Times*, Mumbai, p. 5.

Mitra, M. (2011, November 25). Indovation nation: Creating products in India for the Indian market. *Economic Times*, Mumbai, p. 5.

Porter, M. E. (1990). *The competitive advantage of nations*. New York: Free Press.

Prahalad, C. K. (2004). *The fortune at the bottom of the pyramid: Eradicating poverty through profits*. Upper Saddle River, NJ: Wharton School Publishing.

Prahalad, C. K., & Hart, S. L. (2002). The fortune at the bottom of the pyramid. *Strategy + Business, Spring*(22), 2–14.

Prahalad, C. K., & Lieberthal, K. (1998). The end of corporate imperialism. *Harvard Business Review, 76*(4), 68–79.

Quitzow, R., Walz, R., Köhler, J., & Rennings, K. (2014). The concept of "Lead Markets" revisited: Contribution to environmental innovation theory. *Environmental Innovation and Societal Transitions, 10*, 4–19.

Radjou, N., Prabhu, J., & Ahuja, S. (2012). *Jugaad innovation: Think frugal, be flexible, generate breakthrough growth*. San Francisco: Jossey-Bass.

Sarkar, M. B. (2011). Moving forward by going in reverse: Emerging trends in global innovation and knowledge strategies. *Global Strategy Journal, 1*(3/4), 237–242.

Shimp, T. A., Samiee, S., & Madden, T. J. (1993). Countries and their products: A cognitive structure perspective. *Journal of the Academy of Marketing Science, 21*(4), 323–330.

Tiwari, R., Buse, S., & Herstatt, C. (2007). *Innovation via global route: Proposing a reference model for chances and challenges of global innovation processes*. Second International Conference on Management of Globally Distributed work, Indian Institute of Management, Bangalore.

Tiwari, R., Fischer, L., & Kalogerakis, K. (2016). *Frugal innovation in scholarly and social discourse: An assessment of trends and potential societal implications*. Joint working paper of Fraunhofer MOEZ Leipzig and Hamburg University of Technology in the BMBF-ITA project, Leipzig/Hamburg.

Tiwari, R., & Herstatt, C. (2010). The emergence of Indian multinational enterprises: An empirical study of the motives, current status, and trends of Indian investment in Germany. In K. P. Sauvant, J. P. Pradhan, A. Chatterjee, & B. Harley (Eds.), *The rise of Indian multinationals: Perspectives on Indian outward foreign direct investment* (pp. 233–253). New York: Palgrave Macmillan.

Tiwari, R., & Herstatt, C. (2011). *Role of lead market factors in globalization of innovation: Emerging evidence from India and its implications* (pp. 475–483). IEEE International Technology Management Conference (IEEE-ITMC), IEEE, San José (USA).

Tiwari, R., & Herstatt, C. (2012a). Assessing India's lead market potential for cost-effective innovations. *Journal of Indian Business Research, 4*(2), 97–115.

Tiwari, R., & Herstatt, C. (2012b). Frugal innovation: A global networks' perspective. *Die Unternehmung, 66*(3), 245–274.

Tiwari, R., & Herstatt, C. (2014). *Aiming big with small cars: Emergence of a lead market in India*. Heidelberg: Springer, pp. 29–32.

Tiwari, R., Herstatt, C., & Ranawat, M. (2011). Benevolent benefactor or insensitive regulator? Tracing the role of government policies in the development of India's automobile industry. *Policy Studies,* 58.

van den Waeyenberg, S., & Hens, L. (2008). Crossing the bridge to poverty, with low-cost cars. *Journal of Consumer Marketing, 25*(7), 439–445.

Vernon, R. (1966). International investment and international trade in the product cycle. *Quarterly Journal of Economics, 80*(2), 190–207.

Zeschky, M. B., Winterhalter, S., & Gassmann, O. (2014). From cost to frugal and reverse innovation: Mapping the field and implications for global competitiveness. *Research Technology Management, 57*(4), 20–27.

Part I
Connecting India to Frugal Innovations and Lead Market

Frugal Innovation: An Assessment of Scholarly Discourse, Trends and Potential Societal Implications

Rajnish Tiwari, Luise Fischer, and Katharina Kalogerakis

1 Introduction

The topic of frugal innovation is increasingly gaining relevance in the social as well as scholarly discourse (Bound & Thornton, 2012; Radjou & Prabhu, 2015; Ramdorai & Herstatt, 2015). Frugal innovations have been generally associated with emerging economies where there are large groups of unserved consumers with unmet needs (see, e.g., Brem & Ivens, 2013; Jänicke, 2014; Tiwari & Herstatt, 2012a; Zeschky, Widenmayer, & Gassmann, 2011). But there is now increasing evidence that this phenomenon is getting relevant also in the industrialized nations potentially affecting long-term competitiveness of domestic firms from the developed world not only overseas but also at home (Tiwari & Herstatt, 2013; Zweck et al., 2015). These developments have already led to some initiatives by state institutions in Germany and the European Union to examine the potential mid-to-long term implications of this phenomenon (see, e.g., BMBF, 2014; European Commission, 2015).

At the same time, however, theoretical antecedents of frugal innovation remain largely unclear as of today. The phenomenon of frugal innovation was initially observed in the fast-growing economies of the developing world, such as China and India, and subsequently reported by the business press (see, e.g., Economist, 2009; Lamont, 2010b; Sehgal, Dehoff, & Panneer, 2010). Many scholarly publications that followed have tried to comprehend and define this phenomenon while remaining settled in the context of emerging economies (Tiwari & Herstatt,

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2012a; Zeschky et al., 2011). A deeper going investigation of theoretical antecedents and classification has so far been scarce (see, e.g., Simula, Hossain, & Halme, 2015), despite some notable efforts (e.g. Bhatti, 2012; Herstatt & Tiwari, 2015; Tiwari & Herstatt, 2014; Zeschky, Winterhalter, & Gassmann, 2014b). An in-depth understanding of the theoretical roots is, however, necessary both to understand the mid-to-long term implications of frugal innovation for the various societal stakeholders as well as to assess the longevity of this phenomenon itself.

This paper is part of a study carried out to assess the potentials of frugal innovation and its probable implications in the specific context of Germany.[1] The study is being carried out under the aegis of the ITA programme of the German Federal Ministry of Education and Research (BMBF). In this paper we primarily follow three objectives: (a) We examine the scholarly discourse on frugal innovation to establish its theoretical antecedents; (b) We attempt to identify historical trends of frugality, and their disappearance, to generate hypotheses about its long-term relevance; (c) We seek to understand the social discourse on frugal innovation in the German context to assess its social perception.

Based upon an extensive literature review we hypothesize that frugality was a key social value before the era of unprecedented prosperity in the industrialized world led to saturated markets and inter alia to feature-driven competition (Nowlis & Simonson, 1996) and over-consumption of resources (Bocken & Short, 2016). However, results from an expert workshop and three focus groups held in January 2016 within the framework of this project indicate that new ground realities, e.g., economic downturn in the industrialized world and the rapidly rising consumption in the economically developing world, are expected by many stakeholders to turn frugality into a positive social value and frugal innovation into a critical success factor in the future again.

This paper is structured along the following lines. After this brief introduction we take a closer look at the philosophical context of frugality and prepare the background of Sect. 3, in which we examine the theoretical antecedents of frugal innovation by first examining the origins and perception of frugality in the political economy and then connecting it to other related disciplines. Here frugality is also analysed in the context of innovation management. Results of a workshop and three focus groups are presented in Sect. 4. The paper ends with conclusions in Sect. 5.[2]

[1]This study presents the results achieved in Work Package 1 of the BMBF-supported study "Potenziale, Herausforderungen und gesellschaftliche Relevanz frugaler Innovationen in Deutschland im Kontext des globalen Innovationswettbewerbs" (English title: Potentials, Challenges and Societal Relevance of Frugal Innovations for Germany in the Context of Global Innovation Competition).

[2]This study is the result of a coordinated and shared work between both institutional partners. Fraunhofer MOEZ has been in the lead for the work the philosophical context of frugality (Sect. 2), whereas TUHH has been primarily responsible for working out the theoretical/scientific context of frugal innovation (Sect. 3) and the evaluation of the workshop results (Sect. 4).

2 Philosophical Context of Frugality

> The heart is great which shows moderation in the midst of prosperity.
> (Lucius Annaeus Seneca, c. 4 BC–AD 65)

Having shown that the frugal innovation and frugality are increasingly present in the social discourse in Germany, we turn our attention to the historical perception and relevance of frugality. This is done with the purpose of identifying factors that eventually affect the acceptance of frugality in the society and that, thus, may affect the longevity of the phenomenon of frugal innovation. Based on research of secondary academic literature, the section particularly highlights the role of frugality in ancient times, during the Enlightenment, and since the industrial revolution. It thus points to the importance of investigating the history and geography of frugality, especially when aiming to better understand its relation to questions of innovation, progress, and sustainability. The section provides an insight into the current state of research; it does not claim to be a comprehensive history and geography of the notion "frugality"; such a project would go beyond the scope and purpose of this section.

Whilst a trend towards frugal innovation might seem very recent, the overarching notion of frugality is, in fact, an ancient one. The concept of frugality has philosophical and religious roots both in Western and Eastern traditions. Philosophers and theologians of ancient times promoted temperance, moderation, and self-restraint. Epicurean ethics and Stoic philosophers stressed the benefits of a frugal life. Epicurus emphasised the importance of limiting desires, avoiding lust, and living with moderation (see, e.g., Avotins, 1977; Bouckaert, Opdebeeck, & Zsolnai, 2008). Stoic philosophers, such as Cicero and Seneca, favoured a stoic lifestyle based on simplicity and self-restraint. Also Aristoteles is famous for his arguments on the golden mean and ethics of moderation (see, e.g., Ims & Jakobsen, 2008; Koselleck, 1994). In eastern philosophy, particularly Buddhism and Neo-Confucianism appreciated frugality and material simplicity as virtues (see Lai, 2013; Schumacher, 1966). Lao-Tzu, founder of Daoism, is known for his writings on frugality and simplicity (Low, 2009).

Thoughts on frugality were also popular during the Enlightenment. Particularly at the advent of mercantilism and industrialisation, European Enlightenment thinkers discussed the role of self-control and the passions, of moderation, and frugality. Munzel (2012) has suggested that Immanuel Kant, the founder of German idealism, saw frugality as a way to happiness and simplicity as the order of nature (see, e.g., Meld Shell & Velkley, 2012; Munzel, 2012). Kant distinguished between different kinds of frugality and favoured the virtue of frugality out of choice and based on rational thinking: "The state of the individual who is satisfied because he does not know the amenities is one of simple frugality, while the state of the individual who knows them but voluntarily dispenses with them because he fears to unrest to which they give rise, is one of wise frugality" (Kant cited after Munzel, 2012: 171). Adam Smith thought of frugality as a form of virtuous behaviour; he praised the "frugal man" both in *Theory of Moral Sentiments* (1759) and in *An*

Inquiry into the Nature and Causes of the Wealth of Nations (1776; see also Brown, 1994). Eighteenth-century French philosophers discussed the early industries and debated their moral consequences (Schui, 2005: 124–126). Similarly, also religious groups promoted frugality, as Max Weber has shown in *The Protestant Ethic and the Spirit of Captialism* (Weber, 1904).

During late eighteenth century then, thinkers developed stereotypes of the German and European (especially also English and French) middle class based on Enlightenment theories of civilization and progress fused with ideas of ancient philosophers, such as the Aristotelian tradition (Koselleck, 1994: 210). Frugality and a moderate lifestyle were central elements of these theories and sociological descriptions. The frugal stereotype of the emerging middle class only somewhat lost its importance during the first half of the nineteenth century, especially in the years between the Congress of Vienna and the Revolution in 1848. Also popular during the eighteenth century were utopias and projections into the future including moral projections. The Enlightenment philosopher Adam Weishaupt (1748–1830) argued in 1787 that in future societies, living on a fully populated earth, virtues based on frugality and moderation would not only be a matter of choice but a necessary condition to guarantee peace and social stability (cited after Neugebauer-Wölk, 1996: 184).

With the beginning of the consumer society and the growing appraisal of consumerism amongst a majority of the population in the industrialised countries frugality began to vanish as a virtue in the twentieth century. A certain generation influenced by the wars however still kept their frugal virtues (Budde, 2009; Münkel, 2009). During the last decades, some authors have cautioned against the growth of consumerism. Ernst Friedrich Schumacher promoted a philosophy of "enoughness" in his book *Small is Beautiful: A Study of Economics As If People Mattered* (Schumacher, 1973). As part of his philosophy of "enoughness", Schumacher (1966) coined the notion of "Buddhist Economics". Recent scholarship has advanced this notion. Zsolnai (2008) has suggested Schumacher's Buddhist economics as an alternative to current Western economics: as an economic system not based on profit-making, but centred on benefiting the human character, i.e., not to multiply but to simplify desires (Zsolnai, 2008).

Frugality has also been highlighted since the beginning of the discourse on sustainability. Jonas (1985) has argued for frugality as "a rather old virtue that has lost its importance rather recently." Jonas has pointed to the frugal virtue both in ancient times and in religious texts and teachings. For Jonas, frugality is promoted through upbringing and education. Even more recently, scholars across disciplines have begun to revisit questions concerning the relationship between ethics and economics. Bouckaert et al. (2008) in their edited volume *Frugality: Rebalancing Material and Spiritual Values in Economic Life* discuss the interplay between ethics and economics—the economics of frugality—and suggests that frugality has by many been seen as "contrary to consumerism and wild economic growth" but is, in fact, "not contrary to economic rationality as such" (Bouckaert et al., 2008: viii). Frugality is a global good, "a necessary condition for global sustainability and intergenerational justice" in the world of the twenty-first century, so the

authors (Bouckaert et al., 2008: viii). Frugality is then promoted as an ideal, a lifestyle based on "low material consumption and a simple lifestyle" (Bouckaert et al., 2008: 3).

In this section, we have pointed to the historical role of the concept of frugality since ancient times. We have briefly highlighted its role in ancient Western and Eastern societies, during the European Enlightenment and in relation to early economic debates, and since the industrial revolution. Given the scope of this matter, this section only intended to raise awareness and to offer a few insights into the historical role of frugality. We suggest attending further research to explore the complex history and geography of frugality and economic activity in greater detail.

3 Theoretical Context of Frugal Innovations

This section deals with the investigation of the theoretical base of frugal innovations. Before going into relevant theoretical considerations it is, however, necessary to understand the semantics of this term, which consists of two words. In its dictionary meaning[3] the word "frugal" is an adjective that denotes characteristics of being "economical in use or expenditure; prudently saving or sparing; not wasteful; entailing little expense; requiring few resources". It is derived from Latin *frūgālis* that implies being economical and can be broken into two parts (a) *frūg-* (stem of *frūx* produce, fruit) + *-ālis* (pertaining to). Therefore, it can be also interpreted as being juicy, healthy or useful. Its dictionary antonyms are "wasteful; extravagant; luxurious; lavish", whereas economical and thrifty are its synonyms. Frugal, economical and thrifty all "imply careful and saving use of resources", e.g., prudent planning in the disposition of resources so as to avoid unnecessary waste or expense. "Innovation" in its dictionary meaning refers to "introduction of new things or methods".[4] For the purpose of this study we define innovations, in keeping with the Oslo Manual, as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organisation or external relations" (OECD, 2005: 46).

The term "frugal innovation" being a relatively recent phenomenon does not, as yet, have a single, widely accepted definition. In the following we showcase a few published definitions that have been also adopted, to some extent, in the scientific community:

"It is not simply about reducing cost, but can also involve increasing the affordability power of the buyer through income generation, saving, or alternative payment schemes. Frugal innovation may also mean that the outcome involves

[3] See, http://www.dictionary.com/browse/frugal?s=t, last retrieved: 14.02.2016.

[4] See, http://www.dictionary.com/browse/innovation?s=t, last retrieved: 14.02.2016.

building local entrepreneurship, capacity building and self-reliance or sustainability" (Bhatti, 2012: 18).

"[F]rugal innovations are not re-engineered solutions but products or services developed for very specific applications in resource constrained environments" (Zeschky, Winterhalter, & Gassmann, 2014a: 23).

Frugal innovations can be characterized as "new or significantly improved products (both goods and services), processes, or marketing and organizational methods that seek to minimize the use of material and financial resources in the complete value chain (development, manufacturing, distribution, consumption, and disposal) with the objective of significantly reducing the total cost of ownership and/or usage while fulfilling or even exceeding certain pre-defined criteria of acceptable quality standards" (Tiwari & Herstatt, 2014: 30).

"Frugal innovation is the ability to 'do more with less'—that is, to create significantly more business and social value while minimizing the use of diminishing resources such as energy, capital and time" (Radjou & Prabhu, 2015: xv).

These definitions show that the term "frugal innovation" has been used to refer to a very broad range of innovative solutions, from social innovations by non-profit organizations up to for-profit products aimed at the poor, and from grassroots entrepreneurs in the informal sectors of rural areas in the developing countries to highly formalized product development by multinational corporations (MNCs) targeted at price-sensitive customers. Nevertheless, the scholarly discourse so far has been rather on the practical sides of the phenomenon ("what", "why") so that only few scholarly works have tried to provide a theoretical base ("how") to it (see, e.g., Bhatti, 2012). In this section we present the result of an in-depth literature review to first examine the origins and perception of frugality in scholarly discourse and then to identify the streams of thought leading to frugal innovation. Finally, we briefly differentiate between terms that are often used synonymously by some.

3.1 Frugality in Political Economy

The use of (synonym) nouns "thrift" and "frugality" and adjectives "thrifty" and "frugal" can be traced back in the economic thought right up to the works of Adam Smith, the founding father of political economy. Praising frugality in his *Wealth of Nations* Smith wrote, "[.] the credit of a frugal and thriving man increases much faster than his stock" (Smith, 1776: 131). At another place he saw frugality as one of the preconditions to raise the standard of living:

> "[.] a workman, even of the lowest and poorest order, if he is frugal and industrious, may enjoy a greater share of the necessaries and conveniences of life than it is possible for a savage to acquire" (Smith, 1776: IX).

All in all, there are 38 references to frugality in this work pointing to the great emphasis that he put on it as a core value in business enterprises and private lives of

his day. Smith saw frugality as a golden middle-path that allowed efficient and effective use of resources in life, as can be seen in this statement in his *Theory of Moral Sentiments* (Smith, 1759: 274):

> "[..] the virtue of frugality lies in a middle between avarice and profusion, of which the one consists in an excess, the other in a defect of the proper attention to the objects of self-interest."

Also neoclassical economists like Alfred Marshall (1842–1924) continued to see thrift/frugality as a positive characteristic. In a specific context he mentioned, "thrift and the knowledge of practical details" in combination with industriousness as key to success (Marshall, 1890: 309). He too placed thrift in the middle of the two extremities, extravagance and miserliness (Marshall, 1890). While Marshall criticised the "wastefulness that is found now among some classes in our own country", he also warned against miserliness as a barrier to economic growth and hampering the standard of living (Marshall, 1890: 225). Interestingly, Marshall saw institutional arbitrariness, e.g., in matters of taxation, leading to a loss of frugality in society, as people would rather not prefer to save and accumulate wealth, which might be taken away (1890: 734). Similarly, he mentioned poor law and order as well as too-liberal welfare policies causing negative incentives for a frugal living (Marshall, 1890: 226).

Summing up, it can said that a *healthy* frugality in daily life was considered virtuous, which contradicts the negative connotation it seems to have basically acquired in the post-war period of the twentieth century, when aspiration for "ever-bigger and better" solutions and the quest for unending growth in the face of saturated markets in the economically developed world led to practices like planned obsolescence (Brown & Vergragt, 2015; Slade, 2007).[5] Early calls to return back to a more "prudent" way of living were given in the 1970s (Meadows, Meadows, Randers, and Behrens, 1972; Schumacher, 1973) as discussed in Sect. 3. Such calls produced mixed results, as on the one hand, ecological awareness spread and green movements were initiated around this time. On the other hand, the quest for "big solutions" has remained undiminished in the social discourse, with even developing economies trying to emulate the innovation ideal of the west, for example in preferring large-scale infrastructures over small-scale solutions.

Recent research in marketing and innovation management, nevertheless, suggests setting in of a "feature fatigue" in consumers (Thompson, Hamilton, & Rust, 2005), and a growing demand for reduction in the "needless complexity layered on to technology-based products" (Hanna, 2012: 352). This is at least true for many (affluent) consumers, especially in the developed countries, who opt for frugality out of choice (see, e.g., Herstatt, 2015). Therefore, this cannot be construed as being "simplistic" or "less demanding". As Hanna (2012: 352) points out, "Simplicity is the result of logic and empathy, and it is deceptively hard to achieve".

[5]The big depression in the 1930s also played a key role in a deliberate promotion of consumerism and of planned obsolescence (see, e.g., London, 1932).

3.2 *Frugality in Other Disciplines*

Many people interpret frugality today as the opposite-pole of luxury or the supposedly best-possible solution. However, as shown earlier, frugality can be seen as a golden middle-path that strives for the most efficient and effective use of resources in life. This line of thought is shared by several other disciplines. For example, modern-day psychology often seeks to employ "fast and frugal heuristics". Scholarly research "has shown that quite simple, psychologically plausible mechanisms of inference and choice are, in certain reasonable environments, capable of surprisingly good performance" (Connolly, 1999: 480). This goes right up to the discussion on ethics and consumer psychology. According to Chancellor and Lyubomirsky (2011: 133), *thrift*, with its semantic roots in *thrive*, at its essence, "is about the best, most efficient use of limited resources." They relate "unrestrained materialism" with "numerous costs for the society and the individual". As a matter of fact, Germany in recent years has seen works that have tended to critically question the paradigms of a consumption-driven society (von Schönburg, 2006; Welzer, 2013) and that of economic growth and innovation (Paech, 2012a, 2012b; Welzer, 2013).

In the field of sociology and anthropology, too, thrift/frugality has received significant scholarly attention. Societies have been observed to display varying preference in how they respond to human needs & desires: by (immediate) gratification or by restrain & postponement, which can, in turn, have significant impact on a given culture, personality or social system (see, e.g., Schonberger, 1987: 80 pp.). In Hofstede's model of cultural dimensions, this preference impacts at least two dimensions: short-term vs. long-term orientation; and indulgence vs. restraint, as societies that display a long-term orientation and/or that are more inclined towards restraint tend to display greater acceptance of thrift/frugality as a value (Hofstede, Hofstede, & Minkov, 2010). Anthropologists have long used the term "bricolage" to refer to the practice of dealing with resource-constraints (Levi-Strauss, 1966). Bricolage can be understood as "making do with current resources, and creating new forms and order from tools and materials at hand" (cf. Baker, Miner, & Eesley, 2003).

Another discipline which shows a noteworthy connection to frugality is engineering sciences resulting in discussions on the use of frugal practices in manufacturing (Schonberger, 1987) and product design. Pisano and Wheelwright (1995) highlighted the role of process technologies in creating innovations efficiently and with a significant cost advantage. Some researchers, e.g. Kauppinen et al. (2007), have also warned of overuse of product features that "oversatisfy" customer needs and can lead to price-based competition. They have called for better integration of "requirement engineering" into the process of new product development. This line of argumentation is supported by a study by Kus et al. (2011) that investigated the impact of increasing price-sensitivity and thrift in consumer behaviour on "design-decisions", e.g. range of product features, choice of materials and targeted volume. The study found that amongst other measures manufacturers

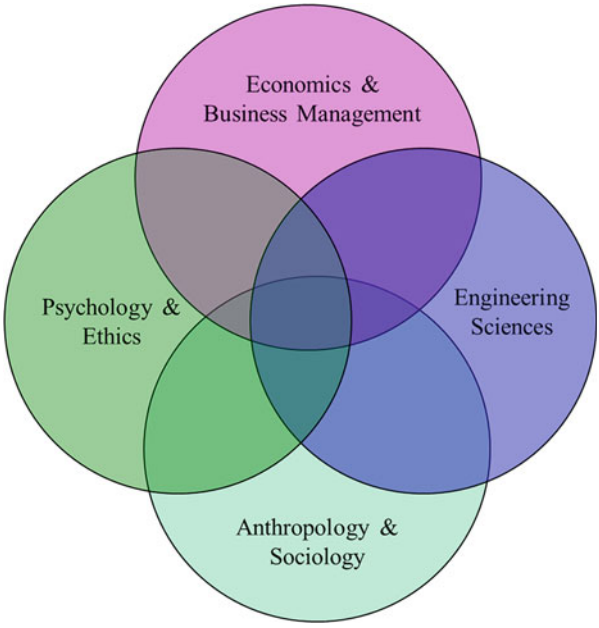

Fig. 1 Frugal innovations as an interplay of various disciplines (Source: Own construction. The figure shows only the main sources of influence on the scholarly discourse of frugality. Other related discussions, such as on environmental and social sustainability, are themselves of multidisciplinary nature and are seen to be subsumed by these overarching disciplines.)

were changing to reduced embellishment, simplification and introduction of generic designs while updating technologies in order to "provide premium service and quality at an affordable price". Several recent scholarly publications from engineering disciplines suggest that high-tech-based frugal innovations are being seen as a key to develop solutions that can help raise the standards of living, improve healthcare or protect environment while ensuring affordability (Baekelandt, 2015; Btatkeu-K, Tchatchueng, Noubactep, and Care, 2015; Davidson et al., 2015; Reardon, 2013; Reynders & Baekelandt, 2015; Urpelainen, 2016).

Summarizing for this section, we might conclude that while the explicit and intentional integration of frugality into the practices of innovation management is a relatively recent phenomenon, the scholarly discourse on frugality taken for itself is not new and has multiple facets that transcend boundaries of several disciplines in the humanities, social & economic sciences as well as engineering, as depicted in Fig. 1.

3.3 Frugal Innovation in Management Sciences

Even though frugality has been present in scholarly discourse for a very long time,[6] the term "frugal innovation" is rather new and its first appearances in scholarly

[6] According to Gemünden (2015: 4), "[t]he desire to get more with fewer resources is an evergreen of management research and practice".

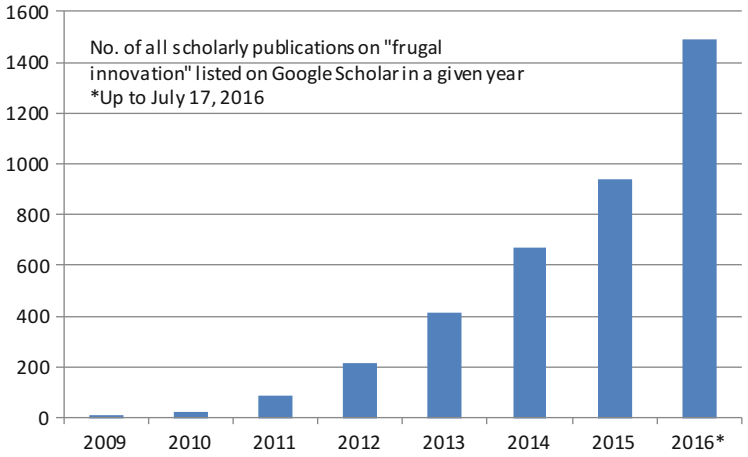

Fig. 2 No. of all articles on Google Scholar for the term "frugal innovation" at year-end

management discourse can be traced back to the last years of the previous decade. Business magazine *The Economist* can be seen as one of the pioneers who *explicitly* combined frugality with innovation, when it published an article titled *Health care in India: Lessons from a frugal innovator* (Economist, 2009).

In those years it was often the business press, which highlighted the emergence and the subsequent spread of this phenomenon in the emerging economies like India (see, e.g., Bellman, Misquitta, & Glader, 2009; Economic Times, 2010; Economist, 2010; Lamont, 2010a; Sehgal et al., 2010).[7] Subsequently this phenomenon caught attention of management researchers and scholarly articles started to be published (see, e.g., Bhatti & Ventresca, 2012; Bound & Thornton, 2012; Fukuda & Watanabe, 2011; Herstatt, Tiwari, Ernst, & Buse, 2008; Radjou, Prabhu, & Ahuja, 2012; Rao, 2013; Tiwari & Herstatt, 2012b; Zeschky et al., 2011).

As Fig. 2 suggests, there has been a rapid increase in the number of scholarly publications on the topic of frugal innovations. While Google Scholar had almost no publications with this keyword at the end of 2009, their number had crossed the mark of 900 scholarly articles by the end of 2015, and then registered an exponential growth, reaching the mark of 1490 by mid-July 2016. It seems that the concept has now reached a critical mass which is creating a self-reinforcing virtuous cycle.

For the purpose of identifying key sources of scholarly influence, we identified 146 journal articles with thematic relevance to the evolution of the concept of frugal innovations. Bibliometric references cited in these articles (numbering 6165) were entered into a database. A preliminary analysis showed that the most often cited author was C.K. Prahalad, who has been one of the key influences in establishing

[7] In many instances these developments were also an indirect result of the globalisation of R&D that started in the 1990s and picked up pace in the first decade of the new millennium (Archibugi & Pietrobelli, 2003; Ernst, 2006; Gerybadze & Reger, 1999).

Table 1 Most cited scholars (with >25 citations) in the dataset

Rank	Author	Key research field	Times cited (citation frequency)
1	C.K. Prahald	Bottom of the pyramid	76 (52 %)
2	V. Govindarajan	Reverse innovation	56 (38 %)
3	C.M. Christensen	Disruptive innovation	53 (36 %)
4	S. Hart	Bottom of the pyramid	44 (30 %)
5	(The Economist)	Emerging markets	43 (30 %)
6	J. Prabhu	Jugaad/frugal innovation	36 (25 %)
7	M. Porter	Strategic management	30 (21 %)
8	C. Herstatt	User/frugal innovation	26 (18 %)

Source: Own analysis; provisional results

the research on the "Bottom of the Pyramid" (see, e.g., Prahalad, 2005). Table 1 gives an overview about those authors and their fields of research who were found to have been cited more than 25 times in the sample:

Based on the results of Table 1 frugal innovations seem to be closely linked with concepts such as "Bottom of the Pyramid" (BOP), "disruptive innovation" and "reverse innovation" but cannot be defined by any single one of them, as explained below[8]:

While BOP, per definition itself, refers to the poor as target consumers and focuses largely on B2C markets (Prahalad, 2005), frugal innovations can be targeted at customers in any segment of the economic pyramid, who may be price-sensitive by choice or merely seek "simpler" products having a better fit to their actual needs. They may also be demanded by customers in both B2B and B2C segments due to price pressures or out of ecological conviction.

Reverse innovation refers to products and services that are initially created in the emerging economies for local markets but later find diffusion in the developed world (Govindarajan & Trimble, 2012). This concept has some similarities to the recent "lead market" research, which has observed emergence of pioneer markets in the emerging economies due to their large volumes and technological competencies (Quitzow, 2015; Quitzow, Walz, Köhler, & Rennings, 2014; Tiwari & Herstatt, 2012a). However, we find instances of frugal innovations taking place both in the developed and the developing world—with or without international diffusion.

Frugal innovations are often characterized by disruptiveness[9] (Rao, 2013; Ramdorai & Herstatt, 2015). Nevertheless, "frugal innovations can [also] have a sustaining effect for the business of an incumbent already engaged in serving [a particular] customer segment" (Tiwari & Herstatt, 2014: 30). There have been

[8]As regard to other terms in Table 1, the link of frugal innovation to "user innovation" shows that the former can often be created by end-users and do not necessarily have to be generated in formal, firm boundaries. The link to "strategic management" as well as "emerging economies" is more in respect of their relevance in the corporate strategy. These terms are not used as synonyms to refer to this type of innovation.

[9]For concept of "disruptive innovations", see, e.g., Christensen and Raynor (2003).

several instances of firms, e.g. the Tata Group and Maruti Suzuki in India, that have long used frugal innovations to create a sustaining effect on their respective businesses.

The Hindi-language term "जुगाड़" ("Jugaad", sometimes transliterated into the Roman script also as "Jugad", "Jugaar" or "Jugar", and often translated into English as "improvisation") has been used by some to refer to products and services that we characterize as being frugal (see, e.g., Hesseldahl, 2013; Holtbrügge, 2013; Menon, 2011; Radjou et al., 2012; OECD, 2009). A problem with this approach, however, is that semantically the term Jugaad is derived (via "Jugat" and Jugati") from "Yukti" in Sanskrit (Prasad, Sahay, & Shrivastav, 2000) that first of all refers to a method/means and not to an outcome; second it can also employ use of a "trick" or "cunning device" (Monier-Williams, 1899). The term Jugaad in its original usage in India refers to non-standard improvisations as an immediate solution (see, e.g., Tully, 2011). However, this might not be a quality solution and might not—in some instances—fulfil the criteria of legality (Birtchnell, 2011; Krishnan, 2010). The term Jugaad, therefore, appears inappropriate for referring to solutions that enable "affordable excellence"[10] by fulfilling all quality norms and standards.

3.4 Defining Frugal Innovations

Due to such considerations we propose the following working definition of frugal innovation, which does not limit this phenomenon to specific geographic areas or income groups on the one hand, and puts emphasis on ensuring acceptable quality standards by adhering to all regulatory norms, on the other:

Frugal innovations seek to create attractive value propositions for their targeted customer groups by focusing on core functionalities and thus minimizing the use of material and financial resources in the complete value chain. They substantially reduce the cost of usage and/or ownership while fulfilling or even exceeding prescribed quality standards.

Key characteristics of this definition may be summed up as follows:

- By focusing on core functionalities and minimizing the use of environmental resources and factors of production frugal innovations attain an in-built sustainability component across the entire value-chain and should lead to "responsible innovation"[11];
- Frugal innovation should substantially reduce not only the price at the point of purchase but during the entire cost of usage/ownership, thus it also includes principles of "sharing economy"[12];

[10](Mashelkar, 2014); some researchers also refer to it as "low cost-high tech" (see, e.g., Schanz, Hüsig, Dowling, & Gerybadze, 2011).

[11]For "responsible innovation", see, e.g. (Bogner, Decker, & Sotoudeh, 2015; Wood, Pitta, & Franzak, 2008).

[12]For "sharing economy", see, e.g. (Belk, 2014).

- Most importantly, this definition frees frugal innovation from the notion of static customer segments and turns it into a dynamic tool. Frugal products and services can be produced for any group of consumers by substantially increasing affordability and opening up a new segment relative to any specific price/performance point.

This working definition was used for the workshop that was organized to validate the initial findings and generate some primary data. The workshop and its results are described in the next section.

4 Evaluation of Workshop Results

The workshop was directed at researchers, practitioners and political actors interested in the phenomenon of frugal innovation.[13] Altogether 30 stakeholders with diverse backgrounds in management, science and politics assembled to discuss research results on frugal innovations and its relevance for German companies as well as the German society. Aim of the workshop was to summarize research findings and collect new insights about the perceived relevance and potential of frugal innovations by stakeholders in Germany.

4.1 Questionnaire

At the beginning of the workshop a questionnaire was distributed to the participants of the workshop. The intention was to capture their view of frugal innovation and its potential at the beginning of the workshop in order to compare this result with the outcome of the focus group discussions held at the end of the workshop.

The questionnaire covered the understanding of the term frugal innovation, the relevance of frugal innovation in different contexts, challenges concerning the diffusion and implementation of frugal innovations as well as personal interests of the participants concerning the topic and their broader societal view. Furthermore, we collected some attributes of the participants as areas of their experience with frugal innovation and their professional background. Answers were mostly collected via a 5 point Likert scale. In our scale, 5 equals full agreement, 3 is a neutral answer and 1 stands for total disagreement. We received 21 complete questionnaires.[14] Most of the respondents (13) were representatives of the business world, 4 of the respondents were scientists and 3 had a political background.

[13]The workshop was held in Hamburg on January 12th, 2016 as an initial part of this BMBF-supported study.

[14]Among the participants six belonged to the project team. These did not participate in the survey in order not to influence the survey outcome by their own opinions/perceptions.

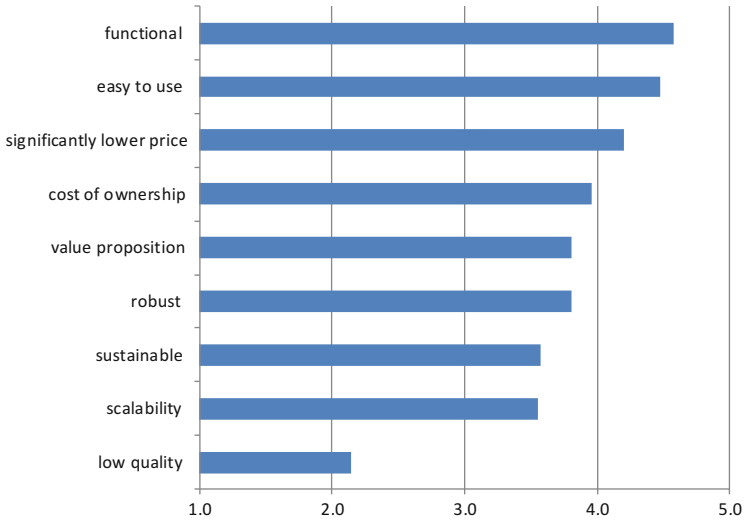

Fig. 3 Primary attributes of frugal innovation

The average answers of all participants concerning the primary attributes of frugal innovation are displayed in Fig. 3.

As expected all suggested characteristics are seen as relevant, except for the item low quality that was included to check negative associations. The three most relevant characteristics are the functionality of the product, an easy use as well as a significantly lower price compared with similar products. Slight differences could be identified if the answers of persons from business, science and politics were separated. For instance, the three participants with political background put more emphasis on the "cost of ownership" instead of the significantly lower price when purchasing the product.

The answers of the participants to the question "How relevant are frugal innovations for Germany with respect to . . ." are displayed in Fig. 4.

At the beginning of the workshop, participants only slightly agreed on the relevance of frugal innovations with respect to business success in Germany or other industrial nations. However, relevance is seen for the success of German companies in emerging economies, for fulfilling social needs concerning the supply with affordable products and services as well as for the use of sustainable resources.

Challenges associated with frugal innovations from a business perspective are displayed in Fig. 5. Participants agreed that challenges could be expected concerning the adaptation of innovation processes, the identification of customer needs as well as resistance in the management. Additional challenges could be added in the questionnaire. Four respondents addressed here cultural challenges in

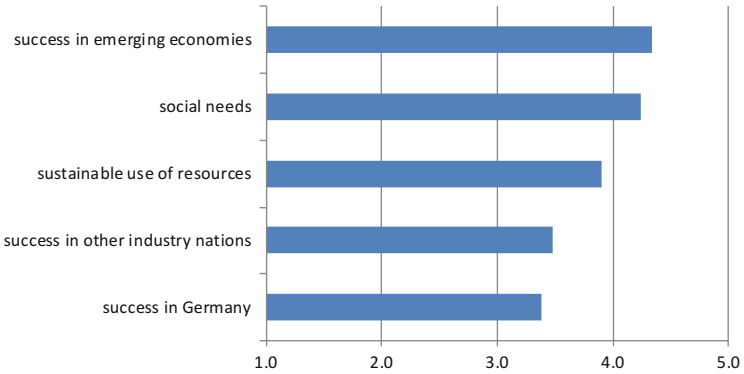

Fig. 4 Relevance of frugal innovation for Germany

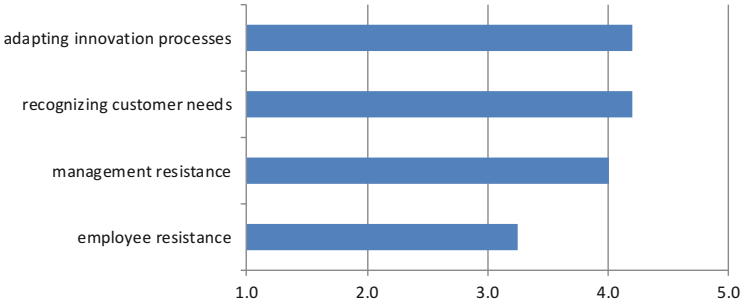

Fig. 5 Challenges of frugal innovation from a business perspective

generating frugal innovations. Responsible engineers need to mentally adopt the goals of frugal innovation. Only if they overcome their tendency to develop complex technologies and if the entire company appreciates frugal innovations, will companies succeed with this new innovation model. Another respondent addressed regulatory challenges imposed by legislation.

At the end of the questionnaire we asked about special interest topics from a personal as well as from a social point of view. New points mentioned in the personal section were frugal services, e.g. in health-care or banking and the marketing of frugal products. Looking at frugal innovation from a social perspective, four respondents mentioned sustainability goals that could be reached by frugal innovation. Another topic addressed is education in frugal practices starting from school-level and reaching to best practices in engineering. Furthermore, twice the question was raised, if consumers in Germany would accept frugal innovations and one respondent asked how the innovation potential of emerging economies could be used for society.

Altogether, all participants of the workshop already had an understanding of frugal innovation; six people even have dealt with frugal innovations for 5 years or longer. The most relevant characteristics of frugal innovations could be identified and all participants agreed on the relevance of the topic for German companies. However, the relevance of frugal products for the domestic German market is not clear yet. Challenges are seen in innovation management and marketing, but also in cultural changes needed to adopt a frugal mind-set.

4.2 Focus Groups

After being presented the research results on frugal innovation including a historical analysis, a scientific analysis and a discourse analysis based on German media,[15] the participants of the workshop discussed frugal innovation in three focus groups. Each focus group represented a mix in age and disciplines. The participants ranged from young students to above 70 years old and covered occupations in science, business and politics. Results were captured on flipcharts and later presented to and discussed with the whole audience.

4.2.1 Focus Group 1

In the first focus group the relevance of frugal innovations for German companies in the domestic market was discussed. Participants of the focus group raised at the beginning the question, if Germany could be a pioneer in frugal innovation and which strengths of German companies and the German society would be supportive to foster frugal innovation in Germany. Hence, the group tried to identify strengths of German companies needed to deal with the challenge of frugal innovation. It was pointed out that frugal innovation should be addressed within a "holistic business ecosystem" and cover management, strategy as well as cultural aspects. Especially for the German market, the sustainability aspect of frugal innovations should be emphasized. In this context, "the total impact on life" of frugal products needs to be addressed in the innovation process as well as in marketing. An advantage of German engineers was seen in their creativity to think differently. Also it was suggested that in Germany one can find a special consumer consciousness fostering the acceptance of frugal products if these are "simple" (→ easy to use) and sustainable following the paradigm "less is more". Perhaps, frugality can establish a trend life style in Germany. Examples of frugal innovations especially suitable for the German market were seen in services in general as well as in the healthcare system. Overall, a definite and increasing relevance of frugal innovations for the German market was identified and agreed upon.

[15]See Sects. 2–4 of this paper.

4.2.2 Focus Group 2

The second focus group dealt with the relevance of frugal innovations for German companies in a global context. Topics of interest were seen in organisational issues as well as in change processes needed to develop and implement a frugal innovation culture. Discussion in the group included: (a) synergies between frugal innovation and "industry 4.0", (b) the role of global open/user innovation to address market needs in emerging economies, and (c) the education of German engineers. A need was identified to train prospective engineers in "high end" vs. "design to cost". As global competition should be state of the art for all German companies there is no way to ignore the trend of frugal innovation. Three business sectors were identified by the group as having potential for frugal innovations: education, health-care and banking. Hence, again the issue of frugal services was addressed. However, processes to develop frugal innovations still need to be identified and improved. How can the local knowledge of foreign markets be best combined with the high engineering competences in Germany? Altogether, the group determined a high relevance of frugal innovations for German companies in a global context.

4.2.3 Focus Group 3

The third focus group addressed socio-political implications of frugal innovation for the German research and innovation system. The overarching agreement amongst the members of the group was that frugal innovation is relevant, present across all generations in Germany and shall be of greater importance in the future due to an ongoing trend towards greater moderation and simplicity. More precisely, frugal innovation was assigned great importance in ensuring social participation and sustainable production and consumption in order to move away from a throw-away society and towards a collecting society. Removing superfluous elements and moving away from technological messiness were given importance.

The role of the social status in relation to consumption and a potential conflict between individuality and product development were mentioned as potential challenges together with the role of research and education. The participants suggested initiating a product life cycle management that was more based on "cradle to cradle"—including product design. That implied, in the opinion of the participants, higher education that taught engineering, product development, marketing and design based on the motto "design for use" and on a better understanding of society and the market.

4.2.4 Summarizing Results of the Focus Groups

Before the workshop, participants mostly associated frugal innovation with emerging economies. In their opinion, primarily companies striving for success in these

regions needed to address this topic. Otherwise, relevance of frugal innovations with respect to business success in Germany or other industrial nations was still questioned.

Based on the presented research findings and plenum discussions, a mind-shift could be observed in the focus groups. The group addressing socio-political implications of frugal innovation for the German research and innovation system (focus group 3) agreed on the high relevance of frugal innovations for the German society. Similarly, the first focus group positively assessed the possibility that frugality could establish a trend in Germany. In both groups this relevance of frugality for Germany was linked to sustainability goals and the establishment of a circular economy. This combination points to "frugal innovations" also being seen as "responsible innovations" in the German context. Furthermore, as was discussed in focus group 2, global competition is reality for all German companies, hence, frugal innovations should also be considered as a global challenge affecting everyone.

Based on answers collected via questionnaires and discussions held during the workshop, several aspects of frugal innovations could be identified that need further research attention. For example, the design of frugal services or the marketing of frugal products in a wide range of customer groups are interesting topics that have been neglected so far. Finally, motivating German engineers and managers to adopt a "frugal mind-set" as well as to design frugal innovation processes are still challenges to be resolved.

5 Conclusions

The discussion above shows that frugal innovations are a necessary by-product of frugality that is increasingly shaping our world even if its roots in the developing and the developed world are somewhat different. While there is a growing-but-still-limited prosperity in the emerging economies allowing many customers in the B2B and B2C segments for the first time to acquire (access to) better-quality products, many customers in the industrialized nations feel the need to adopt "simpler" products. In some cases it may be the financial incentives that influence this decision, but in some others they are also guided by a desire to reduce complexity and preserve the environment. Since natural resources are depleting, many stakeholders in business, research and politics expect the trend of frugality to get stronger in the medium run, as shown in Sect. 5.

The increasing demand for frugality/simplicity acts as a root cause for the development and diffusion of frugal innovations. This trend is, thus, not only true for companies striving for business success in emerging economies, but also increasingly for the future of the (German) society itself. The historical analysis in Sects. 3 and 4 has revealed that frugality—for long periods of civilized life—has been a respected and popular virtue which only lost its place in the post-war era of

prosperity when saturated societies started to seek new avenues for continued economic growth, sometime on the cost of prudence.

At the end of the last decade, however, frugal innovation practices in the emerging economies, such as China and India, started to re-appear and were highlighted by the business press. The relevance and value of frugal innovations are reflected not only in an increasing research interest by scholars but also by other societal stakeholder including managers and policymakers. Nonetheless, as of today, many questions remain unanswered. For example, how small and medium-sized companies can develop frugal business models if they cannot take recourse to economies of scale or if they cannot set up R&D centres in the emerging lead markets in the developing countries; or how firms can cultivate the necessary mind-sets and corporate culture motivating product developers to innovate frugally and not value their product merely by the price-tag it commands.

Further interdisciplinary research is needed to answer most of these questions and to evaluate opportunities and challenges associated with frugal innovations for the various relevant stakeholders in society. As a next step, this project will seek to identify innovation paths and trajectories that foster or hamper the emergence of frugal solutions by studying the auto component industries in India and Germany. The essence of this paper, however, can be probably stated best in the following words of Schonberger (1987: 95):

> "Frugality is not the virtue of some bygone era; it pays today too".

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References

Archibugi, D., & Pietrobelli, C. (2003). The globalisation of technology and its implications for developing countries: Windows of opportunity or further burden? *Technological Forecasting and Social Change, 70*(9), 861–883.

Avotins, I. (1977). Training in frugality in epicurus and seneca. *Phoenix, 31*(3), 214–217.

Baekelandt, J. (2015). Total vaginal NOTES hysterectomy: A new approach to hysterectomy. *Journal of Minimally Invasive Gynecology, 22*(6), 1088–1094.

Baker, T., Miner, A. S., & Eesley, D. T. (2003). Improvising firms: Bricolage, retrospective interpretation and improvisational competencies in the founding process. *Research Policy, 32*, 255–276.

Belk, R. (2014). You are what you can access: Sharing and collaborative consumption online. *Journal of Business Research, 67*(8), 1595–1600.

Bellman, E., Misquitta, S., & Glader, P. (2009, October 21). Indian firms shift focus to the poor. *Wall Street Journal*, New York, p. A14.

Bhatti, Y. A. (2012). What is frugal, what is innovation? Towards a theory of frugal innovation. Working Paper, Said Business School, Oxford.

Bhatti, Y. A., & Ventresca, M. (2012). *The emerging market for frugal innovation: Fad, fashion, or fit?* Working Paper, Said Business School, Oxford.

Birtchnell, T. (2011). Jugaad as systemic risk and disruptive innovation in India. *Contemporary South Asia, 19*(4), 357–372.

BMBF. (2014). Bekanntmachung: Richtlinien zur Förderung von Forschungsvorhaben im Rahmen der Innovations- und Technikanalyse, Berlin, Bundesministerium für Bildung und Forschung (German Federal Ministry of Education and Research), BAnz AT 26.08.2014 B.

Bocken, N. M. P., & Short, S. W. (2016). Towards a sufficiency-driven business model: Experiences and opportunities. *Environmental Innovation and Societal Transitions, 18*, 41–61.

Bogner, A., Decker, M., & Sotoudeh, M. (Eds.). (2015). *Responsible Innovation: Neue Impulse für die Technikfolgenabschätzung*. Baden-Baden: Nomos.

Bouckaert, L., Opdebeeck, H., & Zsolnai, L. (Eds.). (2008). *Frugality. Rebalancing material and spiritual values in economic life*. Oxford: Peter Lang.

Bound, K., & Thornton, I. (2012). *Our frugal future: Lessons from India's innovation system*. London: NESTA.

Brem, A., & Ivens, B. (2013). Do frugal and reverse innovation foster sustainability? Introduction of a conceptual framework. *Journal of Technology Management for Growing Economies, 4*(2), 31–50.

Brown, V. (1994). *Adam Smith's discourse: Canonicity, commerce and conscience*. London: Routledge.

Brown, H. S., & Vergragt, P. J. (2015). From consumerism to wellbeing: Toward a cultural transition? *Journal of Cleaner Production*. doi:10.1016/j.jclepro.2015.04.107

Btatkeu-K, B. D., Tchatchueng, J. B., Noubactep, C., & Care, S. (2015). Designing metallic iron based water filters: Light from methylene blue discoloration. *Journal of Environmental Management, 166*, 567–573.

Budde, G. (2009). Bürgertum und Konsum: Von der repräsentativen Bescheidenheit zu den "feinen Unterschieden". In H.-G. Haupt & C. Torp (Eds.), *Die Konsumgesellschaft in Deutschland 1890–1990: Ein Handbuch* (pp. 131–144). Frankfurt am Main: Campus Verlag.

Chancellor, J., & Lyubomirsky, S. (2011). Happiness and thrift: When (spending) less is (hedonically) more. *Journal of Consumer Psychology, 21*, 131–138.

Christensen, C. M., & Raynor, M. E. (2003). *The innovator's solution: Creating and sustaining successful growth*. Boston: Harvard Business School Press.

Connolly, T. (1999). Action as a fast and frugal heuristic. *Minds and Machines, 9*, 479–496.

Davidson, P. M., Newton, P. J., Tankumpuan, T., Paull, G., & Dennison-Himmelfarb, C. (2015). Multidisciplinary management of chronic heart failure: Principles and future trends. *Clinical Therapeutics, 37*(10), 2225–2233.

Economic Times. (2010, July 26). Intel India wants to partner HRD ministry for 1,500 PC rollout. *The Economic Times*, Mumbai, p. 13.

Economist. (2009, April 18). Health care in India: Lessons from a frugal innovator. *The Economist*, pp. 67–68.

Economist. (2010). *The world turned upside down: A special report on innovation in emerging markets*. London: The Economist.

Ernst, D. (2006). *Innovation offshoring – Asia's emerging role in global innovation networks*. East-West Center (jointly published with the U.S.-Asia Pacific Council), Honolulu.

European Commission. (2015). *Call for tenders: Study on frugal innovation and re-engineering of traditional techniques*. Directorate-General for Research & Innovation, 2015/S 086-154254, Brussels.

Fukuda, K., & Watanabe, C. (2011). A perspective on frugality in growing economies: Triggering a virtuous cycle between consumption propensity and growth. *Journal of Technology Management for Growing Economies, 2*(2), 79–98.

Gemünden, H. G. (2015). When less is more, and when less is less. *Project Management Journal, 46*(3), 3–9.

Gerybadze, A., & Reger, G. (1999). Globalization of R&D: Recent changes in the management of innovation in transnational corporations. *Research Policy, 28*(2–3), 251–274.

Govindarajan, V., & Trimble, C. (2012). *Reverse innovation: Create far from home, win everywhere*. Boston: Harvard Business Review Press.
Hanna, P. (2012). The evolution of simplicity and meaning. *Journal of Product Innovation Management, 29*(3), 352–354.
Herstatt, C. (2015, Jun. 10). Produkteentwicklung: Konsum in Zeiten « frugaler Innovationen ». *Neue Zürcher Zeitung*, Zurich.
Herstatt, C., & Tiwari, R. (2015). Frugale Innovation: Einordnung eines neuen Innovationsbegriffs. *WiSt - Wirtschaftswissenschaftliches Studium*, München, 44 (Heft 11, Nov.), pp. 649–652.
Herstatt, C., Tiwari, R., Ernst, D., & Buse, S. (2008). *India's national innovation system: Key elements and corporate perspectives*. Economics Series, Working Paper No. 96, East-West Center, Honolulu, Hawaii.
Hesseldahl, P. (2013). *Jugaad: The Indian style of innovation*. Sønderborg: Universe Foundation.
Hofstede, G., Hofstede, G. J., & Minkov, M. (2010). *Cultures and organizations: Software of the mind – intercultural cooperation and its importance for survival*. New York: McGraw Hill.
Holtbrügge, D. (2013). Indigenous management research. *Management International Review, 53*, 1–11.
Ims, K., & Jakobsen, O. (2008). Consumerism and frugality: Contradictory principles in economics? In L. Bouckaert, H. Opdebeeck, & L. Zsolnai (Eds.), *Frugality. Rebalancing material and spiritual values in economic life* (pp. 169–184). Oxford: Peter Lang.
Jänicke, M. (2014). Entwicklungsländer als Vorreiter der Nachhaltigkeit? Frugale Technik. *Ökologisches Wirtschaften, 29*(1), 30–36.
Jonas, H. (1985). Auf der Schwelle der Zukunft: Werte von gestern und Werte für morgen. In H. Jonas (Ed.), *Technik, Medizin und Ethik. Zur Praxis des Prinzips Verantwortung* (pp. 53–75). Frankfurt am Main: Peter Lang.
Kauppinen, M., Savolainen, J., & Männistö, T. (2007). Requirements engineering as a driver for innovations. In A. Sutcliffe & P. Jalote (Eds.), *15th IEEE international requirements engineering conference* (pp. 15–20). Delhi: IEEE.
Koselleck, R. (Ed.). (1994). *Bürgerschaft: Rezeption und Innovation der Begrifflichkeit vom Hohen Mittelalter bis ins 19. Jahrhundert*. Stuttgart: Klett-Cotta.
Krishnan, R. T. (2010). *From Jugaad to systematic innovation: The challenge for India*. Bangalore: Utpreraka Foundation.
Kus, R., Bruce, M., & Keeling, K. (2011). *Austerity measures impact design*. 18th International Product Development Management Conference, Delft, The Netherlands.
Lai, W. (2013). Frugality. In O. Leaman (Ed.), *Encyclopedia of eastern philosophy* (pp. 208–209). London: Routledge.
Lamont, J. (2010a, June 14). The age of 'Indovation' dawns. *The Financial Times*, London.
Lamont, J. (2010b, January 19). Indian innovators target nation's high demand. *The Financial Times*, London.
Levi-Strauss, C. (1966). *The savage mind*. Chicago: University of Chicago Press.
London, B. (1932). *Ending the depression through planned obsolescence*. Retrieved March 25, 2016, from https://upload.wikimedia.org/wikipedia/commons/2/27/London_%281932%29_Ending_the_depression_through_planned_obsolescence.pdf
Low, K. C. P. (2009). Lao Tzu's Three treasures, leadership & organizational growth. *Leadership & Organizational Management Journal, 3*, 27–36.
Marshall, A. (1890). *Principles of economics: An introductory volume*. London: Macmillan Press (Reprint 1990).
Mashelkar, R. A. (2014, March 20). *Accelerated inclusive growth through inclusive innovation*. Retrieved April 14, 2013, from http://www.oecd.org/sti/inno/Session_3_Mashelkar_Keynote.pdf
Meadows, D. H., Meadows, D. L., Randers, J., & Behrens, W. W., III. (1972). *The limits to growth: A report for the Club of Rome's project on the predicament of mankind*. New York: Universe Books.

Meld Shell, S., & Velkley, R. (Eds.). (2012). *Kant's Observations and remarks: A critical guide*. Cambridge: Cambridge University Press.

Menon, N. (2011, November 26). Indovation or Indian Jugaad goes abroad. *Economic Times*, Mumbai, p. 5.

Monier-Williams, M. (1899). *Sanskrit-English dictionary*. New Delhi: Bhartiya Granth NIketan (enlarged edition, 2004).

Münkel, D. (2009). Konsum auf dem Land vom Kaiserreich bis in die Bundesrepublik. In H.-G. Haupt & C. Torp (Eds.), *Die Konsumgesellschaft in Deutschland 1890–1990: Ein Handbuch* (pp. 205–220). Frankfurt am Main: Campus Verlag.

Munzel, G. F. (2012). Relative goodness and ambivalence of human traits. In S. Meld Shell & R. Velkley (Eds.), *Kant's Observations and remarks: A critical guide* (pp. 165–184). Cambridge: Cambridge University Press.

Neugebauer-Wölk, M. (1996). Die utopische Struktur gesellschaftlicher Zielprojektionen im Illuminatenbund. In M. Neugebauer-Wölk & R. Saage (Eds.), *Die Politisierung des Utopischen im 18. Jahrhundert: Vom utopischen Systementwurf zum Zeitalter der Revolution* (pp. 169–197). Tübingen: Max Niemeyer Verlag.

Nowlis, S. M., & Simonson, I. (1996). The effect of new product features on brand choice. *Journal of Marketing Research, 33*(1), 36–46.

OECD. (2005). *Oslo manual: Guidelines for collecting and interpreting innovation data*. Paris: Organisation for Economic Co-Operation and Development (in joint publication with Eurostat).

OECD. (2009). *The development dimension: ICTs for development, improving policy coherence*. Paris: Organisation for Economic Co-Operation and Development.

Paech, N. (2012a). *Befreiung vom Überfluss: Auf dem Weg in die Postwachstumsökonomie*. Munich: Oekom Verlag (7th ed., 2014).

Paech, N. (2012b). *Nachhaltiges Wirtschaften jenseits von Innovationsorientierung und Wchatum: Eine unternehmensbezogene Transformationsthoerie*. Marburg: Metropolis-Verlag.

Pisano, G. P., & Wheelwright, S. C. (1995). The new logic of high-tech R&D. *Harvard Business Review, 73*(5), 93–105.

Prahalad, C. K. (2005). *The fortune at the bottom of the pyramid: Eradicating poverty through profits*. Upper Saddle River, NJ: Wharton School Publishing.

Prasad, K., Sahay, R., & Shrivastav, M. (2000). *Brihat hindi kosh*. Varanasi: Gyanmandal Limited.

Quitzow, R. (2015). Dynamics of a policy-driven market: The co-evolution of technological innovation systems for solar photovoltaics in China and Germany. *Environmental Innovation and Societal Transitions, 17*, 126–148.

Quitzow, R., Walz, R., Köhler, J., & Rennings, K. (2014). The concept of "Lead Markets" revisited: Contribution to environmental innovation theory. *Environmental Innovation and Societal Transitions, 10*, 4–19.

Radjou, N., & Prabhu, J. (2015). *Frugal innovation: How to do more with less*. London: The Economist.

Radjou, N., Prabhu, J., & Ahuja, S. (2012). *Jugaad innovation: Think frugal, be flexible, generate breakthrough growth*. San Francisco: Jossey-Bass.

Ramdorai, A., & Herstatt, C. (2015). *Frugal innovation in healthcare: How targeting low-income markets leads to disruptive innovation*. Heidelberg: Springer.

Rao, B. C. (2013). How disruptive is frugal? *Technology in Society, 35*(1), 65–73.

Reardon, S. (2013). Frugal science gets DIY diagnostics to world's poorest. *New Scientist, 219* (2933), 20–21.

Reynders, A., & Baekelandt, J. (2015). Low-cost total laparoscopic hysterectomy by single-incision laparoscopic surgery using only reusable standard laparoscopic instruments. *Gynecological Surgery, 12*(2), 101–105.

Schanz, C., Hüsig, S., Dowling, M., & Gerybadze, A. (2011). 'Low cost-high tech' innovations for China: Why setting up a separate R&D unit is not always the best approach. *R&D Management, 41*(3), 307–317.

Schonberger, R. J. (1987). Fraugal manufacturing. *Harvard Business Review, 65*(5), 95–100.
Schui, F. (2005). *Early debates about industry: Voltaire and his contemporaries*. Basingstoke: Palgrave Macmillan.
Schumacher, E. F. (1966). Buddhist economics. In G. Wint (Ed.), *Asia: A handbook* (pp. 695–701). London: Anthony Blond Ltd.
Schumacher, E. F. (1973). *Small is beautiful: A study of economics as if people mattered*. London: Blond & Briggs.
Sehgal, V., Dehoff, K., & Panneer, G. (2010). The importance of frugal engineering. *Strategy + Business, Summer*(59), 1–5.
Simula, H., Hossain, M., & Halme, M. (2015). Frugal and reverse innovations – Quo Vadis? *Current Science, 109*(9), 1567–1572.
Slade, G. (2007). *Made to break: Technology and obsolescence in America*. Cambridge, MA: Harvard University Press.
Smith, A. (1759). *The theory of moral sentiments*. Mineola: Dover Publications. Reprint 2006.
Smith, A. (1776). *An inquiry into the nature and causes of the wealth of nations*. New York: Random House. Reprint 1994.
Thompson, D. V., Hamilton, R. W., & Rust, R. T. (2005). Feature fatigue: When product capabilities become too much of a good thing. *Journal of Marketing Research, XLII*, 431–442.
Tiwari, R., & Herstatt, C. (2012a). Assessing India's lead market potential for cost-effective innovations. *Journal of Indian Business Research, 4*(2), 97–115.
Tiwari, R., & Herstatt, C. (2012b). Frugal innovation: A global networks' perspective. *Die Unternehmung, 66*(3), 245–274.
Tiwari, R., & Herstatt, C. (2013). *"Too good" to succeed? Why not just try "good enough"! Some deliberations on the prospects of frugal innovations*. Working paper No. 76, Institute for Technology and Innovation Management, Hamburg University of Technology, Hamburg.
Tiwari, R., & Herstatt, C. (2014). *Aiming big with small cars: Emergence of a lead market in India*. Heidelberg: Springer.
Tully, M. (2011). *Non-stop India*. New Delhi: Allen Lane.
Urpelainen, J. (2016). Energy poverty and perceptions of solar power in marginalized communities: Survey evidence from Uttar Pradesh, India. *Renewable Energy, 85*, 534–539.
von Schönburg, A. (2006). *Die Kunst des stilvollen Verarmens: Wie man ohne Geld reich wird*. Reinbek: Rowohlt Taschenbuch Verlag.
Weber, M. (1904). *Die protestantische Ethik und der Geist des Kapitalismus*. Tübingen: Mohr.
Welzer, H. (2013). *Selbst denken: Eine Anleitung zum Widerstand*. Frankfurt am Main: S. Fischer Verlag.
Wood, V. R., Pitta, D. A., & Franzak, F. J. (2008). Successful marketing by multinational firms to the bottom of the pyramid: Connecting share of heart, global "umbrella brands", and responsible marketing. *Journal of Consumer Marketing, 25*(7), 419–429.
Zeschky, M., Widenmayer, B., & Gassmann, O. (2011). Frugal innovations in emerging markets. *Research Technology Management, 54*(4), 38–45.
Zeschky, M. B., Winterhalter, S., & Gassmann, O. (2014a). From cost to frugal and reverse innovation: Mapping the field and implications for global competitiveness. *Research Technology Management, 57*(4), 20–27.
Zeschky, M. B., Winterhalter, S., & Gassmann, O. (2014b). *"Resource-constrained innovation": Classification and implication for multinational firms*. The XXV ISPIM Conference – Innovation for Sustainable Economy & Society, ISPIM, Dublin.
Zsolnai, L. (2008). Buddhist economic strategy. In L. Bouckaert, H. Opdebeeck, & L. Zsolnai (Eds.), *Frugality. Rebalancing material and spiritual values in economic life* (pp. 279–304). Oxford: Peter Lang.
Zweck, A., Holtmannspötter, D., Braun, M., Hirt, M., Kimpeler, S., & Warnke, P. (2015). *Gesellschaftliche Veränderungen 2030: Ergebnisband 1 zur Suchphase von BMBF-Foresight Zyklus II*. Zukünftige Technologien Nr. 100, Innovationsbegleitung und Innovationsberatung der VDI Technologiezentrum GmbH, Düsseldorf.

Frugality in Indian Context: What Makes India a Lead Market for Affordable Excellence?

Rajnish Tiwari

1 Introduction

In recent years, a phenomenon called "frugal innovation" has increasingly and consistently gained traction cutting across boundaries of disciplines, industries and professional domains.[1] The number of entries for academic papers containing the term "frugal innovation" on Google Scholar increased impressively from 11 at year-end 2009 to 1490 by mid-July 2016 indicating a growing interest of the research community. Today, academics as well as practitioners; engineering sciences as well as management sciences; medicine as well as humanities; developing countries as well as developed nations are trying to comprehend this phenomenon and its (potential) implications for their respective domains, as is documented in chapter "Frugal Innovation: An Assessment of Scholarly Discourse, Trends and Potential Societal Implications" of this contributed volume.

A recent review of published scholarly articles on frugal innovation showed that "research on frugal innovation has been predominantly contextualized for emerging economies, especially India" (Tiwari, Kalogerakis, & Herstatt, 2016: 11). A keyword analysis of published peer-reviewed, journal articles on frugal innovations showed that "India" was explicitly cited as a keyword in about 18 % of the articles, whilst three other terms ("Jugaad", "Bottom of the Pyramid", and "reverse innovation"), often associated with India, accounted for another 56 % (Tiwari, Kalogerakis, et al., 2016). Another study of media reports on frugal innovations in German-speaking countries brought a similar result (Bergmann & Tiwari, 2016).

[1] See, e.g., Economist (2009), Bhatti and Ventresca (2012), Tiwari and Herstatt (2012), Brem and Ivens (2013), Arnett and Claas (2015), Radjou and Prabhu (2015), Rosca, Arnold, and Bendul, (2016).

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Apparently, India has quietly acquired the role of a pioneer for innovations that aim at combining affordability with high quality, cutting across sectoral boundaries. But what is it that makes India a forerunner for an innovation paradigm with increasing global relevance? Some very obvious factors that contribute to this image are described below.

First, the prevalence of English language in the country makes reports on innovations emanating from India in the era of the Internet instantly accessible to the global village. Reports appearing in the business press have created a virtuous cycle for India's pioneering role in inventing affordability-driven solutions (e.g., Economic Times, 2012; Economist, 2009; Lamont, 2010; Lavallee & Veach, 2010; Menon, 2011; Mitra, 2011; Philip, 2008; Saraf, 2009).

Second, the scholarly discourse on innovation paradigms concerned with affordability, inclusion and emerging markets has been often set in the context of India, which has been a large and growing economy beset with serious levels of poverty and infrastructural difficulties. This has given rise to a discourse on the need for inclusive growth that can be spurred by inclusive innovation (Dutz, 2007; Hall, Matos, Sheehan, & Silvestre, 2012; Reficco & Márquez, 2012). Then, India also turned into a leading destination for business- and knowledge-process outsourcing (Kobayashi-Hillary, 2005; KPMG, 2008); partly also contributing to innovative solutions being created by global firms (Immelt, Govindarajan, & Trimble, 2009; Kumar & Puranam, 2012). Indian multinational enterprises (MNEs) started to invest overseas creating a scholarly curiosity in these MNEs and their product and innovation profiles.[2] These developments have given considerable visibility to India and innovation activities taking place there in the corporate sector and beyond (see, e.g., Bound & Thornton, 2012; Cappelli, Singh, Singh, & Useem, 2010).

Finally, the scholarly discourse on these kinds of innovations has also seen a relatively large participation by Indian-origin academics. For example, the discourse on grassroots innovations has been largely influenced by works of Anil K. Gupta (e.g., 2000, 2000, 2003, 2010); the debate on the "Bottom of the Pyramid" (BOP) has been strongly shaped by works of the late C.K. Prahalad (see, e.g., Hammond & Prahalad, 2004; Prahalad, 2002, 2012; Prahalad & Mashelkar, 2010); and the concept of "reverse innovation" got traction with works of Vijay Govindarajan (Govindarajan & Ramamurti, 2013; Govindarajan & Trimble, 2012; Immelt et al., 2009). The concept of "frugal innovation" too has seen significant involvement of Indian-origin scholars.[3] A recent bibliometric analysis showed that four of the top-five cited first authors (natural persons) in papers on frugal innovation were of Indian-origin; among top-ten the number was five (Tiwari, Kalogerakis, et al., 2016). Involvement of many Indian scholars would

[2]See, e.g., Bruche (2009), Pradhan and Singh (2009), Sauvant Pradhan, Chatterjee, and Harley (2010), Bruche and Wäldchen (2013), Holtbrügge (2013), Tiwari (2014).

[3]See, e.g., Agarwal and Brem (2012), Singh, Gambhir, Sotiropoulos, and Duckworth (2012), Tiwari and Herstatt (2012), Basu, Banerjee, and Sweeny (2013), Radjou and Prabhu (2013, 2015), Rao (2013), Tiwari, Kalogerakis, and Herstatt (2014), Ramdorai and Herstatt (2015), Tiwari, Kalogerakis, et al. (2016).

almost necessarily implicate that they would report on innovative products and services that they more easily come in contact with, resulting in a positive, and also not necessarily false, perception about the innovativeness of the country.

However, I posit that the above mentioned factors alone cannot explain the emergence of a lead market, much less the emanation of so many commercially successful innovative products, services and business models from India that unite in combining affordability with excellent quality and the "right" amount of functionality. The above-mentioned factors, in my opinion, are more often a result not the root cause of the actual developments on the ground. After all, we have seen India acting as a "test lab" for scores of domestic and global innovators in their pursuit to create highly disruptive and affordable products and services in fields as diverse as healthcare, automobiles, space research, consumer and household goods, or mobile technologies, to name but a few.

In this paper, I propose that the "lead market" theory can explain, to a sufficient extent, the attractiveness of India for frugal solutions and for their subsequent diffusion overseas ("reverse innovation"). On one hand, there are concrete economic factors that give rise to resource-efficient and affordable solutions to problems faced by people and companies in day-to-day life. On the other hand, frugality has been long regarded a virtuous social value in India. The socio-cultural context of the country, therefore, provides a conducive environment for the acceptance of frugal products and services on both demand and supply sides. For example, it has been reported that "to succeed in India, you need a product which costs 30 % of the global price and offers 95 % of the performance" (Tiwari & Herstatt, 2014a: 6). Managing Director of CLAAS, a German MNE operating successfully with localized products in India, has been quoted as saying that "every step in design also has to answer the question: Is the customer willing to pay for it?" (Böttcher, 2012: 6). The R&D head of a leading carmaker in India told this author, "It's about the aspirations of the youth in India. They want everything; they know everything; but they are not prepared to pay extra" (reported in: Tiwari & Herstatt, 2014a: 6). Head of the manufacturing planning team of the Tata Nano, the world's cheapest car, was reported as saying (Chacko, Noronha, & Agrawal, 2010: 67):

> Much of what we are using at our plant is also used by manufacturers such as Mercedes and BMW. [...] What we have done is remove all the frills and all the excess automation. We have taken exactly what we want and we have aggressively chased the costing we wanted.

India, therefore, seems to favor "design features, which avoid excessive or unjustified economic rents" while inducing demand to an extent that is "sufficient for enabling technological innovation and diffusion" (Quitzow, 2015: 236). This might pose a challenge for engineers and products designers in industrialized countries as they are more often used to technological optimization than to radical cost reductions (Dierig, Doll, Hegmann, & Kaiser, 2015; Oliver Wyman, 2013). Many frugal innovations originating in India, on the other hand, are known for radically reducing the total cost of ownership (TCO) and drastically increasing affordability (Govindarajan & Ramamurti, 2013; Rao, 2013). Path dependencies, e.g. resulting from the use of certain technological platforms over a long period of

time and spreading across product lines, may also impose invisible-yet-significant barriers on non-conventional, simple solutions. Researchers have, therefore, raised the question, "whether the firm headquarters located in developed countries fully appreciate the implications of such a challenge and whether this challenge gets duly reflected in the product strategy of the respective firm for the Indian market" (Tiwari & Buse, 2014: 5).

This study aims to investigate whether India enjoys a lead market advantage in respect of frugal innovations and, if yes, what factors contribute to this advantage. It also seeks to examine the possible connection of soft factors like national culture to this lead market advantage. The study is conceptualized as a qualitative investigation based on thick description (cf. Barzelay, 1993) to generate some potentially significant insights and create impulses for future research. This paper, apart from investigating the concept of lead markets and its application in the context of frugal innovations in India, also presents some qualitative results of an empirical survey conducted by the author that included Indian students at Hamburg University of Technology (TUHH). The results underscore the role of cultural factors as they show a significant variance between the preferences of Indian respondents and those of the rest of the respondents.

The paper is structured as follows: After this brief introduction, a definitional framework for frugal innovations is provided in Sect. 2. The concept of lead markets is introduced and applied to India in regard to frugal innovations in Sect. 3. In Sect. 4, culture is connected with the concept of frugality and anecdotal evidence from India is presented regarding social acceptance of frugal lifestyles and solutions. In Sect. 5, selected results of an empirical survey are presented that differentiate between responses by Indian and non-Indian participants. This non-representative survey helps in generating some interesting insights. For example, it appears as if frugal solutions are (a) especially popular with Indian respondents, and (b) the key motivation is of financial nature. The paper concludes with some summarizing thoughts in Sect. 6.

2 Definitional Framework for Frugal Innovations

Frugal innovations can be understood as products that do not compromise on *necessary* quality, reliability or safety standards but can enable significant cost reductions by, for example, making use of R&D, state-of-the-art technologies, inventive analogies and accessing open global innovation networks (Tiwari & Buse, 2014). They can be a medium to cater to the needs and aspiration of customers in an aspiration-driven market like India (Maira, 2005; Mashelkar, 2011).

However, a suitable definition of frugal innovation today must take into account the trends and development on a global level. Use of advanced technologies such as 3D-printing is reducing the barriers to entry for small and medium-sized enterprises (SMEs) because they can significantly reduce the need for economies of scale and

reduce costs (von Hippel, 2005). Many business customers and private consumers in the economically developed world are opening up for frugal solutions and the concept of "voluntary simplicity" is gaining traction (Elgin, 1981; Leadbeater, 2014; Thompson, Hamilton, & Rust, 2005). Therefore, Frugal innovations are no more a forte of emerging economies only and frugality as a societal virtue is, broadly speaking, experiencing a third renaissance in the long history of human civilization:

Frugality 1.0 Prior to 1945, frugality was seen as a universal value propagated by all major world religions and schools of philosophy (see, e.g., Lai, 2013; Rezvani & Zarei, 2012; Tiwari, Fischer, & Kalogerakis, 2016; Witkowski, 2010). The economic crisis of the 1930s and the resultant recourse to planned obsolescence led to disappearance of frugality as a social virtue from public life in the industrialized world (Adamson, 2003; London, 1932; Slade, 2007). The affluence of the post-War era further cemented this mind-set, which started to perceive frugality as a potential threat to prosperity and economic growth in saturated markets.

Frugality 2.0 Revival of frugality as an acceptable social value came bottom-up as a means of raising standards of living in emerging economies from non-existent or non-appropriate ("bad") solutions to appropriate and modest solutions (Baron, 1978; Economist, 2009; Grieve, 2004; Immelt et al., 2009; Prahalad & Mashelkar, 2010). Customers sought localized, functional and affordable solutions in lieu of (a) cheap but poor-quality solutions often coming from non-organized local producers (Prahalad, 2004); and (b) non-adopted, over-engineered, expensive and yet technologically outdated solutions of global MNEs (Prahalad & Lieberthal, 1998).

Frugality 3.0 Today, we can observe spread of frugality towards being again a more universal value due to factors such as financial constraints, environmental concerns and market saturation in the industrialized world, having a considerable overlap with "responsible innovation" (Chancellor & Lyubomirsky, 2011; Hanna, 2012; Herstatt, 2015).

Therefore, for the purpose of this study, I propose to work with the following definition of frugal innovations that can cater to considerations of frugality 3.0 (Tiwari, Fischer, et al., 2016: 17):

> Frugal innovations seek to create attractive value propositions for their targeted customer groups by focusing on core functionalities and thus minimizing the use of material and financial resources in the complete value chain. They substantially reduce the cost of usage and/or ownership while fulfilling or even exceeding prescribed quality standards.

That frugal innovations do not necessarily have to be restricted to commercial products and services but can also encompass marketing methods and organizational processes is evident from the definition. Key characteristics of frugal innovations that pertain to this definition have been articulated by Bergmann and Tiwari (2016) using a keyword analysis of around 115 published online reports in German-speaking nations, see Table 1.

Table 1 Key characteristics of frugal innovations

Letter	Characteristic	Occurrence
F	Functional	7 %
R	Resource-efficient	9 %
U	User-friendly	6 %
G	Good-enough	4 %
A	Affordable	20 %
L	Less-complex and simplified	13 %

3 India's Lead Market Potential

Lead markets are generally national markets that can be seen as pioneers in specific product categories. Innovations that succeed here have good chances to succeed in other markets as well, as has been proven in case of mobile telephony, robotics, renewable energies or computer industry to cite but a few example (Beise, 2001, 2004; Cleff & Rennings, 2012; Levsen, 2015). According to Bartlett and Ghoshal (1990: 242):

> In most industries, a few key markets lead the industry's evolution. They are often the largest, most sophisticated and most competitive markets in which the nature of impending global changes is first mirrored.

Lead markets were long thought to emerge and exist in the economically developed countries. More recent research, however, has shown that developing countries too, despite lacking in high per-capita income and customer sophistication, can acquire the role of a lead market if they are large enough and possess technological capabilities (Quitzow, Walz, Köhler, & Rennings, 2014; Tiwari & Herstatt, 2014a). The likelihood of the emergence of lead market in a developing country is greater, "if the product does not require path-breaking, high cost research; or if the innovation process can be contextualized in [open] global innovation networks to reduce market and technological uncertainty" (Tiwari & Herstatt, 2014b: 70). Research with involvement of this author had identified the emergence of a lead market for small cars in India (Tiwari & Herstatt, 2014a). Meanwhile, according to one report, 31 % of all small cars sold globally in fiscal year 2014–2015 were manufactured in India (IBEF, 2016).

For the purpose of this study, we work with the following definition of lead markets (Tiwari & Herstatt, 2014a: 205):

> A lead market is a national market, which primarily on account of the size of its domestic demand, its access to technological capabilities and its embeddedness in the global economy provides key innovation impetus to a particular category of products.

The lead market potential of a country is dependent on several mutually-reinforcing factors (see Fig. 1). In this section we will introduce the individual factors briefly; the emphasis however would be on elaborating demand and technological advantages, which have been identified in earlier research as two key factors responsible for the emergence of lead markets in emerging economies (Tiwari & Herstatt, 2014a).

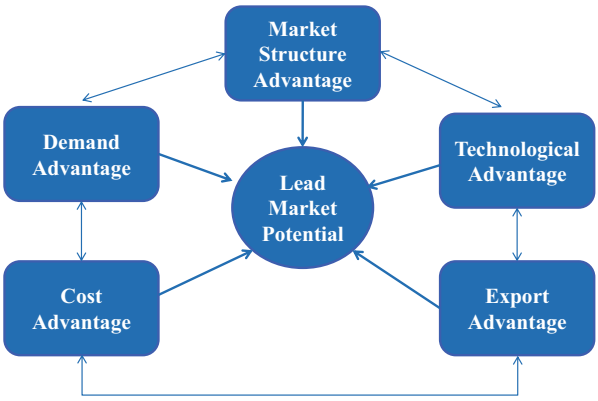

Fig. 1 The 'lead market' model

3.1 India's Market Structure Advantage

Market structure advantage means that a value-chain network with sufficient depth is available and that there is enough competition amongst firms to motivate them to innovate. This can be illustrated with one example from the automobile sector, which has changed from being a seller's market in the *license raj* era prior to economic liberalization to a fully competitive market now. The biography of K.P.S. Gill, former Director General of Police (DGP) in Punjab and often credited with putting down a militant insurgency, mentions that in the 1990s the Punjab Police was told by India's Union Home Ministry to wait for "2–3 years" for *placing* an order for bulletproof cars. Hindustan Motors, then the only licensed manufacturer of passenger cars ("Ambassadors") in India was able to produce only five bulletproof cars a month and was having a huge backlog (Chandan, 2013). According to R.C. Bhargava (2010: 244), former managing director of Maruti, India's leading carmaker, "the concepts of marketing and customer satisfaction were almost alien to the automobile industry" in the pre-liberalization era. Today, India is the seventh largest manufacturer of automobiles with a healthy mix of several domestic and global players. It has a large base of supporting and related industries that have been partly built as a deliberate government policy to promote self-reliance and sometimes also born as a necessity due to shortage of foreign exchange in the pre-liberalization period (Bhargava, 2010; Tiwari, Herstatt, & Ranawat, 2011). Today, in a liberalized economy India is home to a great number of active and successful entrepreneurs (Khanna, 2008); and country's competitiveness is largely rooted in the success of India's private sector firms (Das, 2012).

3.2 India's Export Advantage

A country can be seen as enjoying export advantages, when—for example—its domestic demand structure has similarities to foreign market conditions and when it has an industrial base that allows it to export its goods (or services) at competitive prices (Beise & Gemünden, 2004), without being significantly affected by negative country-of-origin effects (Johansson, Ronkainen, & Czinkota, 1994; Kotler & Gertner, 2002). The country should rather have positive visibility in international forums. Foreign trade and openness of a country for both incoming and outbound FDI generally have a positive impact on innovation capabilities of a country (Goel, Dahlman, & Dutz, 2007). In turn, a lead market enables these innovations to diffuse more easily in other countries (Beise, 2001); creating a virtuous cycle between global integration of an economy and its lead market potential (Tiwari & Herstatt, 2014a).

India enjoys a lot of visibility in the field of affordable solutions, as has been discussed in Sect. 1. Furthermore, India's membership in the World Trade Organization (WTO) and other multilateral organizations ensures an unrestricted access to most overseas markets for firms based in India. The country has become increasingly integrated in the global economy. Its total exports grew more than 17-folds within less than 25 years; from around US$18 billion in FY 1990–1991 to US$311 billion in FY 2014–2015 (RBI, 2015). Trade developments of recent past continue to confirm this trend: in 5 years between FY 2009–2010 and FY 2014–2015, the export of engineering and electronic goods from India doubled from about US$39 billion to US$79 billion. The share of engineering and electronic goods in India's total exports also increased from 21 % to 25 % within this timeframe (RBI, 2015). Also in terms of FDI, a similar picture can be observed. According to available data, the stock of outward FDI by Indian firms at the end of 2015 stood at US$139 billion up from less than 0.5 billion in 1995; in case of inward FDI by foreign MNEs, the stock at the end of 2015 was about US$282 billion (UNCTAD, 2016). This has helped open up new export avenues and also reduced the negative country-of-origin effects. Brand name of globally-renowned MNEs using India as an innovation and production base and "brand engineering" strategies adopted by some firms have mitigated the eventual negative effects of a "made in India" brand (Tiwari & Herstatt, 2014a).

3.3 India's Cost Advantage

India remains a low-cost nation in international comparison and the opportunity to benefit from large economies of scale helps further reduce the unit costs of production. As Table 2 shows, India enjoys a significant cost arbitrage in the manufacturing sector.

India's cost advantage goes beyond manufacturing and spreads across industry sectors and profession. Lower costs, along with sheer availability of skilled

Table 2 Average hourly compensation in manufacturing sector (in US$)

	India	China	USA	Germany
2012	1.59	3.07	37.71	42.42

Based on data by the Conference Board (2016)

professionals, remain one of the key drivers for the growth of India's IT industry (Prasad, 2008; Scholtissek, 2008; Simon, Näher, & Lauritzen, 2008). It is due to the availability of highly-skilled software engineers and their in international comparison well-affordable wages that have let Bangalore in India evolve into "a top-caliber cluster for low-cost, high-quality software development" (Simon et al., 2008: 368). India's labor cost arbitrage is likely to remain "significant for decades to come" (Haddock & Jullens, 2009: 48).

The large base of supported and related industries also enables a high degree of localization. Use of local components reduces the dependence on imports of components and helps reduce costs (cf. Bhargava, 2010).

3.4 India's Demand Advantage

India possesses a very significant demand advantage in the field of frugal innovations. It is the second most-populous country in the world with close to 1.25 billion people and a large share of youth, which make it one of the largest unsaturated markets worldwide (GOI, 2012; Maira, 2005). As per Census 2011, the country is home to 247 million households of which many still lack basic assets like refrigerators, televisions, telephones, computers, mediums of mobility, or access to formal banking services (GOI, 2012). For some items the penetration was reported as low as 3 % (access to the Internet) or 5 % (ownership of a four-wheeler). A succinct but most articulate elaboration of India's demand advantage is probably given by Rama Bijapurkar (2013: 4 f.) in her book "A Never-Before World: Tracking the Evolution of Consumer India":

> Never before have we seen so many consumers, mostly with modest incomes, mostly young (half of them below the age of twenty-five), subjected to so much technology in the after-Internet, after-cell-phones era, living in an age of optimism that comes from having had their real incomes consistently growing, sometimes four-fold in just one generation. Never before has there been a market so globally connected, and so connected with at the same time with an ancient past. Never before has there been a youth culture defined by a whopping 600 million people below the age of twenty-five, mostly poor, but raised in a heady environment of rising incomes, aspirations and freedom of thought and speech, stimulated by an overactive media [...]"

India is a growing economy. Its GDP/capita is expected to increase by US$1000 from US$1617 in 2015 to US$2617 by 2021 (IMF, 2016), creating an immense consumption potential. Apart from standard, known solutions, this also presents an opportunity for disruptive, non-conventional frugal solutions, e.g. on the basis of share economy or through social entrepreneurships. The opportunities for affordability-enabling, excellent solutions in all industry and customer segments

(e.g. public sector, B2B and B2C) are abound in a growing economy that is home to a very young population and still has to create a large-scale, state of the art public infrastructure. In fact, scholars like Rama Bijapurkar (2009) have attributed the growth in India's overall consumption more to growth in the affordability of products and services than to growth in incomes.

One of the reasons why India has become a hotbed for frugal innovations seems to lie in the prevailing socio-economic conditions of the country. First, cost-considerations have been always very prominent here. Bijapurkar (2013: 287 f.) cites the example of many Indian consumers who ask, "Why should I pay for all these fancy boxes and cartons" and reports that as a result of this consumer behavior "traditionally, suppliers in India have been very frugal with packaging due to cost considerations". Second, the socio-economic considerations have motivated people to innovate for social welfare. For example, Cyrus Poonawalla, founder of the Serum Institute of India, "got down to developing vaccines because that was the dire need in an agrarian country such as India" (Pawar, 2016: 245). Poonawalla, originally a student of commerce went on to study immune-biology, motivated by a desire to help the society, and is reported to sell "his vaccines on a 'no loss, no profit' basis in India" (Pawar, 2016: 245). India's young and unsaturated market with vast, yet-unmet needs is charaterized by less "innovation resistance" against new technologies. The large demand-base for affordable and appropriate solutions endows India with a tremendous advantage in terms of its lead market potential.

3.5 India's Technological Advantage

A country is thought to possess technological advantage if it is endowed with the necessary technological infrastructure and has access to tacit, first-hand knowledge (Tiwari & Herstatt, 2014a). Ever since independence Indian state and the private sector have continuously invested in creating technological capabilities (Gupta & Dutta, 2005; Herstatt, Tiwari, Ernst, & Buse, 2008), which has helped create a domestic technology base with certain pockets of excellence, e.g. in information technology, chemical industries and pharma. Indian companies have learnt to innovate within high resource-constraints (see, e.g., Maira, 2015; Mashelkar, 2011) and are traditionally open to both collaborative and non-technical forms of innovations. Arun Maira, former Head of Boston Consulting Group in India who earlier also worked in various management positions at TELCO as Tata Motors was earlier called, recounts one of his experiences from the pre-economic liberalization era in the 1980s (Maira, 2015: 57 pp.):

> If TELCO wanted to enter the light commercial vehicle market, the government ruled that TELCO would not be allowed to import either technology or parts. The products would have to be designed in India and all parts would have to be made in India. The company decided to take up the challenge. [. . .] An audacious goal, with very high levels of cooperation within the team, enabled TELCO to produce a very successful 4-tonne commercial vehicle, the Tata 407, within eighteen months. This was a world record in

> new product development time. Moreover, the Tata 407 was better suited to Indian conditions than the Japanese products.

Resource-constraints, in an aspiring environment, are known to trigger cost-effective, good-quality solutions (Gibbert, Hoegl, & Välikangas, 2007; Sharma & Iyer, 2012). NASA's space research to develop "affordable excellence" under resource-constraints is well documented (Majchrzak, Cooper, & Neece, 2004; Mccurdy, 2001). Significantly less study of economic aspects of space research by Indian Space Research Organization (ISRO) has taken place, even though it has managed to achieve significant technological accomplishments like Lunar and Mars missions on a shoestring budget. But the role of resource-constraints in creating affordable, high-tech solutions in India's space program is well documented in works of Dr. Abdul Kalam, former President of India, who had a long association with ISRO (Kalam, 2003; Kalam & Tiwari, 2002).

Another interesting example is delivered by the Punjab Police, which, while engaged in combating insurgency in the state, reportedly "established a working alliance with research labs all over the country" to overcome resource-constraints (Chandan, 2013: 146). This recourse to "open innovation" produced some very interesting results, apparently leading to certain radical innovations, as described in the biography of then-DGP KPS Gill by author Rahul Chandan (2013: 147)

> Gill laid emphasis on locally produced, low-cost improvements, rather than expensive imported equipment. A workshop was established [... that ...] developed bulletproof vehicles, bulletproof tractors, bulletproof mobile morcha, infrared torches, robots to handle live explosives and mobile elevated police posts/nakas. These innovations proved their mettle during anti-terrorist operations and were highly acclaimed improvisations. [...] The local laboratories also developed an electronic timer detector for time bombs. The device was, at that time, not available even in the international market. The cost of this device was only four percent of the commercial cost of comparable equipment after it was subsequently launched in the international market.

But also on the formal R&D front, India's expenditure has increased sevenfolds within about two decades, as per the last available figures, see Fig. 2 (GOI, 2013). The per capita expenditure on R&D doubled from US$4.8 in FY 2004–2005 to US $9.5 in FY 2009–2010.

At the same time, the share of the corporate sector in the national expenditure on R&D remains low. As per results of a national innovation survey in India, more than half of the innovative firms in the country "do not employ any scientists or engineers". Most of the innovations coming out of such firms are incremental innovations that are "new to firm" but not really "new to world" (GOI, 2014).

"The diffusion and absorption of market-relevant knowledge from abroad can occur through a number of complementary channels—including trade and foreign direct investment (FDI), direct trade of knowledge through technology licensing, and mobility of people (foreign education, foreign training of nationals, and knowledge flows driven by the diaspora [...])" (Goel et al., 2007: 85). On all these fronts India possesses significant advantages, some of which are elaborated in the following.

India has a large and professionally successful diaspora abroad. Especially the Indian community in the Silicon Valley in the United States is known to have

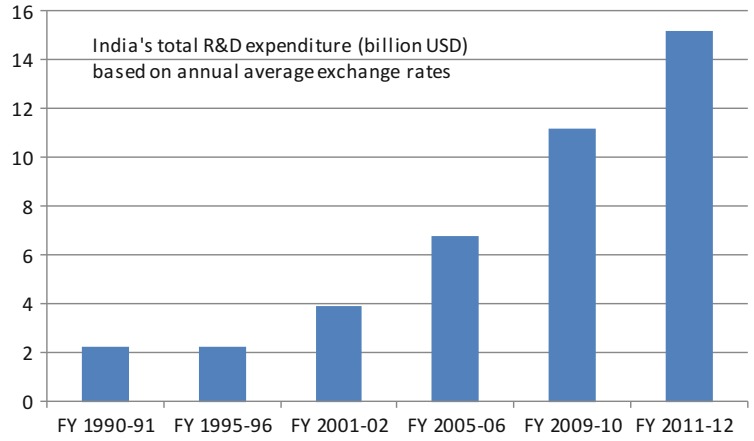

Fig. 2 Trends in India's R&D expenditure in billion US$ (based on data published by Department of Science and Technology, Govt. of India. Values have been converted from rupees into US dollars as per RBI's official average annual exchange rates.)

contributed to India's emergence as a technologically-advanced nation and contributed to the establishment and subsequent growth of the outsourcing/offshoring industry (Kapur, 2001; Nilekani, 2008; Tung, 2008). Today, India is estimated to have a 28 % market share in the US$72 billion-strong global sourcing market for engineering, R&D and product development services, according to industry body NASSCOM (2016). This resultant experience of designing products for global companies and providing engineering and R&D services creates tacit knowledge, which increases the innovative capability of the domestic industry.

Technology licensing can be seen as a "key channel of domestic and global knowledge absorption" that was long underused in India (Goel et al., 2007: 89). The situation has, however, changed completely in the past 5–6 years, see Fig. 3.

As Fig. 3 shows India's payments for using intellectual property of overseas entities have grown almost exponentially. From being practically non-existent in the early 1990s, they climbed to almost US$5 billion in FY 2015–2016 as per data released by the Reserve Bank of India (RBI). The data also reveals that Indian organizations too, even if on a low base, have started to generate revenues for their intellectual property. The integration in the global economy has given rise to new avenues in terms of technology-access for firms (Pradhan & Singh, 2009; Tiwari, 2011), and made it possible for firms to engage in "open global innovation networks" in the post-liberalization era (Tiwari & Herstatt, 2012). For example, the increasing share of sophisticated smart phones in India is estimated to cause India-based handset manufacturers to "together pay at least Rs. 2000 crore [close to US $300 million] in royalty payments over the next 4 years [2016–2020] to foreign telecom equipment makers" (Rajendran, 2016).

In respect of non-technological innovations India ranks amongst highly innovative nations, as about 60 % firms polled in a national innovation survey claimed to engage in non-technological innovations (GOI, 2014). An interesting example for

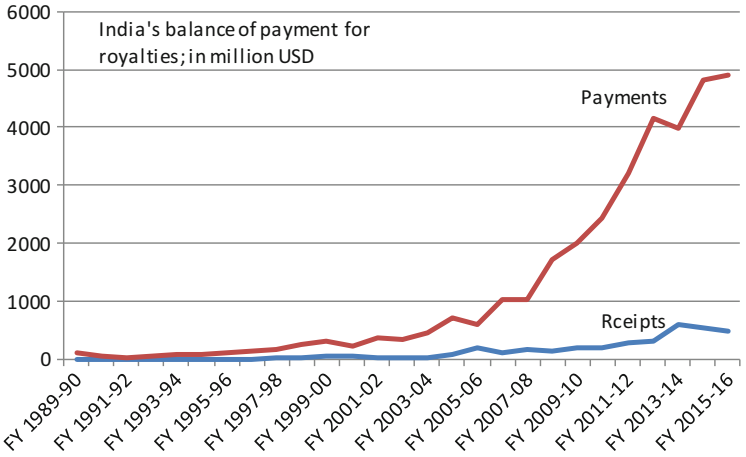

Fig. 3 India's balance of payment for use of intellectual property (Self-construction based on RBI data from various years; data from FY 2011–2012 onwards in the BPM6 format (1.A.b.8: "Charges for the use of intellectual property n.i.e."). Prior data relates to payments and receipts for royalties)

frugality-oriented organizational processes in state institutions is provided by the Punjab Police, which while fighting an armed insurgency in the state in 1990, came up with the idea of "mobile-cum-naka contingents" (a kind of police barricades) to free-up resources tied up at police pickets and barricades; and thereby created an additional and effective operational force with little extra expenses (Chandan, 2013). Rich descriptions of how organizational innovations have helped create highly disruptive, frugal products and services in India's automobile industry can be found in Bhargava (2010), Chacko et al. (2010), and Freiberg, Freiberg, and Dunston (2011).

Table 3 summarizes the most important factors for the individual advantage groups at a meta-level. It documents that overall India has a very high potential to turn into a lead market for frugal innovations.

4 Connecting Culture with Frugality

4.1 Role of (National) Culture

While frugal innovations are increasingly gaining relevance in today's world, it is only recently that the role of interdisciplinary research, such as that of psychological and sociological factors as determinants of consumer acceptance for frugal products and services has been highlighted in scholarly discourse (Tiwari, Fischer, et al., 2016). In the realm of culture, it is a rather undisputed fact that societies respond differently to human needs & desires. While some display greater permissiveness by allowing a more immediate gratification, other show an inclination

Table 3 A meta-level assessment of factors of lead market advantage

Group	Factor	Endowment
Demand advantage	Size of domestic demand (B2C; B2B)	Very large
	Growth prospects (unsaturated market)	High
	Overall share of "frugal solutions" in the market	Very high
	Financial need for low cost of ownership (a proxy for innovation resistance against frugal solutions; negatively correlated to per-capita income)	Very high (GDP/capita $1700)
Cost advantage	Economies of scale (see size of demand, above)	Very large
	Manufacturing costs	Low
	State incentives for production of "frugal" solutions	Exist
Export advantage	Significant cost arbitrage (low cost manufacturing)	Yes
	Similarity of demand with key target markets/customer segment	Developing Asia, Africa, South America
	Embeddedness in international trade	Yes
	Overseas presence of domestic MNEs (a proxy for estimating avenues of sales; measured in no. of foreign affiliates and/or outward FDI stock)	Outward FDI stock US$138 billion
Market structure advantage	A large and competitive industry	Yes
	Presence of strong domestic and "quasi-domestic" players	Yes
	A large base of domestic and global players	Yes
	Strong base of other supporting industries	Yes
Technology advantage	Availability of skilled professionals and technical manpower	High
	First-hand, tacit understanding of customer needs/wishes in resource-constrained contexts	High
	A long-established R&D base of domestic firms	Limited
	Policy support for R&D (weighted tax deduction)	Yes
	Level of protection for IPR	Controversial/improving
	Access to open global innovation networks	High

Based on Tiwari and Herstatt (2014a: 191)

towards restraint & postponement (see, e.g., Parsons, Shils, and Olds, 1951). In the following we examine some possible connections of the various dimensions of "national culture" (Hofstede, Hofstede, & Minkov, 2010) on the acceptance of frugality in a society.

In Geert Hofstede's model, the societal preference for thrift or frugality explicitly impacts at least two dimensions of culture, i.e. "short-term vs. long-term orientation"; and "indulgence vs. restraint". Societies that display a long-term orientation and/or that are more inclined towards restraint tend to display greater acceptance of thrift/frugality as a value. Indulgence, on the other hand, has been found to correlate "negatively with choosing thrift as a valuable trait for children" (Hofstede et al., 2010: 281). Cultures with long-term orientation seem to favor thrift

and "being sparing with resources" as people are more willing to subordinate themselves for a purpose, whilst cultures with short-term orientation tend to create "social pressure towards spending" as these are more concerned "with social and status obligations" (Hofstede et al., 2010: 243).

Also other dimensions, to a varying degree and in specific contexts, let themselves connect to frugality or the lack thereof. For example, Hofstede and his co-authors state that "status symbols are suspect" in cultures with low "power distance", and that "subordinates will most likely comment negatively to their neighbors if their boss spends company money on an expensive car" (Hofstede et al., 2010: 74). Conversely, in cultures with high power distance there may be tendencies to acquire status symbols, leading to extravagance by some; but those not belonging to the elite class may be more open to frugal solutions.

Collectivist societies, on average, tend to having lower per-capita income in comparison to more individualist societies. As a norm, people in collectivist societies seem to be more open to sharing resources with relatives, whereas individualist societies prefer personal ownership of resources, even for small children (Hofstede et al., 2010: 113). Therefore, it seems probable that societies that tend to be rather collectivist, would be more open for a frugal lifestyle and, as a consequence, more willing to adopt frugal solutions.

In societies tending towards masculinity, "challenges, earnings, recognition, and advancements are important", and men are expected to be "assertive, ambitious, and tough", whereas in more feminine cultures both genders are expected to be modest (Hofstede et al., 2010: 155). Relating this cultural dimension to consumer behavior, Hofstede et al. (2010: 165) assert that "more status products are sold" in masculine societies. This would indicate that cultures that are rather feminine should be expected to be more open for frugal products and services.

Cultures with less need for "uncertainty avoidance" tend to feel "comfortable in ambiguous situations and with unfamiliar risks", while people in cultures with high uncertainty avoidance feel more often threatened by unfamiliar risks (Hofstede et al., 2010: 203). As a result, we may expect that cultures with high uncertainty avoidance may more often seek "the perfect" solutions and therefore might be more skeptical of frugal solutions. This inference is in line with the observation by Hofstede et al. (2010: 208) that in societies with strong uncertainty avoidance advertiser rather use the appeal of expertise than appeal of humor.

4.2 Conventional Role of Frugality in India

Applying the Hofstede model to India we can observe (see Fig. 4) that the country tends more towards restraint than indulgence. It also seems to be less inclined to uncertainty avoidance, collectivism and long-term orientation. All in all, the scores suggest that the society, on average, may be more open to towards frugality in life.

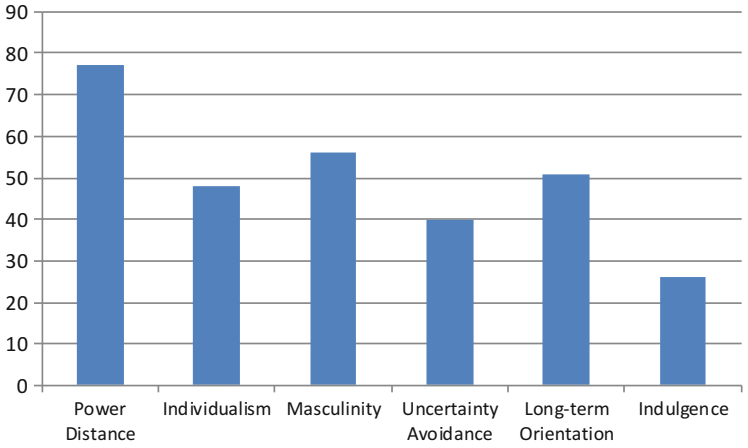

Fig. 4 India's scores on the cultural dimensions of the Hofstede model (based on values available at www.geert-hofstede.com, retrieved July 16, 2016)

I now wish to cross-verify this indicator with anecdotal evidence from ancient and modern-day India to generate some potentially interesting, even if preliminary, insights about the conventional role of frugality in India.

Kautilya, advisor to Emperor Chandragupta Maurya (ca. 322–297 BCE) and renowned author of Arthashastra—a much-celebrated treatise on statecraft—advises the state to be *prudent* (a synonym for being frugal as per its dictionary meaning). According to a translation of original Sanskrit text, Kautilya, sometimes referred to as Indian Machiavelli, advises that "the state should run a diversified economy actively, efficiently, prudently and profitably" (Rangarajan, 1992: 74). Writing about Kautilya's contemporary Indian society, later-day Greek geographer and historian Strabo (ca. 64 BCE–ca. 24 AD) reported that Indians "live sparingly and are healthy, even though their country produces everything in abundance" (Jain, 2011: 17). Quoting accounts provided by Megasthenes, Greek ambassador in the court of Chandragupta Maurya, Strabo writes further:

> The Indians all live frugally [. . .]. They lead nevertheless happy lives, being simple in their manners and frugal. [. . .] In contrast to the simplicity they observe in other matters, they love finery and ornament. They wear dresses worked in gold, and adorned with precious stones, and also flowered robes made of fine muslin. [. . .] they hold beauty in high esteem and resort to any device which helps to improve their looks (Jain, 2011: 21).

This shows that for ancient Indians frugality was not an outcome of poverty. Rather, it was a rooted in culture, which allowed them to indulge in other pleasures. According to Bijapurkar (2013: 319), "acquiring things has not been taboo; the ascetic and abstemious life was not the prescription at all for the householder—it only cautioned people to enjoy, but not get attached". Looking at the contemporary India one might get the impression that, leaving aside stark generalizations, not much has changed in this regard in the society. Writing about 2000 years after

Strabo, Mark Tully, the long-time correspondent of British Broadcasting Corporation in India and a prolific author, observed (Tully, 1992: 101):

> There is nothing that Hindus respect more than austerity in others, no matter how much difficulty they may find in practising it themselves. Austerity was one of the keys to Mahatma Gandhi's success.

So while the frugality of Indians in times of Chandragupta Maurya seems to be more of a voluntary/cultural phenomenon, Tully's observations, if correct, would point to a set of ideals, which—though not achievable for everyone—act as a "moral compass". Mahatma Gandhi's choosing a frugal lifestyle has been also analyzed by Rajiv Malhotra (2011: 348), who dwells into the motives of Gandhi:

> The unsustainability of British industrialization was prominent among his [Mahatma Gandhi's] concerns, making him arguably the first modern environmentalist. He noticed that the ever-increasing consumption in an industrial economy depletes the natural resources and destroys the self-sustaining villages which comprise the social fabric of India. In response to this he advocated and embodied a simple lifestyle. The sum total of all of his belongings were his glasses, a pair of sandals, a pen and a few dhotis.

This brings to the fore a new dimension, that of voluntary simplicity, one which arises as a deliberate choice out of social/environmental concerns. However, involuntary frugal lifestyles too simultaneously co-exist in India, which has been highlighted by Shashi Tharoor (2007: 341): "Asceticism always thrives better in penury". This statement may well be true for many Indian consumers today who are faced with financial constraints.

Nevertheless, prevalent cultural norms in India, in conjunction with given socio-economic factors, lead to acceptance of simplicity and frugality as a respected social value so that a person leading a frugal lifestyle, voluntary or otherwise, does not necessarily have to feel ashamed, as can be seen in this narration by Chetan Bhagat (2012: viii p.), a celebrated author from contemporary India, of his childhood:

> I come from a simple middle-class family. Both my parents worked for the government and I grew up in Delhi. Throughout my childhood, I remember the shortage of money being a constant theme in the house. We had enough to run the kitchen and pay for utilities but little to build assets on or make major expenses. For instance, we couldn't repair a broken sofa for years. When guests came to our house, we found it expensive to serve Coke and served lemonade instead. We rarely ate out in restaurants and when we did, we did so with caution, figuring out the cheapest and most-filling items on the menu. Funnily enough, we never felt deprived. I took the shortage of money as an essential factor of life. In a country like India, we were still better off than millions.

5 Select Results of an Empirical Survey

5.1 Survey Settings

In a survey conducted with students of Hamburg University of Technology (TUHH) the respondents were asked to state their preferences in the hypothetical

situation of purchasing a car. The respondents, who were international students of industrial-engineering related Master courses, all held an engineer's degree in Bachelors and had visited one compulsory course in Intercultural Management and Communication; but they did not necessarily know about frugal innovation. The respondents were asked to imagine that they were about to purchase a car and had financial resources to be able to afford a high-end (premium) car with many technological functions or a frugal car with good-enough quality and better fuel efficiency so that its total cost of ownership (TCO) was 33 % lower than that of the high-end car. Both models, otherwise, fulfilled the core needs (e.g. space, number of seats) in a similar fashion. The respondents were then requested to elaborate their answers and state lower and upper thresholds in terms of the "price point" and TCO. Later they were asked to relate their choice to any three dimensions of culture based on the Hofstede model and whether they thought their choice was in sync with their respective national culture.

5.2 Key Results and an Indian Perspective

The survey returned 111 valid responses. Respondents displayed a remarkable preference for the frugal model, 76 of the 111 participants (68 %) said they would chose a good enough car, while the rest said they preferred a high-end car. Amongst German students (n = 62), 61 % chose a frugal car. Amongst international students Indians constituted the largest group (n = 22), here an overwhelming majority (18; 82 %) stated to opt for a frugal model. In general students from developing and emerging economies (31 out of 40; 78 %) had an above-average preference for the frugal car, while students from the industrialized world (47 out of 71; 66 %) were also not far behind. Within the group of non-industrialized countries excluding India the preference for the frugal car stood at 73 %.

The open-ended responses by participants selecting a frugal model were analyzed and condensed into categories that led to identification of eight primary motivation factors. This analysis brought to fore a few interesting perspectives (see Table 4).

While most respondents desired to save money by preferring a frugal car, this reason was even stronger with Indian respondents. Interesting to note is that this is the singularly dominant reason for survey participants from India to purchase a frugal model, whereas among non-Indian participants many expressed the view that a car is a mere mode of transport and also a significant number cited environmental concerns for his or her choice. Some rejected purchasing status symbols. Interestingly, not a single Indian respondent gave an answer, which could be interpreted as rejecting status symbols.

The results seem to indicate that the frugality in India is often motivated by financial considerations that can be easily correlated to cultural dimensions like long-term orientation and restraint. It must be, of course, noted that this is a non-representative survey with a small group sample. The results are rather

Table 4 Comparison of motivational factors in preferring frugal solutions

Motivation for preferring a frugal car (multiple options)	Indian respondents (n = 18)	Other respondents (n = 58)
Save money (for some other purchase)	89 %	78 %
A car is a mere mode of transport	33 %	53 %
Avoid unnecessary technological functionalities	28 %	29 %
Simplicity as a moral principle	17 %	10 %
Chance to often purchase replacement products	6 %	0 %
Environmental concerns	6 %	43 %
Allows me to look different	6 %	0 %
I reject purchasing status symbols	0 %	43 %

meant to generate some plausible working hypotheses for a more detailed study at a later stage and here they seem in alignment with the insights generated in other sections of this paper.

6 Conclusions

This study set out to assess frugality in the Indian context and then to investigate what makes India a lead market for affordable excellence. For this purpose we followed a two-pronged strategy. First, we applied the lead market model, at a meta level, to the Indian context and analyzed the various advantage factors regarding their lead market potential. These factors revealed that India is endowed with many advantages—especially on the demand and technological capabilities fronts—that make it a very attractive market for frugal innovations, which can be then introduced in other markets with comparable socio-economic conditions or even in the industrialized world. India's increasing integration in the global economy provides a conducive atmosphere for that.

The second component of the research design for this paper was to analyze India's penchant for frugality with the lens of culture. Our analysis showed that India traditionally has had, even if for a variety of reasons, a positive attitude towards frugality. Resource-constraints have been used in India as a motivator to come up with affordable yet high-quality solutions.

Finally, the survey with Indian students confirmed these insights and indicated that Indian consumers show a high preference for frugal solutions. The acceptance seems to be, however, primarily motivated by financial considerations and in that it varies from their global counterparts, who also put emphasis on environmental aspects in their pursuit of frugality. This also puts limits on India's potential as a lead market for those countries where environmental concerns are a key driver to frugality. This is an area where Indian managers and policymakers need to look into

to fully utilize the country's lead market potential. In words of Rama Bijapurkar (2013: 287)

> India has the opportunity to get there [green products and sustainable development] ahead of others by not starting down the bad road at all, because most of India is yet to seriously begin its consumptions journey. Recycling has always been what the 'value-conscious' Indian consumer has always done, never wanting to throw anything away.

In the end it must be noted that the results are still of preliminary nature and need to be confirmed in larger-scale, representative studies. But one thing may be said with relative certainty: India is endowed with a culture and other socio-economic factors that increase the acceptance of frugal innovations. Demand for affordable excellence is increasing globally and India may benefit from it immensely, provided it does its homework.

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References

Adamson, G. (Ed.). (2003). *Industrial strength design: How Brooks Stevens shaped your world*. Cambridge, MA: MIT Press.

Agarwal, N., & Brem, A. (2012). Frugal and reverse innovation – literature overview and case study insights from a German MNC in India and China. In B. Katzi, T. Holzmann, K. Sailer, & K. D. Thoben (Eds.), *Proceedings of the 2012 18th international conference on Engineering, Technology and Innovation*. IEEE: Munich.

Arnett, D. K., & Claas, S. A. (2015). Frugal innovation: Solutions for sustainable global cardiovascular health. In J. P. Andrade, F. J. Pinto, & D. K. Arnett (Eds.), *Prevention of cardiovascular diseases: From current evidence to clinical practice*. Cham: Springer International.

Baron, C. (1978). Appropriate technology comes of age: A review of some recent literature and aid policy statements. *International Labour Review, 117*(5), 625–634.

Bartlett, C. A., & Ghoshal, S. (1990). Managing innovation in the transnational corporation. In C. A. Bartlett, Y. L. Doz, & G. Hedlund (Eds.), *Managing the global firm* (pp. 215–255). London: Routledge.

Barzelay, M. (1993). The single case study as intellectually ambitious inquiry. *Journal of Public Administration Research and Theory, 3*(3), 305–318.

Basu, R. R., Banerjee, P. M., & Sweeny, E. G. (2013). Frugal innovation: Core competencies to address global sustainability. *Journal of Management for Global Sustainability, 2*, 63–82.

Beise, M. (2001). *Lead markets: Country-specific success factors of the global diffusion of innovations*. Heidelberg: Physica-Verlag.

Beise, M. (2004). Lead markets: Country-specific success factors of the global diffusion of innovations. *Research Policy, 33*(6-7), 997–1018.

Beise, M., & Gemünden, H. G. (2004). Lead markets: A new framework for the international diffusion of innovation. *Management International Review, 44* (Special Issue 2004/03), 83–102.

Bergmann, S., & Tiwari, R. (2016). *Visibility and acceptance of frugal innovation in German-speaking countries*. Scientific Symposium on Potentials of Frugal Innovation in Industrial Countries, Fraunhofer Center for International Management and Knowledge Economy, Leipzig.

Bhagat, C. (2012). *What young India wants: Selected essays and columns*. New Delhi: Rupa Publications.
Bhargava, R. C. (2010). *The Maruti story: How a public sector put India on wheels*. New Delhi: Collins Business.
Bhatti, Y. A., & Ventresca, M. (2012). *The emerging market for frugal innovation: Fad, fashion, or fit?* Working Paper, Said Business School, Oxford.
Bijapurkar, R. (2009). *We are like that only: Understanding the logic of Consumer India*. New Delhi: Penguin Books.
Bijapurkar, R. (2013). *A never-before world: Tracking the evolution of consumer India*. New Delhi: Penguin Books.
Böttcher, D. (2012). The land of many fields. In CLAAS Group (Ed.), *2012 Annual report: New ways* (pp. 5–13). Harsewinkel: CLAAS KGaA mbH.
Bound, K., & Thornton, I. (2012). *Our frugal future: Lessons from India's innovation system*. London: NESTA.
Brem, A., & Ivens, B. (2013). Do frugal and reverse innovation foster sustainability? Introduction of a conceptual framework. *Journal of Technology Management for Growing Economies, 4*(2), 31–50.
Bruche, G. (2009). The emergence of China and India as new competitors in MNC's innovation networks. *Competition and Change, 13*(3), 267–288.
Bruche, G., & Wäldchen, D. (2013). Racing to the top? Catch-up strategies of Chinese and Indian independent car manufacturers. *International Journal of Automotive Technology and Management, 13*(1).
Cappelli, P., Singh, H., Singh, J., & Useem, M. (2010). The India way: Lessons for the U.S. *Academy of Management Perspectives, 24*(2), 6–24.
Chacko, P., Noronha, C., & Agrawal, S. (2010). *Small wonder: The making of the nano*. Chennai: Westland Ltd.
Chancellor, J., & Lyubomirsky, S. (2011). Happiness and thrift: When (spending) less is (hedonically) more. *Journal of Consumer Psychology, 21*, 131–138.
Chandan, R. (2013). *KPS Gill: The paramount cop*. Noida: Maple Press.
Cleff, T., & Rennings, K. (2012). Are there any first-mover advantages for pioneering firms? Lead market orientated business strategies for environmental innovation. *European Journal of Innovation Management, 15*(4), 491–513.
Conference Board. (2016, April 12). *International comparisons of hourly compensation costs in manufacturing, 2015 – summary tables*. Retrieved July 17, 2016, from https://www.conference-board.org/ilcprogram/index.cfm?id=38269
Das, G. (2012). *India grows at night: A liberal case for a strong state*. New Delhi: Allen Lane.
Dierig, C., Doll, N., Hegmann, G., & Kaiser, T. (2015, June 30). *Made in Germany: Dank deutscher Naivität schnappt China-Falle zu*. Retrieved July 17, 2015, from http://www.welt.de/wirtschaft/article143307503/Dank-deutscher-Naivitaet-schnappt-China-Falle-zu.html
Dutz, M. A. (Ed.). (2007). *Unleashing India's innovation: Toward sustainable and inclusive growth*. Washington, DC: The World Bank.
Economic Times. (2012, January 3). Solar ATMs fuel rural revolution in India. *Economic Times*, Mumbai.
Economist. (2009, April 18). Health care in India: Lessons from a frugal innovator. *The Economist*, pp. 67–68.
Elgin, D. (1981). *Voluntary simplicity: Towards a way of life that is outwardly simple, inwardly rich*. New York: Harper.
Freiberg, K., Freiberg, J., & Dunston, D. (2011). *Nanovation: How a little car can teach the world to think big and act bold*. Nashville, TN: Thomas Nelson.
Gibbert, M., Hoegl, M., & Välikangas, L. (2007). In praise of resource constraints. *MIT Sloan Management Review, 48*(3), 15–17.

Goel, V. K., Dahlman, C., & Dutz, M. A. (2007). Diffusing and absorbing knowledge. In M. A. Dutz (Ed.), *Unleashing India's innovation: Toward sustainable and inclusive growth* (pp. 83–103). Washington, DC: The World Bank.

GOI. (2012). *Housing, household amenities and assets – key results from Census 2011*. New Delhi: Government of India – Registrar General & Census Commissioner.

GOI. (2013). *Research and development statistics, 2011–12*. New Delhi: Government of India – Department of Science and Technology (NSTMIS Division).

GOI. (2014). *Understanding innovation: Indian national innovation survey*. New Delhi: National Science and Technology Management Information System (NSTMIS), Department of Science and Technology (DST), Government of India.

Govindarajan, V., & Ramamurti, R. (2013). Delivering world class healthcare, affordably: Innovative hospitals in India are pointing the way. *Harvard Business Review, 91*(11), 1–7.

Govindarajan, V., & Trimble, C. (2012). Reverse innovation: A global growth strategy that could pre-empt disruption at home. *Strategy and Leadership, 40*(5), 5–11.

Grieve, R. H. (2004). Appropriate technology in a globalizing world. *International Journal of Technology Management and Sustainable Development, 3*(3), 173–187.

Gupta, A. K. (2000). Grassroot innovations for survival. *LEISA India, 2*(2), 20–21.

Gupta, A. K. (2003). Conserving biodiversity and rewarding associated knowledge and innovation systems: Honey bee perspective. In T. Cottier & P. C. Mavroidis (Eds.), *Intellectual property: Trade, competition, and sustainable development* (Vol. 3, pp. 373–402). Ann Arbor, MI: University of Michigan Press.

Gupta, A. K. (2010). Grassroot green innovations for inclusive, sustainable development. In A. López-Carlos (Ed.), *The innovation for development report 2009–2010: Strengthening innovation for the prosperity of nations* (pp. 137–146). Hampshire: Palgrave Macmillan.

Gupta, A., & Dutta, P. K. (2005). Indian innovation system – perspectives and challenges. In UN-ESCAP (Ed.), *National innovation systems (NIS) in the Asia-Pacific Region* (pp. 92–114). New York: United Nations' Economic and Social Commission for Asia and the Pacific.

Haddock, R., & Jullens, J. (2009). The best years of the auto industry are still to come. *Strategy + Business, Summer*(55), 36–48.

Hall, J., Matos, S., Sheehan, L., & Silvestre, B. (2012). Entrepreneurship and innovation at the base of the pyramid: A recipe for inclusive growth or social exclusion? *Journal of Management Studies, 49*(4), 785–812.

Hammond, A. L., & Prahalad, C. K. (2004). Selling to the poor. *Foreign Policy, May–June*, 30–37.

Hanna, P. (2012). The evolution of simplicity and meaning. *Journal of Product Innovation Management, 29*(3), 352–354.

Herstatt, C. (2015, Jun. 10). Produkteentwicklung: Konsum in Zeiten « frugaler Innovationen ». *Neue Zürcher Zeitung*, Zurich.

Herstatt, C., Tiwari, R., Ernst, D., & Buse, S. (2008). *India's national innovation system: Key elements and corporate perspectives*. Economics Series, Working Paper No. 96, East-West Center, Honolulu, Hawaii.

Hofstede, G., Hofstede, G. J., & Minkov, M. (2010). *Cultures and organizations: Software of the mind – intercultural cooperation and its importance for survival*. New York: McGraw-Hill Books.

Holtbrügge, D. (2013). Indigenous management research. *Management International Review, 53*, 1–11.

IBEF. (2016). *Automobile industry in India*. New Delhi: India Brand Equity Foundation.

IMF. (2016). *World economic outlook (April 2016): Too slow for two long*. Washington, DC: International Monetary Fund.

Immelt, J. R., Govindarajan, V., & Trimble, C. (2009). How GE is disrupting itself. *Harvard Business Review, 87*(10), 56–65.

Jain, S. (Ed.). (2011). *The India they saw. Foreign accounts: 5th century BC – 7th century AD*. New Delhi: Ocean Books.

Johansson, J. K., Ronkainen, I. A., & Czinkota, M. R. (1994). Negative country-of-origin effects: The case of the new Russia. *Journal of International Business Studies, 25*(1), 157–176.
Kalam, A. P. J. A. (2003). *Ignited minds: Unleashing the power within India*. New Delhi: Penguin Books.
Kalam, A. P. J. A., & Tiwari, A. (2002). *Wings of fire: An autobiography*. Hyderabad: Universities Press.
Kapur, D. (2001). Diasporas and technology transfer. *Journal of Human Development, 2*(2), 265–286.
Khanna, T. (2008). *Billions of entrepreneurs: How China and India are reshaping their fortunes – and yours*. New Delhi: Penguin.
Kobayashi-Hillary, M. (2005). *Outsourcing to India: The offshore advantage*. Heidelberg: Springer.
Kotler, P., & Gertner, D. (2002). Country as brand, products, and beyond: A place marketing and brand management perspective. *Journal of Brand Management, 9*(4/5), 249–261.
KPMG. (2008). *Knowledge process outsourcing: Unlocking top-line growth by outsourcing "the core"*. IT Advisory, KPMG.
Kumar, N., & Puranam, P. (2012). *India inside: The emerging innovation challenge to the West*. Boston: Harvard Business Review Press.
Lai, W. (2013). Frugality. In O. Leaman (Ed.), *Encyclopedia of eastern philosophy* (pp. 208–209). London: Routledge.
Lamont, J. (2010, June 14). The age of 'Indovation' dawns. *The Financial Times*, London.
Lavallee, A., & Veach, E. (2010, February 25). Tata water purifier wins the top prize for novel product. *Wall Street Journal*. Retrieved from http://online.wsj.com/article/SB10001424052702304388304575574022361799134.html
Leadbeater, C. (2014). *The frugal innovator: Creating change on a shoestring budget*. Hampshire: Palgrave Macmillan.
Levsen, N. (2015). *Lead markets in age-based innovations: Demographic change and internationally successful innovations*. Wiesbaden: Springer Gabler.
London, B. (1932). *Ending the depression through planned obsolescence*. Retrieved March 25, 2016, from https://upload.wikimedia.org/wikipedia/commons/2/27/London_%281932%29_Ending_the_depression_through_planned_obsolescence.pdf
Maira, A. (2005). Aspiration alignment: A hidden key to competitive advantage. *Journal of Business Strategy, 26*(6), 12–18.
Maira, A. (2015). *An upstart in the Government: Journeys of change and learning*. New Delhi: Rupa Publications.
Majchrzak, A., Cooper, L. P., & Neece, O. E. (2004). Knowledge reuse for innovation. *Management Science, 50*(2), 174–188.
Malhotra, R. (2011). *Being different: An Indian challenge to western universalism*. Noida: HarperCollins.
Mashelkar, R. A. (2011). *Reinventing India*. Pune: Sahyadri Prkashan.
Mccurdy, H. E. (2001). *Faster, better, cheaper: Low-cost innovation in the U.S. space program*. Baltimore: John Hopkins University Press.
Menon, N. (2011, November 26). Indovation or Indian Jugaad goes abroad. *Economic Times*, Mumbai, p. 5.
Mitra, M. (2011, November 25). Indovation nation: Creating products in India for the Indian market. *Economic Times*, Mumbai, p. 5.
NASSCOM. (2016, n.d.). *ER&D and product development – snapshot*. Retrieved July 19, 2016, from http://www.nasscom.in/engineering-rd-erdembedded-systems
Nilekani, N. (2008). *Imagining India: Ideas for the new century*. New Delhi: Penguin.
Parsons, T., Shils, E. H., & Olds, J. (1951). Values, motives, and systems of action. In T. Parsons & E. H. Shils (Eds.), *Toward a general theory of action* (pp. 47–243). Cambridge, MA: Harvard University Press (Seventh Printing 1976).

Pawar, S. (2016). *On my terms: From the grassroots to the corridors of power*. New Delhi: Speaking Tiger Publishing.
Philip, L. (2008, September 20). Mumbai to be design hub for Renault's ultra low cost car. *Economic Times*, Mumbai.
Pradhan, J. P., & Singh, N. (2009). Outward FDI and knowledge flows: A study of the Indian automotive sector. *International Journal of Institutions and Economies, 1*(1), 106–133.
Prahalad, C. K. (2002). Strategies for the bottom of the economic pyramid: India as a source of innovation. *Reflections, 3*(4), 6–17.
Prahalad, C. K. (2004). *The fortune at the bottom of the pyramid: Eradicating poverty through profits*. Upper Saddle River, NJ: Wharton School Publishing.
Prahalad, C. K. (2012). Bottom of the pyramid as a source of breakthrough innovations. *Journal of Product Innovation Management, 29*(1), 6–12.
Prahalad, C. K., & Lieberthal, K. (1998). The end of corporate imperialism. *Harvard Business Review, 76*(4), 68–79.
Prahalad, C. K., & Mashelkar, R. A. (2010). Innovation's holy grail. *Harvard Business Review, 88* (7/8), 132–141.
Prasad, S. (2008, August 5). *India emerging as low-cost development hub*. Retrieved December 25, 2010, from http://www.zdnetasia.com
Quitzow, R. (2015). Assessing policy strategies for the promotion of environmental technologies: A review of India's national solar mission. *Research Policy, 44*, 233–243.
Quitzow, R., Walz, R., Köhler, J., & Rennings, K. (2014). The concept of "Lead Markets" revisited: Contribution to environmental innovation theory. *Environmental Innovation and Societal Transitions, 10*, 4–19.
Radjou, N., & Prabhu, J. (2013, January 10). Frugal innovation. A new business paradigm. *Insead Knowledge*. Retrieved January 2, 2016, from http://knowledge.insead.edu/innovation/frugal-innovation-a-new-business-paradigm-2375
Radjou, N., & Prabhu, J. (2015). *Frugal innovation: How to do more with less*. London: The Economist.
Rajendran, M. (2016, February 23). *Make in India runs into high royalty fee hurdle*. Retrieved July 16, 2016, from http://www.hindustantimes.com/business/make-in-india-runs-into-high-royalty-fee-hurdle/story-yUJWvgL1KSRBhAJ0R4ty6I.html
Ramdorai, A., & Herstatt, C. (2015). *Frugal innovation in healthcare: How targeting low-income markets leads to disruptive innovation*. Heidelberg: Springer.
Rangarajan, L. N. (1992). *Kautilya: The Arthashastra – edited, rearranged, translated and introduced*. New Delhi: Penguin Books.
Rao, B. C. (2013). How disruptive is frugal? *Technology in Society, 35*(1), 65–73.
RBI. (2015). *Handbook of statistics on the Indian economy*. Mumbai: Reserve Bank of India.
Reficco, E., & Márquez, P. (2012). Inclusive networks for building BOP markets. *Business and Society, 51*(3), 512–554.
Rezvani, A., & Zarei, M. (2012). The effects and consequences of extravagance and frugality from the perspective of Qur'an. *Journal of Basic and Applied Scientific Research, 2*(4), 3508–3514.
Rosca, E., Arnold, M., & Bendul, J. C. (2016). Business models for sustainable innovation – an empirical analysis of frugal products and services. *Journal of Cleaner Production,* forthcoming, 1–13.
Saraf, D. (2009, July 13). *India's indigenous genius: Jugaad*. Retrieved April 30, 2016, from http://www.wsj.com/articles/SB124745880685131765
Sauvant, K. P., Pradhan, J. P., Chatterjee, A., & Harley, B. (Eds.). (2010). *The rise of Indian multinationals: Perspectives on Indian outward foreign direct investment*. New York: Palgrave Macmillan.
Scholtissek, S. (2008). *Multipolare Welt: Die Zukunft der Globalisierung und wie Deutschland davon profitieren kann*. Hamburg: Murmann Verlag.
Sharma, A., & Iyer, G. R. (2012). Resource-constrained product development: Implications for green marketing and green supply chains. *Industrial Marketing Management, 41*(4), 599–608.

Simon, S., Näher, U., & Lauritzen, M. D. (2008). R&D: Aligning the interface with production. In E. Abele, T. Meyer, U. Näher, G. Strube, & R. Sykes (Eds.), *Global production: A handbook for strategy and implementation* (pp. 350–371). Heidelberg: Springer.

Singh, S. K., Gambhir, A., Sotiropoulos, A., & Duckworth, S. (2012). *Frugal innovation: Learning from social entrepreneurs in India*. Hampshire: The Serco Institute.

Slade, G. (2007). *Made to break: Technology and obsolescence in America*. Cambridge, MA: Harvard University Press.

Tharoor, S. (2007). *The elephant, the tiget and the cellphone: Reflections on India in the twenty-first century*. New Delhi: Penguin Books.

Thompson, D. V., Hamilton, R. W., & Rust, R. T. (2005). Feature fatigue: When product capabilities become too much of a good thing. *Journal of Marketing Research, XLII*, 431–442.

Tiwari, R. (2011). Indian investments in Germany: Innovation and R&D gain momentum in a stable partnership. In *Annual review 2011* (pp. 119–123). Mumbai: Indo-German Chamber of Commerce.

Tiwari, R. (2014). R&D internationalisation from an Indo-German perspective. In B. Dachs, R. Stehrer, & G. Zahradnik (Eds.), *The internationalisation of business R&D* (pp. 159–182). Cheltenham: Edward Elgar.

Tiwari, R., & Buse, S. (2014). German Mittelstand discovers BRIC: A survey of product strategies of German 'Hidden Champions' in China and India. *Indo-German Economy, 58*, 5–11.

Tiwari, R., Fischer, L., & Kalogerakis, K. (2016). *Frugal innovation in scholarly and social discourse: An assessment of trends and potential societal implications*. Joint working paper of Fraunhofer MOEZ Leipzig and Hamburg University of Technology in the BMBF-ITA project, Leipzig/Hamburg.

Tiwari, R., & Herstatt, C. (2012). Frugal innovation: A global networks' perspective. *Die Unternehmung, 66*(3), 245–274.

Tiwari, R., & Herstatt, C. (2014a). *Aiming big with small cars: Emergence of a lead market in India*. Heidelberg: Springer.

Tiwari, R., & Herstatt, C. (2014b). Changing dynamics of lead markets: A new role for emerging economies as innovation hubs. *The European Financial Review, April–May*, 69–72.

Tiwari, R., Herstatt, C., & Ranawat, M. (2011). Benevolent benefactor or insensitive regulator? Tracing the role of government policies in the development of India's automobile industry. *Policy Studies,* 58.

Tiwari, R., Kalogerakis, K., & Herstatt, C. (2014). *Frugal innovation and analogies: Some propositions for product development in emerging economies* (pp. 15–23). R&D Management Conference, IAT Universität Stuttgart, Fraunhofer IAO, Stuttgart.

Tiwari, R., Kalogerakis, K., & Herstatt, C. (2016). *Frugal innovations in the mirror of scholarly discourse: Tracing theoretical basis and antecedents*. R&D Management Conference, Cambridge, UK.

Tully, M. (1992). *No full stops in India*. New Delhi: Penguin Books.

Tung, R. L. (2008). Brain circulation, diaspora, and international competitiveness. *European Management Journal, 26*(5), 298–304.

UNCTAD. (2016). *World Investment Report 2016 – investor nationality: Policy challenges*. New York: United Nations Conference on Trade and Development.

von Hippel, E. (2005). *Democratizing innovation*. Cambridge, MA: The MIT Press.

Witkowski, T. H. (2010). A brief history of frugality discourses in the United States. *Consumption Markets and Culture, 13*(3), 235–258.

Wyman, O. (2013). *Global construction equipment market: Chinese companies set the pace*. New York: Oliver Wyman Group.

Part II
Connecting Frugal Innovations to Grassroots and the Bottom of the (Economic) Pyramid

Emerging Patterns of Grassroots Innovations: Results of a Conceptual Study Based on Selected Cases from India

Anup Karath Nair, Rajnish Tiwari, and Stephan Buse

1 Introduction

Innovations from developing economies have been the subject of intense scrutiny and debate (see, e.g., Agtmael, 2007; Immelt, Govindarajan, & Trimble, 2009; Prahalad & Mashelkar, 2010; Schanz, Hüsig, Dowling, & Gerybadze, 2011; Schumann, 2010; Von Zedtwitz, Corsi, Søberg, & Frega, 2015). There exists a variety of literature on low-cost innovations and innovations emanating from emerging markets. Various terms such as "Bottom of the Pyramid" (BOP) Innovations (Prahalad & Hart, 2002), Frugal Innovations (Tiwari, Kalogerakis, & Herstatt, 2016), Gandhian Innovations (Prahalad & Mashelkar, 2010), Jugaad (Radjou, Prabhu, & Ahuja, 2012), "Low-cost, high tech" innovations (Schanz et al., 2011) and Reverse Innovations (Immelt et al., 2009) have entered the innovation lexicon in a relatively short space of time. The surrounding rhapsody has caused a phenomenon called Grassroots Innovations to go relatively unnoticed.

Grassroots Innovations generally refer to products developed by "economically poor but knowledge rich people" who are disconnected from formal market ecosystems, but are able to creatively deploy their indigenous skills and local knowledge (Gupta, 2010). This concept has been chiefly popularized by works of Prof. Anil K. Gupta, who has undertaken numerous *shodhyatras* in India. In his own words, "Most of these innovations have been discovered through the shodhyatra - a journey to explore creativity at the grassroots level by walking through villages in different parts of the country - or, in other words, scouting expeditions" (Gupta,

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2016: 19). Although several scholars have based their analyses on the psychological, sociological, agricultural sciences and policy dimensions of Grassroots Innovations, as will be demonstrated later, so far not much attention has been paid to it from the perspective of innovation management, except for a few recent, notable exceptions such as by Praceus (2014), Praceus and Herstatt (2014), and Krämer (2015). Grassroots innovations often take place in resource-constrained contexts where an innovator sees the need for a creative solution in the absence of an (affordable) alternative from the formal channels. The innovation process is often non-systematic. According to Gupta (2016: 1), "Many people solve problems not always knowing that their solutions are very innovative, or that they have stumbled upon something that others can learn from". As a result, we continue to have limited understanding of how entrepreneurial actors can capitalize on indigenous knowledge and creativity and transform it into tools for revenue generation and inclusive economic development.

The primary focus of this paper is to study Grassroots Innovations through the lens of innovation management literature. The first segment of this study deals with the definitional aspects of Grassroots Innovations. Due to the limited availability of academic research, Grassroots Innovations have often been clubbed along with BOP Innovations and Frugal Innovations despite having their own unique flavors which distinguishes them (Tiwari & Herstatt, 2014). It is therefore essential for us to analyze these different categories of innovations and highlight the differences.

The second segment, explores the phenomenon of Grassroots Innovations in greater depth. In this segment, we introduce the concept of "innovation bricolage" by blending theory from the field of anthropology. This conceptualization allows us to classify the various processes involved in Grassroots Innovations. The primary data from a variety of Grassroots Innovation endeavors are closely examined in more specific contexts. This information is then synthesized to identify the parameters influencing the innovations.

All the inputs for this study originate from data gathered from 37 qualitative case studies from India. These cases were documented by Anup Karath Nair during the extensive fieldwork he undertook as an intern with the National Innovation Foundation (NIF) India. This study explores how the Grassroots paradigm might offer a unique model to promote development in which the poor not only play a part, but potentially also assume a leadership role in the creation of 'shared value'.

This paper is organized as follows: Sect. 2 introduces the definitional framework of Grassroots Innovations, while Sect. 3 deals with the research methodology. Section 4 contains 4 detailed case studies grassroots innovators. Section 5 characterizes Grassroots Innovations based on a broader, more generalizable data sample. This is followed by Sect. 6 which discusses the implications of the study and concludes with a summary.

2 Definitional Framework of Grassroots Innovations

Since the beginning of this century, "micro innovations" which can produce "macro results" (Wood & Hamel, 2002) are being recognized as new ways to advance the cause of economic prosperity. The view that engaging the poor in increased economic activity can help them become an engine of economic growth for the poor is increasingly gaining attention (Prahalad & Hammond, 2002; Prahalad & Hart, 2002; Seelos & Mair, 2007). However, so far the participation of the poor in the development process has been limited. In words of Anil K. Gupta (2000: 20): "Not only is there little opportunity for them to articulate their ideas, there is seldom an institutional space where their ingenuity and creativity in solving their problems can be recognized, respected and rewarded".

Several reasons exist why the participation of the poor in the development process is limited. Globally, the poor, especially those in rural areas, suffer from market access disadvantages that affect both the inbound and out-bound flow of goods and services, creating an adverse effect on "the rural population's income and quality of life" (Vachani & Smith, 2008: 53). In fact "limited local demand, combined with the high cost of transporting goods, to and from remote villages, depresses farmers' incomes and results in higher prices for the agricultural inputs and consumer goods they acquire from urban areas" (Vachani & Smith, 2008: 54). Weak infrastructure which includes poor roads, inadequate telecom services and disrupted electricity supply as well as lack of information combined with, inadequate knowledge and skills and widespread illiteracy all impede market access. Furthermore, three broad types of institutional voids negatively impact the market participation among the poor: institutional voids impairing market functioning (Khanna & Palepu, 2000; Leff, 1978), institutional voids hampering market development (Polanyi, 1994; Woodruff, 1999) and institutional voids impeding market participation (Mair & Marti, 2009). These conditions constitute the breeding ground for Grassroots Innovations.

2.1 Review of Literature on Grassroots Innovations

Grassroots innovations are a nebulous field as far as academic research is concerned and there are several schools of thought influencing theory building in this field. In order to trace the theory behind Grassroots Innovation, an extensive literature review was undertaken. The key words used include "grassroots innovation", "grassroot innovation" and various permutations and combinations of these keywords. This search yielded 34 publications. In a next step, the articles were then classified as relevant or irrelevant to the subject by reading their respective abstracts.

Of these 34 articles, 23 were found to be both relevant as well as available for an analysis. These included 2 book chapters, 13 journal articles, 5 conference papers,

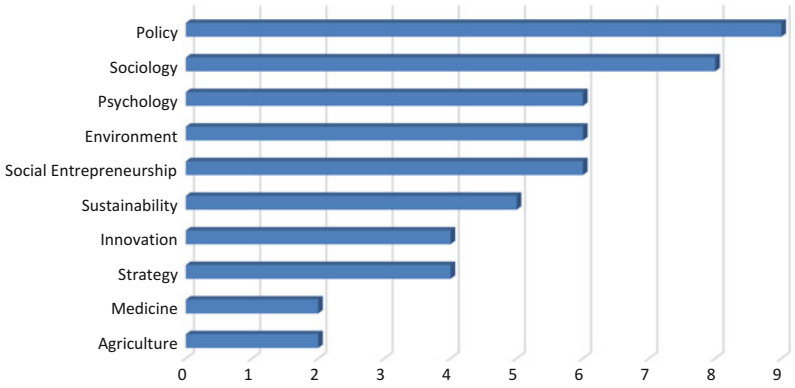

Fig. 1 Origin of theory: overall dominant contributors

and 3 working papers. An analysis of contributions by the authors involved in the 23 entries showed that Anil K. Gupta was the leading voice in the field followed by Adrian Smith.

All bibliographical references in these 23 articles were then keyed-in in a Microsoft Excel database to further analyze the origin of theory resulting in 302 unique entries. The number of citations of these references was recorded to analyze the impact of the work's contribution towards theory. Self-edited and self-cited entries were filtered out reducing the list to 136 unique results. These results were then further classified based upon the title of the article and the journals in which they were published, where applicable. During the classification, preference was first given to the Journal title and then to the title of the article. As a result, ten unique streams were identified (see Fig. 1). It seems that policy and social factors have so far been the most-important factors of influence in the research on Grassroots Innovations.

An analysis of the most cited authors was also carried out, which brought up some interesting results. The highest number of citations was six, which was shared by four authors. Adrian Smith emerges as the only author who not only focuses on Grassroots Innovation but also significantly contributes to its theory building (see Fig. 2).

Among the most cited authors, Adrian Smith's research revolves around policies impacting environment and sustainability (see, e.g., Smith, 2006). Kemp researches environmental issues (see, e.g., Kemp & Rotmans, 2005), Deci has contributed to psychology and motivation theories (see, e.g., Deci, 1971) and Geels' research incorporates flavors of innovation and sociology (see, e.g., Geels, 2004).

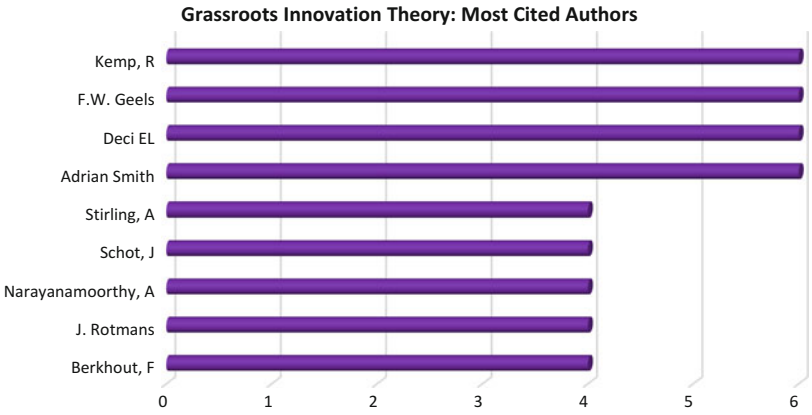

Fig. 2 Most-cited authors in the literature on grassroots innovations

2.2 Philosophy of Grassroots Innovations

"The enormous upsurge of creativity at grassroots demonstrates to the positive energy that has been locked up due to institutional inertia over several decades and centuries" (Gupta et al., 2003: 984). Yet, the potential for a knowledge intensive approach to promote economic development has rarely been explored (Gupta, 2010; Gupta et al., 2003). The possibilities that "the knowledge of the marginalized people may become a new counter point" (Gupta et al., 2003: 977) while dealing with issues pertaining to economic and environmental sustainability has yet to gain steam to fully realize its potential.

By grassroots innovations, we refer to the products developed by the economically poor people who are disconnected from formal market ecosystems, but successfully and creatively deploy their indigenous skills and local knowledge. One of the significant features of grassroots innovations is the context of the innovation itself. The reality is that even though grassroots innovation may be easy to grasp at a subjective level, yet its definition is riddled with several complexities.

This is because Grassroots Innovations are mostly minor or incremental changes to existing technological products making them better suited to local needs. Thus, the conventional definition of innovation, which emphasizes the complete newness or *significant improvements* (cf. OECD & Eurostat, 2005), is ill suited to define grassroots innovations. In spite the fact that grassroots innovations blend a lot of local, contextual and traditional knowledge to modify mainstream modern technologies, the innovativeness of this activity has rarely been acknowledged (Gupta, 2010; Gupta et al., 2003; Seyfang & Smith, 2007). A major reason for this contradiction is because grassroots innovations and commercialization; two important strands for decentralized, dispersed economic entrepreneurship have not hitherto been linked.

Seyfang and Smith (2007: 585) have attempted to circumvent the shortcomings of the conventional understanding of innovation by defining Grassroots Innovations as:

> Networks of activists and organizations generating novel bottom up solutions for sustainable development: solutions that respond to the local situation and the interests and values of the communities involved.

This definition originates from the attempt to bridge innovation with community action in the context of sustainability. However, even though this definition emphasizes on how grassroots niche innovations differ from mainstream business innovations and highlights most of its features, it seems to neglect the role of markets and individual innovators in grassroots innovations, thereby confining grassroots innovations, to the social economy of community activities and social enterprise.

Yet another definition of grassroots innovations was proposed by Bhaduri and Kumar (2009: 3):

> The term grassroots refer to individual innovators, who often undertake innovative efforts to solve localized problems, and generally work outside the realm of formal organizations like business firms or research institutes.

Furthermore, Bhaduri and Kumar (2009: 5) see grassroots innovations representing "a complex set of socio-political and economic aspiration of people, who normally bank on their skills and practical experience, rather than formal body of technical knowledge, to carry out technological activities."

The third definition of grassroots innovation emerges indirectly from the field of social entrepreneurship in words of Masse and Dorst (2007: 3), who describe grassroots social entrepreneurs as "citizens with an innovative idea to solve a social problem, but without an existing organization backing them". This definition would imply that grassroots innovations are those innovative products and services by social entrepreneurs that seek to solve problems while operating in the informal sector. While it may be true that grassroots innovators solve social problems but as rightly pointed by Anil Gupta et al. (2003), grassroots innovators sometime may not like to become entrepreneurs themselves. Therefore, defining grassroots innovations by blending social entrepreneurship with innovation poses a deficiency which could limit our understanding of the phenomenon and its potentials.

Before describing any innovation, the first step should be to consider the question of perspective (Abernathy & Clark, 1985). Understanding grassroots innovations depends on a sound understanding of localized contexts in which these innovations are rooted. Many inhabitants of these areas "live in poverty and relative isolation: their local products are unfamiliar in most of the world, their public infrastructures are weak, and their skills are unrecognized" (Gupta, 2006: 49). Formal markets and institutions usually do not find solutions for the highly localized problems faced by people in these regions (Gupta, Sinha, Koradia, Prakash, & Vivekanandan, 2001), as has been also pointed by some researchers in a critique of the BOP paradigm (Karamchandani, Kubzansky, & Lalwani, 2011; Karnani, 2007).

Subsistence is "a constant challenge" in these regions, as Gupta (2006: 49) points out: "Local individuals and tribal communities have long met those challenges by drawing on their local environments, inventing effective agricultural techniques. [...] Harsh conditions have done as much to induce individual creativity and innovation as to limit them". Not surprisingly, every now and then, an innovative solution emerges to solve some problem of day-to-day life (Gupta et al., 2001). Such innovations, then, "may be based on traditional knowledge and resources or emanate from an entirely contemporary context" (Gupta et al., 2001: 7), and due to their context-specific, focused and resource-efficient approach may be regarded as "appropriate technologies" (Grieve, 2004; Kaplinsky, 2011; Schumacher, 1973; Stewart, 1987). Such appropriate solutions, leading to minor or incremental innovations, "are most commonly observed in technologically backward countries primarily to make an existing technology suit better in an environment, where market size is small, capital scarcity is high, and preference for novelty is relatively low" (Bhaduri & Kumar, 2009: 4). According to Tiwari (2011: 17) "many local users in rural areas come up with inventions that are not only innovative and useful but also less expensive than the usual solutions available in the market". Another important feature of grassroots innovations is that they are generally "environment friendly and in sync with the given infrastructural conditions" (Tiwari, 2011). We, therefore, propose to define grassroots innovations from this perspective and propose the following framework:

> Grassroots innovations are products developed by people endowed with technical or traditional knowledge but disconnected from formal market systems. The inventors and potential customers need not necessarily be poor but are generally located in rural and/or semi-urban areas. The market size for such products can be large but fragmented, capital scarcity tends to be high, while need for novelty is relatively low. The inventors make a creative deployment of their indigenous skills and local knowledge.

The above definition is important, because it allows us to conceptualize the grassroots innovation processes around a concept called *bricolage*, which was first introduced by anthropologist Levi-Strauss (1966) and has found application in research on innovation management in resource-constrained environments (Baker, Miner, & Eesley, 2003; Baker & Nelson, 2005; Garud & Karnøe, 2003; Tiwari, Fischer, & Kalogerakis, 2016). Our present study adopts the term "bricolage" to describe the process of "making do" by recombining elements at hand (Mair & Marti, 2007). We argue that grassroots innovations can be thought of as 'innovation bricolage' because the innovators often make do with the resources and institutions at hand.

As a result, the process of grassroots innovation is often participative allowing individuals and communities to "benefit in terms of greater empowerment and confidence, skills and capacity" (Seyfang & Smith, 2007: 595) to enable market participation. Grassroots creativity can thus be used to "harness global capital and entrepreneurial support for decentralized development" (Gupta et al., 2003: 984). Since grassroots innovators are constantly making the trade-offs between accuracy, affordability, accessibility and local adaptability (Gupta, 2010), their knowledge and innovations can be utilized by firms to customize their products and

technological portfolios. Therefore, the grassroots paradigm provides firms not only with a large surface area for experimentation but also access to previously untapped markets.

Seelos and Mair (2007) point to works by London and Hart (2004) who have posited that MNCs need to re-equip their strategy tool kits by rethinking not just how they manage their resources "but also to develop and acquire new resources and capabilities and forge a multitude of relationships and alliances with local non-traditional BOP partners" (Seelos & Mair, 2007: 51). Seelos and Mair (2007) also refer to works by Hart and Sharma (2004) who have called for "the development of radically new capabilities and proposed the use of laboratories to bring about new business models that account for the concerns of fringe stakeholders, i.e. local customers and activist groups" (Seelos & Mair, 2007: 51). We will argue that grassroots strategy is an efficient means by which firms can "draw upon the experimental reserve that local community or individual knowledge experts have already accumulated through their own struggles in the past" (Gupta, 2000).

3 Methodology and Research Objectives

The data for this study was gathered between June 2010 and September 2010 when first-author, Anup Karath Nair, worked at the National Innovation Foundation, (NIF) India, as a summer intern. The NIF, as per information available on its webpage was established by the Ministry of Science and Technology, Government of India in year 2000 with the "main goal of providing institutional support in scouting, spawning, sustaining and scaling up grassroots green innovations and helping their transition to self-supporting activities".

Of the 37 samples of grassroots innovations which were investigated for this study, the author personally gathered data for 16 cases. Anup Karath Nair travelled through the Indian states of Gujarat, Kerala and Tamil Nadu to meet the grassroots innovators. Data was gathered through a questioner which captured the respondents' views pertaining to various aspects of innovation. To make the exercise representative and robust, all the innovators were interviewed at their respective innovation sites. A phenomenological approach (Davis, 1971) was adopted in order to capture the reality as perceived by the grassroots innovators. The remaining 21 innovations were selected from similar scouting and documentation reports carried out by two other Summer Interns at the NIF.

In addition to these interviews objective data, such as sales figures, was also sought from the innovators. The responses from the innovators were transcribed on the questionnaire. Photographs and video recordings of the innovations were made for future references. Furthermore, secondary data was gathered from various media sources including the internet.

All the innovators were required to sign a Prior Informed Consent (PIC) which allows NIF to use their data/knowledge for academic/commercialization purposes.

Pictures of the innovations and the videos capturing the work have been recorded and shared with the NIF where it is archived.

A combination of narrative and visual mapping strategies was deployed to analyze the data of the 37 cases. The narrative approach, in accordance with Maase and Dorst (2010: 186), was "used as a preliminary step aimed at preparing a chronological overview of what happened over time". This technique is particularly useful while writing the case studies selected to highlight the 'grassroots innovations' phenomena. Visual mapping was used to "compare and identify patterns" in the innovation process (Maase & Dorst, 2010: 186). The case cluster method allowed us to compile objective data from the field work. The objective data was statistically analyzed to identify patterns of innovation. This analysis fuels the discussion section where some of the findings can be linked to propositions, statements and themes of the literature review. A more detailed presentation of the cases than in this paper has been made available in a working paper, published as Nair, Tiwari, and Buse (2012).

4 Case Studies of Grassroots Inventors

In this segment, four detailed case studies are presented to highlight the complexities in the origin, process and evolution of the phenomenon called grassroots innovations.

4.1 Case Study A: Mansukhbhai Prajapati

Mansukhbhai Prajapati hails from the Western Indian state of Gujarat. He lives in a small village called Wankaner near a town called Morbi. Rajkot is the closest city. Morbi is one of the leading ceramic tiles manufacturing hubs in India manufacturing about 70 % of the total Indian ceramic production and home to more than 390 manufacturing units. Mansukhbhai Prajapati was 44 years old at the time of interview and a potter by profession. He lives with his wife and two sons. His parents were also potters who in addition worked as masons laying bricks for a living. Financial constraints on the family forced him to drop out of school when he was in the 10th Standard. After this he was employed at one of the local ceramic tile factories for 5 years where he earned a wage of 300 (approximately 5€) a month.

In the year 1989, Mansukhbhai quit his job at the tiles factory after a minor disagreement with the management. Without a job and a livelihood, he decided to utilize his skills as a potter to earn a living. In those days, he recalls witnessing a need for clay pans (called *tawa*) which the village folk used to cook their daily meals. Being a potter and with the baking skills he had acquired during his stint at the ceramics factory, Mansukhbhai focussed on baking and selling clay pans for as less as 3 (approx. 0.05€) a day. This venture was funded by a local private money

lender who Mansukhbhai was acquainted with from his factory days. He recalls paying an interest rate of 1 % per day.

Obviously, these pans were low in quality and need to be replaced every 15 days. All the competing clay pans in the villages were roughly the same quality. This was when Mansukhbhai first thought of improving the quality of his product. The experiences he gained while manufacturing the pans enabled him to realize that the clay was not being pressurized into consistent thickness causing the premature breakage of the pans. This insight motivated him to design a *tawa* machine.

While the design of the machine was perfected through trial and error, Mansukhbhai was assisted by a local mechanic in Morbi, to build the machine. This mechanic was one of the technicians who are called on to repair faults in the manufacturing units of the local ceramic companies. Mansukhbhai, grew his business from 1989 until 2001 by largely selling his tawas to the nearby villages. In 1995, he designed a water filter which was designed on a principle which exploited the porosity of clay but the main business still remained the clay pan.

In the year 2001, Gujarat was devastated by a massive earthquake which caused massive damage to life and property. The local Gujarati newspaper carried a photograph of a pile of broken earthen clay pots designed by potters of the region with a caption reading "The poor man's fridge is broken!" This was a reference to the traditional technique followed in Indian villages where water is stored in earthen clay pots which allows it to remain cool while drinking. The scientific principle that 'evaporation causes cooling' has been blended with traditional aesthetics to design utensils for everyday use.

Reading this caption was a "eureka" moment for Mansuhkbhai. It struck him that he could use his skills as a potter to design a clay chiller which is cooled using water and thus expand his product line. This was when he adopted the brand 'Mitticool' from the Hindustani word "Mitti" which means mud or clay and the English word 'cool' to denote cooling. A clay chiller designed on such a simple scientific principle would have none of the disadvantages of a traditional fridge which was expensive, and required electricity. The merits and demerits of the chillers are summarized in Table 1.

Table 1 Advantages and disadvantages of Mitticool chillers

Mitticool chiller	
Advantages	Disadvantages
Does not require any electricity and therefore no recurring cost	The cooling efficiency decreases in winters.
Food quality does not deteriorate for up to a week.	It's bulky and difficult to transport.
Locals claim that it better preserves the original taste of the fruits and vegetables.	A clay based design means that users have to regularly clean the interiors to avoid the growth of fungus.
Eco-friendly	

Source: Self-construction

Even though Mansukhbhai was buoyed by the success of his new product, his best-selling innovation did not happen until 2005. In 2005, his wife asked him to bring home a non-stick cooking pan. The non-stick pans were gaining popularity among the Indian households as they were easy to clean and consumed less oil while cooking. When Mansukhbhai, enquired the price for a non-stick cook pan and found out that it costed 450 (approx. 8.0€), he instantly knew that he would not be able to afford it. He was also aware that several people who bought his products would not be able to afford a metallic non-stick clay pan and this was the trigger for inventing the Clay non-stick tawa.

Back in 2005, Mansukhbhai had no idea about non-stick material. Neither was he aware about procurement of it, nor did he know a process by which he could coat clay pans. He even attempted to visit the Nirlep factory in Mumbai (financial capital of India). Nirlep was one of the largest selling brands of non-stick cookware in India. He was denied entry into the factory premises, but was able to track the details of a supplier in his home state Gujarat who later would provide him with the non-stick material he required for experimenting. The entire information gathering was done using personal contacts and informal channels.

Having sourced the materials, Mansukhbhai began to apply his previous skills such as spraying and glazing techniques, he had learnt at the ceramics manufacturing plant. He even updated some of these skills to be able to work with the new technologies. After a 1½-year struggle, he was able to produce his first non-stick clay tawa. He now sells the tawa for 100 (approx. 1.50€) and is constantly trying to improve the product features and design based upon feedback from his local customers. The significance of this innovation is best captured in words of Anil Gupta (2008):

> When a potter, Mansukhbhai, paints an earthen clay hot plate (*tawa*) with non-stick *Azo Nobel* (liquid) akin to Teflon, he makes a non-stick pan available in a dollar which would cost otherwise around 10 dollars (with a metallic base). Scientists at Bombay University Institute of Chemical Technology, one of the leading chemical technology labs in India, find unique property of this new affordable and accessible clay. Because of the porosity of clay plate, the paint gets embedded much better and does not come off as it happens in the metallic surface. The gas consumption is lesser than the aluminum pane and efficiency is much higher than the available panes. Health hazards are reduced whereas the advantage of low fat cooking are achieved in an extremely low cost manner.

4.2 Case Study B: M. Sadhasivam

M. Sadhasivam was a 45-year-old farmer in Palakkad, a small town in the south Indian state Kerala, at the time of field visit. Kerala is a socially advanced state in India but paradoxically, its economic development has not kept pace with its social development (Parayil, 1996). Sadhasivam, who had won several awards at school science exhibitions, dropped out when he failed his 12th standard exams. He lives in a village named Chittur with his wife and two children.

Being a small time rice farmer in the state of Kerala has several daunting challenges. Kerala has acute labor problems: Shortage of labor and high wage structure; employing a worker then costs 250 a day which was approx. 4.20€ and relatively high for Indian standards. This has prompted farmers to rent threshing and harvesting machines. These machines are very expensive and cost in the range of 2,500,000–4,000,000 (42,000–67,000€) which make them expensive to own. However, a farmer also has the opportunity to pay 2000/h (approx. 34€/h) to rent such a machine. A small scale agriculturist would require to rent the machine for about 13 h which means, it's going to cost 26,000/– (approx. 350€) per harvest. However, it is difficult to find a machine for rental at peak season causing potential losses in case of rains or other bad weather conditions. Since most of the farmers in India do not require and cannot afford large machines, Mr Sadhashivan conceived and prototyped a small threshing and harvesting machine.

This machine was entirely conceived, designed and prototyped by the innovator. The entire process lasted for 3 months, which is fairly quick for grassroots innovations. This machine has several advantages over the existing market solutions. The new device promises a 62.5 % cost reduction which makes it significantly cheaper than the existing products in the market. The existing harvesting and threshing machines cannot be transported by road which makes them more expensive to use during the harvesting season. Machine mobility is one of the significant contributions of this innovation. The wheels allow the farmer to drive the machine on the road to the required site of harvest. The hay collected after harvesting is important to several farming communities in India as they use it to feed their cattle and livestock. Existing harvesting and threshing machines, due to their design destroy the hay. Sadhasivam's prototype on the other hand is designed to harvest and thresh paddy in a manner which retains the hay. Finally, the differential engines used in his design achieve the twin benefits of improved efficiency and reduced fuel consumption.

Sadhasivam, in 2010, decided to supplement his farm income by selling a tender coconut packaged drink. Coconut palms are abundant in the costal state of Kerala. Sadhasivam distributes this drink in the local market. The efficient production of this drink required several tender coconuts to be split so that the water could be drained and the flesh/pulp removed. Traditionally, this is done by hiring laborers who wield the sickle and de-husk the tender coconut. They then proceed to crack open the nut and drain the water. This process is laborious and time consuming. Besides, as pointed earlier, labor is short and expensive in Kerala. The Tender Coconut Cutter was designed to overcome this problem.

At 4000 (approx. 67€) this innovation was entirely conceived and designed by this innovator. He built the device at a local hardware store with technicians executing the design. The innovations were completely funded from the innovator's personal savings. But in order to be able to sell the drink, the innovator was required to ensure its safe packaging. This was the trigger for his subsequent innovation "The Low Cost Packaging Machine".

The drink is packaged into polythene packs which ensure that packaging meets hygiene standards set by the Food Corporation of India. Liquid packaging is used

by several juice and shampoo manufacturing companies. It is also used extensively to package milk. Small scale co-operatives and entrepreneurs cannot afford the prices that large scale industrial packaging commands. The low cost equipment currently available in the market costs 150,000 (approx. 2500€) and can pack 16 packs/min. Small scale cottage industry products do not have the money to invest into such a machine, nor do they require to pack 16 packs/min. The alternative Paddle packing machines are available at 15,000 (approx. 250€) but they are not convenient to use. Hence, the innovator's product not only fulfils his personal need but can also fill a large market need when commercialized.

4.3 Case Study C: K.S. Sudheer

K.S. Sudheer was a 48-year-old driver, when he was visited for the purpose of this research. He lived in Ollur, a village in the Thrishur district of Kerala. Sudheer owns an auto rickshaw tempo which he drives to transport goods and earn a living. He has studied until the 10th standard after which he discontinued his education. He lives with his wife and their two children.

Sudheer has previously won a couple of local innovation awards and has always had a keen interest in mechanics. There was an instance where he modified the traditional steering handle of his tempo to incorporate a steering wheel. This made the vehicle easier to control and reduced the stress on the driver. But the Regional Transport Office (RTO) which issues licenses and decides who and what vehicles are allowed on the road, refused to recognize this modification and made driving of this vehicle illegal. Even though Sudheer had to forgo this innovation, he retained the same curious enthusiasm for mechanics.

As a driver, the innovator used to transport coconuts. He often used to hear complaints from the coconut workers about aching hands and shoulders. Besides, his wife too needed a quicker technique to de-husk coconuts which is a staple ingredient in many South Indian cuisines. Sudheer, a keen enthusiast in mechanics, designed a series of de-huskers by utilizing the spare parts from an adjoining workshop. There were several delays while working on this project and additionally, time too was a constraint. Sudheer has fallen short of cash on several occasions and at times used up the entire prize money he received during the events which felicitated his innovations to fund his product development. He recalled the technical difficulties he faced while innovating:

> The main technical challenge was the selection of the right kind of spring with adequate tensile strength so that the design functions efficiently.

This points to the deficiency of technical knowledge but remarkably, the innovator has persisted and successfully productized his innovation.

Sudheers' second but even more impressive innovation is the Auto Rickshaw Control for the Limbless. Sudheer poignantly recalls his inspiration for this innovation. His physically challenged friend had recently lost both his legs in an

accident. He still has both hands and good upper body strength but no means of livelihood. One afternoon, he requested Sudheer chiding him saying "You have developed several innovations some of which have benefitted our community but could you ever make something which will ensure my livelihood?"

This conversation inspired Sudheer to innovate and develop a device which ensures that he can drive an auto rickshaw, which can be totally controlled by his hands. This original innovation was invented in December 2009 and its operation was successfully demonstrated at several public forums and received a lot of appreciation.

The device acts like a normal auto rickshaw handle but differs in the fact that the mass cylinder which contains the fluid used to activate the breaks is situated on the top of the handle. Pressing the handle, down causes the fluid to be released causing the breaks to operate. This would bring the vehicle to a halt. The major technical challenge faced by the innovator was to perfect the fluid breaking system. It required several adjustments before it could work properly. The lack of formal technical knowledge meant that the innovator had to incur a substantially higher cost to innovate. The 'hit and trial' methods deployed meant that a lot of time was wasted on techniques which weren't useful.

4.4 Case Study D: S. Rajamani

S. Rajamani was a 46 years old cassava farmer at the time of our interview. He lived in Attur, a village in the Salem district of the south Indian state Tamil Nadu. Tapioca, yam and cassava are the staple crops grown in this region. Sago rice derived from cassava is the main diet for most locals in this region. Rajamani has studied until the 12th Standard and now lives with his wife and their three children.

The procurement price of the cassava crop is dependent on the starch content of the random sample being tested. The traditional manual process of determining the starch content is cumbersome and riddled with inaccuracies. In the most widely prevalent measurement process, the cassava is put into a bucket and the weight on the pan is balanced and the scale is locked. The tuber is then immersed in water and the lower point scale is adjusted until the balance is re-established. The reading on the point scale reveals the starch content of the tuber. This method is called the Reinmann Density Method. In these machines, the scales are directly graduated in percentage of starch.

During the crop auction, a farmer is paid for the quality of his products. Since the manual process is time consuming, only a small sample is tested and the whole procurement is made based on that reading. This causes the farmers to lose money. This situation provided the motivation for an innovation. Rajamani now uses the device in his farm while selling Cassava. The device is an excellent example of product fusion where the innovator has picked up the manual machine and fitted it with a digital weighing scale. He then goes on to replicate the starch point scale

digitally within the equipment. At the point of field visit he had been using this device for 4 years.

Rajamani has replicated the manual process on a digital scale with an enhanced design which reduces the number of pans being used. One is also not required to manually shift the tapioca from one pan to another as the leaver is used to submerge the tuber in or remove it from water. While the innovation was conceived and designed by Rajamani, he required help from his brother who worked in an electrical shop to design the digital scales.

The total cost of construction incurred by the innovator for a single piece of the equipment was 16,000 (approx. 270€). He self-financed the innovation and has had this product since 2007 when he first developed its prototype. He did not face a lot of financial difficulties while developing the prototype. This is a significant innovation for the entire community as now the farmers can get a reliable measure of the quality of their crops and are armed with this information during the procurement process.

4.5 Summarizing Analysis of the Case Studies

The previous segment allows us to get a comprehensive narrative of grassroots innovations. This segment contains a combined analysis of these innovations. The trends identified here are then applied to the complete sample which has been gathered during the field trip. Table 2 summarizes the details of the case studies.

Table 2 Comparison of the case studies

	Case 1	Case 2	Case 3	Case 4
Name	Mansukhbhai Prajapati	M. Sadhasivam	K.S. Sudheer	S. Rajamani
Number of innovations	2	3	2	1
Gender	Male	Male	Male	Male
Formal education	10th Standard	12th Standard	10th Standard	12th Standard
Profession	Potter	Farmer	Driver	Farmer
Prior work experience	Yes	No	No	No
Type of innovation	Radical	Radical	Incremental, radical	Radical
Impact of innovation	Cost, efficiency, usability	Cost, productivity	Comfort, productivity, usability	Efficiency
Change in product cost achieved	−72 %	−52 % to −63 %	51 %	N/A

Source: Self-construction

Table 2 allows us to analyze the preliminary trends which could emerge from this data. All four innovators in these case studies were men. Of the four grassroots innovators, two had the maximum number of 12 years of formal education. Sadhasivam who had the maximum number of years of formal education also had the maximum number of innovations. Does this mean that those with more number of years of formal education are more inclined to innovate serially? What can also be observed from this small sample is that most of the grassroots innovators are farmers. This poses the question: What are the professions of grassroots innovators?

All but one of the innovations can be classified as radical. A product is classified as a radical product if it is previously unobserved within the community of the innovator and is perceived as significantly new by the formal markets. An incremental grassroots innovation would refer to small but significant modifications to already existing products used within the grassroots innovator's community. Using this definition, only the coconut de-husking machine was a significant improvement of an already existing product. Thus, it was classified as in incremental innovation. All the other products were radical innovations.

We also observe that only one innovator had prior work experience in the formal industry where as all the other innovators were confined to one profession. But we also observe that the cost reduction achieved by the innovator with multiple industry experiences is the highest. Could the skills picked up by working in different industries impact the reduction in cost of the innovation?

Finally, we see that all these grassroots innovations have impacted the cost, efficiency, productivity, usability or comfort of the products or the processes they were used in. Is this an all-inclusive classification of the possible impacts of grassroots innovations or could grassroots innovations impact products across more dimensions? Are innovations with multiple impacts costlier or are they cheaper than innovations with single impact? Here in this sample, innovators with less number of years of formal education have been able to produce more dimensions of impact in their innovations. Is there any reason why this might be so?

Figure 3 depicts steps followed by the respective inventors in each step of the innovation process, as defined by Herstatt and Verworn (2004). This Grassroots Innovations Development Process illustrates some of the possible pathways for grassroots inventors. It also shows that grassroots innovations may take recourse to a sort of "open innovation" by availing assistance from their circle of acquaintances. One interesting point in the cases discussed here is that many of the inventions are yet to be introduced to the market; underlining the fact that commercialization remains a major problem for grassroots inventors.

All these observations and questions require us to carry out a detailed study with a larger sample size of grassroots innovators. Such an analysis holds the key to identifying established and possibly more generalizable trends, if any, within the field of grassroots innovations. The next segment deals with such an analysis.

Case 1	Trial & Error	Focus on Materials	Assistance availed	Assistance availed	Introduced
Case 2	Sketches	Focus on Design	Assistance availed	Assistance availed	Yet to be Introduced
Case 3	Trial & Error	Focus on both Materials and Design	No assistance was availed	No assistance was availed	Yet to be Introduced
Case 4	Process Study	Focus on Design	Assistance availed	Assistance availed	Yet to be Introduced

Source: Self-Construction

Fig. 3 Grassroot innovations development process

5 Characterizing Grassroots Innovations

The previous case studies illustrated the complexities involved in grassroots innovation process. Informal knowledge, traditional skills, personal networks, private capital and contextual insights all cross paths to evoke grassroots innovation. This segment presents the analysis of the data gathered on the field. The information is then used to highlight certain trends which could form the agenda for future research.

5.1 Gender and Age of Grassroots Inventors

Most of the grassroots innovators in our survey were male. Of the total of 32 innovators which our survey captured, 29 innovators were male and only 3 of the innovators were female. This trend is consistent with the observations made in the case study where all the four innovators are male.

It is also interesting to note that while the male innovators were spread across various professions (discussed in detail later on), all three female grassroots innovators were students, and in the age group of 11–20 years. One of the possible reasons for the low level of female grassroots innovators solving technological problems, may be the social constraints imposed on women, which have "prevented them from acquiring blacksmithy or carpentry tools" (Gupta et al., 2003: 981). While our results statistically support the dominance of male innovators over female innovators at the grassroots, further studies are required to foster a better understanding of such engendering and creative capacities.

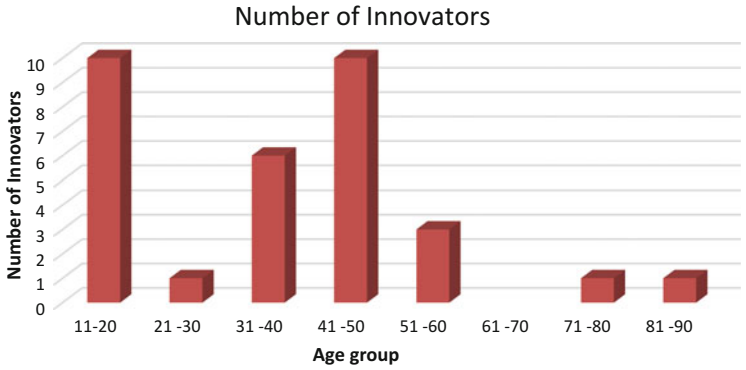

Fig. 4 Age-groups of grassroot inventors

The field data contained the age details of 32 grassroots innovators and as can be seen in Fig. 4, a majority of the grassroots innovators can be clubbed into two age groups, i.e. between 11 and 20 years and between 41 and 50 years. All of the innovators who fell between the 11 and 20 age brackets were students who were still attending their local village schools, potentially indicating the role of (formal) education in promoting innovation capability and innovative behavior. The two octogenarian grassroots innovators in the sample relied on the traditional practices and knowledge rooted in the community to execute their respective innovations. This trend is also consistent with the observations which we made during the case study where the innovators in all the four cases fell between the age brackets 41 and 50 years.

5.2 Formal Education and Grassroots Innovations

Education plays a significant role in development. How does formal education impact grassroots innovations?

Figure 5 depicts the impact of education on grassroots innovators. The data reveals that most of the grassroots innovators have received at least 7 years or more of formal education. There were eight innovators with 10 years of formal education and seven who had 12 years of formal education. There were only four grassroots innovators with University degrees.

Therefore, in general, we can observe a positive correlation between the number of years of formal education and grassroots innovations. What is also interesting is the absence of a significant number of grassroots innovators with college degrees. This could be because, a university degree allows a candidate to enter the formal employment market and work for firms where his or her skills are acknowledged through formal channels. Since necessity was always a key trigger for grassroots

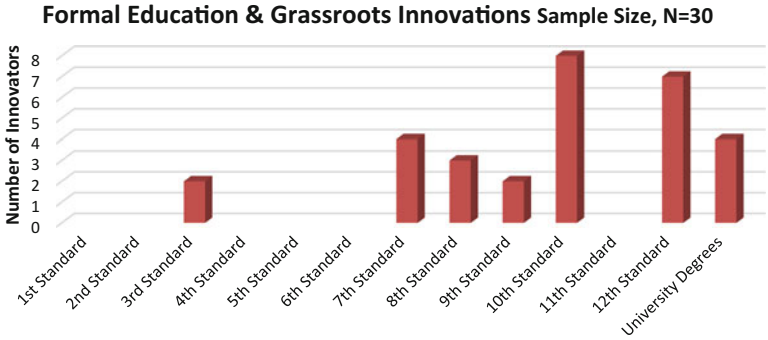

Fig. 5 Formal education of grassroot inventors

innovations, the incentive to innovate at a grassroots level decreases with the increase of formal education.

It was also observed that the innovators with the maximum number of innovations (three each), both had 12 or more years of formal education. However, the impact of the innovator who was less educated among the two was greater and the products more radical. It's also important to point out that all innovators with two or more innovations had 10 or more years of formal education.

When this data is jointly analyzed with the data about the age, we find that irrespective of the age, grassroots innovations require an average threshold of 8.5 years of formal education.

5.3 Occupations and Grassroots Innovations

When they are not busy innovating, what exactly do these grassroots innovators do for a living? A quick snapshot of the classification of the grassroots innovators by their professions can be found in Fig. 6.

Thus, we can see that the majority of the grassroots innovators in this sample are students (31 %). Farmers and technicians jointly occupy the second spot and each constitutes 22 % of the innovators in this survey. Other semi-skilled workers and small business men formed 16 % and 9 % of the innovators respectively.

Here it's essential to point out that all the auto mechanics, electrical mechanics and electronics mechanics were combined into the category of technicians. Auto mechanics were here the most dominant category comprising 71 % of the technicians. Other semi-skilled workers collectively refer to the people employed as potters, tailors, drivers and traditional stove makers. This is an extremely fragmented category and provides the vibrancy and diversity to the kinds of grassroots innovations which we encountered.

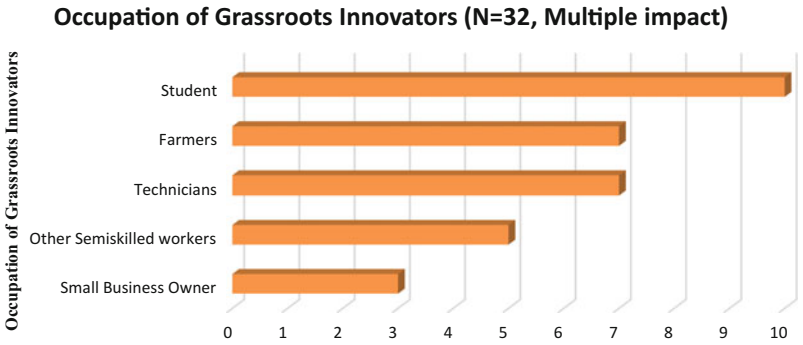

Fig. 6 Occupation of grassroot inventors

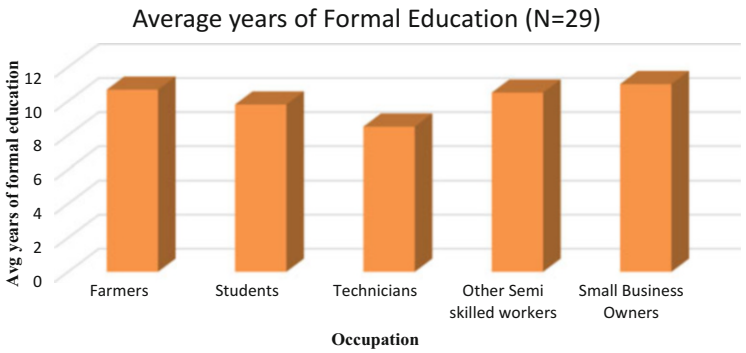

Fig. 7 Average years of formal education vis-à-vis occupation

A quick comparison of the average formal education received by the innovators classified by profession was carried out. The results for this (Fig. 7) make an interesting discussion.

Form Fig. 7 we can see that if students are ignored, then, probably not surprisingly, the small business owners are the beneficiaries of maximum number of years of formal education. Their average years of formal education are 11 years. This is slightly more than the average for the farmers at 10.7 years. This information could suggest why a combination of their innovativeness and base education has not helped them commercialize their respective innovations. Of the business owners in the survey, only one small business owner innovator is running a business based on his innovations. The technicians are the innovators with the least average years of formal education but what they lack for in theory, they make up for it with the on the job experience. Most of their innovations are solutions to persistent problems which they encounter in their daily lives.

5.4 Sources of Grassroots Innovations

To gain a better understanding of the practices involved in grassroots innovation, we mapped the innovator's knowledge in his base domain (profession) and analyze its transfer to the target domain (field of impact of the innovation). In order to do this, we used the framework developed by Kalogerakis, Lüthje, and Herstatt (2010). Since, grassroots innovators have a limited amount of formal knowledge to carry out their innovations, they rely on several processes to transfer their base knowledge to the target domain or the innovation. The complexity of the processes can be gathered from the case studies present at the beginning of this section. However, it is clear that the process being adopted allows the innovator to learn new skills, as well as induces new learning. Both these traits are vital strands of the "analogical thinking process" (Kalogerakis et al., 2010).

Grassroots innovations involve transfer of knowledge for both, (a) technological solution or functional principle, and (b) shapes, designs and arrangements. Here it can be observed that a majority of the radical innovations occur when the grassroots innovators applies his skills to another product category. An example of a case in this category is the Power driven Harvesting and threshing machine in which the farmer uses his knowledge of farming into the target domain of auto mechanics. A lot of tacit, functional knowledge has gone into the design of the innovation. A similar process occurs in the case of 'Electric Rocking bed with auto timer' where a small textile business owner and an electrician combined their skills to design a solution which fell in neither of their domains.

Data showed that an increase in the transfer distance between the base and the target domain has a positive impact on the novelty of the solution. 79 % of the identified radical grassroots solutions fell in the "another product category" or the "non-product knowledge domain". However, what is less understood is the reason why the innovators chose to innovate in their respective domains. The next section discusses the triggers for these innovations.

5.5 Innovation Triggers

Over the years, scholars have often drawn a distinction between voluntary or intrinsic motivation and "goal directive" or extrinsic motivation (Deci, 1971). This distinction makes it tempting to apply this theory to identify the underlying reason for grassroots innovators to innovate. *Prima facie*, a task riddled with uncertainties should be challenging to provide the motivation to innovate. Therefore intrinsic motivation could be an obvious driver for grassroots innovations. But, it has also been argued by some scholars that the "perceived payoff of an innovation" may be a key determinant of his/her decision to innovate (see, Bhaduri & Kumar, 2009: 7). Grassroots innovation, as discussed earlier, is a complex

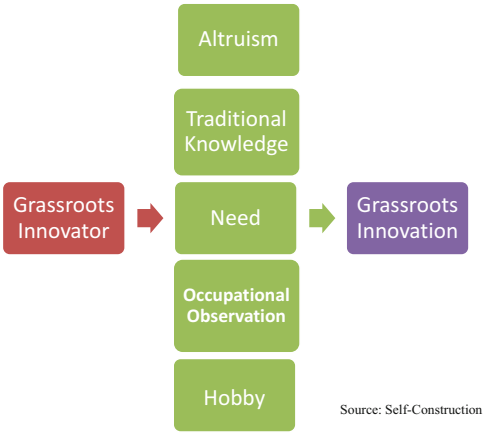

Fig. 8 Triggers of grassroot innovations

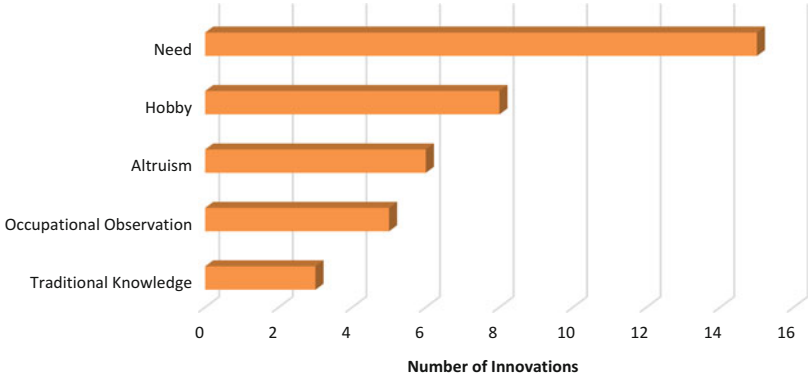

Fig. 9 Impact of individual triggers on grassroots innovations

phenomenon, driven by interplay of several multi-dimensional forces located in the surroundings of the inventor.

Innovation triggers facilitate the engagement between 'how to innovate' and 'why innovate' and the outcome of the dialogue triggers the grassroots innovation. Figure 8 lists the grassroots innovation triggers identified in this study.

We analyzed these triggers to identify their role in individual grassroots innovations and the results are summarized in Fig. 9.

It appears from Fig. 11 that most often it is a personal need which motivates a grassroots innovator to create a solution. Other factors, such as a hobby or the desire to help someone in his or her daily life (altruism), are also important drivers of grassroots innovations. At other times the innovator observes some needs/opportunities in his professional life and tries to make use of them by coming with an

attractive product or service. Finally, the desire to utilize and preserve traditional knowledge can also act as a trigger to innovations at the grassroots.

When these triggers are used to compare the radicalness of innovations, it was found that of the 14 innovations perceived as radical, only 6 innovations stemmed from (personal) needs. Of these six, only two were driven by a business requirement. There were five radical innovations which emerged from the hobbies of the innovator, two from altruism and one from traditional knowledge. It shows that a perceived personal need does not necessarily have to be the sole source of motivation for a radical innovation at the grassroots.

5.6 *Impact of Grassroots Inventions*

So why should grassroots innovations draw attention from beyond the communities they impact? This question is best answered by analyzing the impact of the grassroots innovations. The dimensions impacted by grassroots innovations are summarized in Fig. 10:

We can therefore see that a majority of the grassroots innovations revolved around enhancing the comfort and usability of existing products or solutions. Productivity was the next most impacted dimension followed by cost. So contrary to popular belief, grassroots innovations are not merely low-cost products competing on cost alone. They can be perceived as products which enhance the utility of a particular product.

It would be also worthwhile to carry out a classification of the grassroots innovations into radical and incremental innovations, based on how they are perceived by the local communities from which they emerge. From the sample, we calculate that 38 % of all the observed innovations may be considered radical innovations and the remaining 62 % of the innovations as incremental. The sample was then analyzed as per these classifications to see if the dimensional priorities

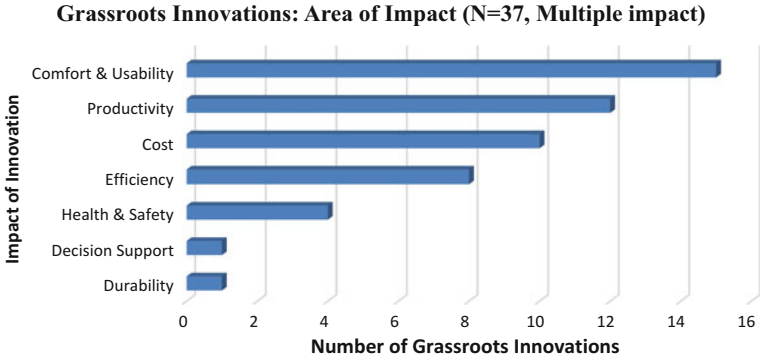

Fig. 10 Area of impact of grassroots innovations

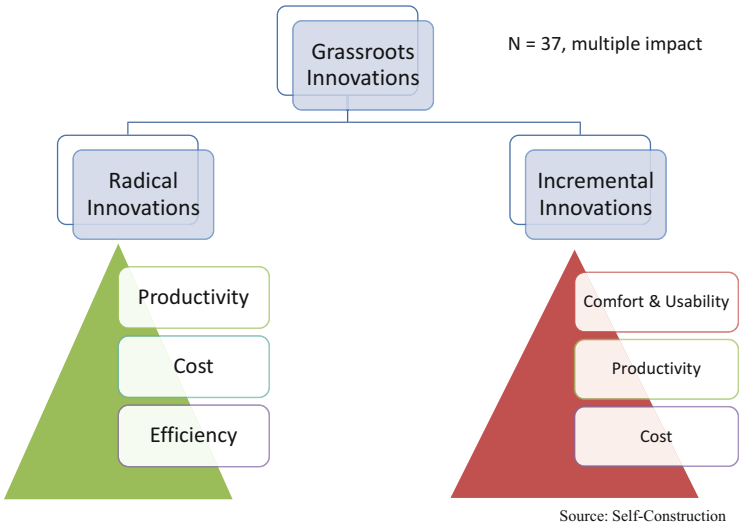

Fig. 11 Difference in dimensional priorities, grassroot innovations

differ for radical grassroots innovations vis-à-vis incremental grassroots innovations. Figure 11 summarizes the difference in priorities of these dimensions.

We can thus observe that for radical innovations, productivity, cost and efficiency were the most important criteria in that order of preference, whereas for the incremental innovations, comfort and usability were by far the overwhelming features of the innovations. This was followed by productivity and cost. This goes on to highlight that product cost is definitely an important feature which grassroots innovators consider while they innovate.

It was also observed that the grassroots innovators with radical innovations had on an average 10.7 years of formal education when compared to incremental grassroots innovators that had 9.9 years of formal education. This observation further highlights the potentially important role formal education plays in the grassroots innovations process.

While analyzing this data across professions, farmers and other semi-skilled workers jointly had the most number of radical innovations at three innovations each. This is in complete agreement with the previously observed trend where farmers and other semi-skilled workers had a higher level of average formal education. This probably also explains why these people are more inclined to innovate radically.

5.7 Cost of Grassroots Inventions

Of the various benefits accrued from innovations, cost is an important dimension. Product costs play an important role in determining the commercial viability of an innovation. Therefore, we carried out a detailed analysis of the cost and its impact on grassroots innovations. We analyzed data for 18 grassroots innovations, and gathered information about the competing product along with its price to perform this analysis.

Of the 18 grassroots innovations analyzed, only 3 innovations were more expensive when compared to similar competing products. Of the three, namely the universal gear joint leaver actuator, the foot pedal operated coconut de-husker and the domestic arsenal removal water filter, two i.e. the universal gear joint leaver actuator and the foot pedal operated coconut de-husker were vastly superior in quality when compared to the existing products in the market. A mini survey conducted among the users of these innovations revealed that they were willing to pay this price premium to acquire these products. No such information could be gathered for the water filter.

About 83 % of the grassroots innovations were able to offer their users the desired core functionality at a lower price. The reduction in cost varied from 25 % to 72 %. The radical innovations achieved a price reduction in the range of 51–71 %, whereas the incremental innovations achieved a price reduction in the range of 25–30 %.

Next we looked at the variation of cost along the dimensions of productivity and comfort & usability. These two dimensions were chosen because both these dimensions were the top priority for radical and incremental grassroots innovations respectively. The analysis showed that only one innovation which increased productivity was more expensive than the existing product. This observation lends support to the claim that grassroots innovations can be both superior as well as more affordable when compared to existing products in the. An analysis of the relation between comfort and utility with respect to product cost showed that all products except one were able to enhance utility while significantly reducing the cost. The reduced cost as a percentage varies from 20 % to 85 % suggesting great potential for innovation commercialization. These observations also seem to be in line with a study by Rao (2013), who found similar patterns of cost reduction in case of 13 frugal products.

5.8 Sources of Finance for Grassroots Inventions

Undertaking an innovation is a significant financial consideration for a grassroots innovator. Innovations are associated with uncertainty and current government support programs are not adequate to support such endeavors. The graphic below shows how grassroots innovators have been supporting their endeavors (Fig. 12).

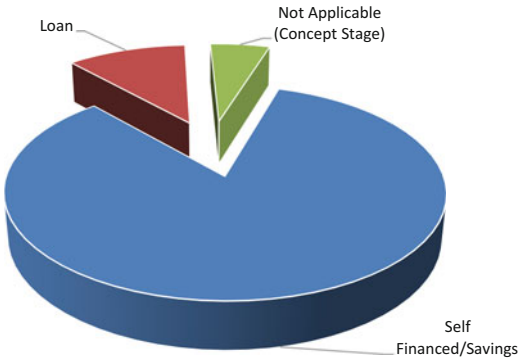

Fig. 12 Sources of finance

It can be seen that most of the grassroots innovators do not enjoy any kind of monetary support to carry out their innovation endeavors. Some of the innovators we spoke to have expressed their anguish and frustration when their innovations get stalled due to lack of funds. K.S. Sudheer, from the case study had to utilize the prize money he won as recognition for some of his innovations to fund future developments. Another innovator, who had built an amphibious car too complained about how difficult it was to access a bank loan despite being creditworthy. There were, undoubtedly, instances of inventors getting support from government institutions involved with agriculture and rural development. But there seems to be a need for action by policymakers to better support such innovative activities at the grassroots.

6 Summary and Conclusions

The analysis above allows us to identify some preliminary patterns, which are presented in the following:

a) Grassroots innovations in India seem to be dominated by male innovators (91 %). Social constraints imposed on women as a consequence of cultural institutions might be one reason behind the apparently low level of participation of female grassroots innovators. Possible is also that their inventions, for instance, if they are done for some household application, do not come to public notice as often as those of their male counterparts.
b) The study found a positive correlation between the number of years of formal education and grassroots innovations. Grassroots innovations seem to "require" an average threshold of 8.5 years of formal education.
c) If student innovators are left out, then farmers and technicians jointly constitute 22 % each of grassroots innovators surveyed. Other semi-skilled workers and small business men formed 16 % and 9 % of the innovators respectively.

d) The study reveals that an increase in the transfer distance between the base and the target domain has a positive impact on the novelty of the solution. 79 % of the radical grassroots solutions fell in the "another product category" or the "non-product knowledge domain".
e) Personal needs, hobbies, occupational observation, traditional knowledge and altruism were identified as grassroots innovations triggers.
f) For radical innovations, productivity, cost and efficiency were the most important areas of impact criteria in that order of preference, whereas for the incremental innovations, comfort and usability were by far the overwhelming features of the innovations. This was followed by productivity and cost.
g) About 83 % of the grassroots innovations were able to offer their users the desired core functionality at a lower price.
h) Eighty-four per cent of grassroots innovations were self-funded by the innovators. Only 11 % of the innovators had access to loans to fund their innovations.

This study contributes to the nebulous but evolving research about grassroots innovations. It seeks to enrich the innovation academic debate as well as suggests the possibilities such innovations hold. We have argued that grassroots innovations are neither imitations of the BOP innovations philosophy nor are they mere mutations of the frugal innovation paradigm. In fact, grassroots innovations have been articulated as "innovation bricolage" where we link the theory from anthropology with product innovation.

Understanding the emerging patterns of grassroots innovations should inform policy makers on "how value can be created from [grassroots] resources, which would enable them to make "better-informed decisions" while allocating resources which support the grassroots paradigm]" (Seelos & Mair, 2007: 61). The data for this research is drawn from a single country, India. Further research set in various emerging economies is required to analyze and compare the patterns which we isolated in this study. A comparison of the various patterns in different setting could further enrich and inform the research in grassroots innovations.

The case studies in this thesis contribute to a better understanding of the complexities associated with grassroots innovations and allow scholars to perceive their limits and challenges. While researchers in management and development economics have always called for specific strategies to pull the poor into a market economy (Karnani, 2007), research with strategies in which the poor are treated as producers is limited. Our work hopefully contributes to reducing this literature deficiency.

The ability of managers to integrate resources that create "more value than the cost of the resources" is vital to economic success (Seelos & Mair, 2007: 61). Grassroots innovations, can become, what Seelos and Mair (2007: 61) have called "a source for economically undervalued resources and capabilities". This is akin to unpolished diamonds, whose true worth is revealed when polished. Grassroots innovators, just like "adequate BOP partners", "may thus constitute a scarce resource, and identifying them early may enable companies to preempt market access and reap the benefits of first-mover advantage" (Seelos & Mair, 2007: 63).

Grassroots innovations can also complement the BOP and frugal innovation strategies to realize to help alleviate poverty, foster sustainable economic development and reach the "Millennium Development Goals" of the United Nations. The funding provided for official development assistance can be utilized to overcome the important hurdles for grassroots innovations.

Operationalizing Grassroots Innovations requires the coming together of various institutions, each of which plays a clearly defined role in the process. Managing the roles of the grassroots innovators, government institutions, private enterprises and non-governmental organizations (NGOs) is complex and requires clear but simple regulations. Such a framework may require time and effort to foster but that shouldn't deter policy makers from acting. To cite the instructions that Hubert Lyautey, a French general, according to an article in The Economist (2011) gave to his gardener: "if a tree takes 150 years to mature, that's all the more reason to plant it as soon as possible".

A better understanding of grassroots innovations would not only ensure a freer world where skills and intellect are rewarded, in some cases handsomely, but would also tackle the most unfair sorts of income disparity, and allow more people to move socially upwards by ensuring their participation in wealth creation. We hope that this study will help this subject get its due.

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References

Abernathy, W. J., & Clark, K. B. (1985). Innovation: Mapping the winds of creative destruction. *Research Policy, 14*(1), 3–22.

Agtmael, A. v. (2007). *The emerging markets century: How a new breed of world-class companies is overtaking the world.* New York: Free Press.

Baker, T., Miner, A. S., & Eesley, D. T. (2003). Improvising firms: Bricolage, retrospective interpretation and improvisational competencies in the founding process. *Research Policy, 32*, 255–276.

Baker, T., & Nelson, R. E. (2005). Creating something from nothing: Resource construction through entrepreneurial bricolage. *Administrative Science Quarterly, 50*(3), 329–366.

Bhaduri, S., & Kumar, H. (2009). *Tracing the motivation to innovate: A study of 'grassroot' innovators in India*. Working Paper # 0912. Evolutionary Economics Group, Max Planck Institute of Economics, Jena.

Davis, M. S. (1971). That's interesting! Towards a phenomenology of sociology and a sociology of phenomenology. *Philosophy of the Social Sciences, 1*(4), 309–344.

Deci, E. L. (1971). Effects of externally mediated rewards on intrinsic motivation. *Journal of Personality and Social Psychology, 18*(1), 105–115.

Economist. (2011, June 2). Wanted: Chief firefighter. *The Economist*. Retrieved July 19, 2016.

Garud, R., & Karnøe, P. (2003). Bricolage versus breakthrough: Distributed and embedded agency in technology entrepreneurship. *Research Policy, 32*, 277–300.

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy, 33*(6–7), 897–920.

Grieve, R. H. (2004). Appropriate technology in a globalizing world. *International Journal of Technology Management and Sustainable Development, 3*(3), 173–187.

Gupta, A. K. (2000). Grassroot innovations for survival. *LEISA India, 2*(2), 20–21.

Gupta, A. K. (2006). From sink to source: The honey bee network documents indigenous knowledge and innovations in India. *Innovations, 1*(3), 49–66.

Gupta, A. K. (2016). *Grassroots innovation: Minds on the margin are not marginal minds*. Gurgaon: Penguin Books.

Gupta, A. K. (2008, February 28). *What can we learn from green grassroots innovators: Blending reductionist and holistic perspectives for sustainability science*. Lecture delivered at Center for International Development, Harvard's Sustainability Science Program, Harvard University. Retrieved July 14, 2016, from www.iimahd.ernet.in/users/anilg/files/Articles/What%2520can%2520we%2520learn%2520from%2520green%2520grassroots%2520innovators.doc

Gupta, A. K. (2010). Grassroot green innovations for inclusive, sustainable development. In A. López-Carlos (Ed.), *The innovation for development report 2009–2010: Strengthening innovation for the prosperity of nations* (pp. 137–146). Hampshire: Palgrave Macmillan.

Gupta, A. K., Sinha, R., Koradia, D., Patel, R., Parmar, M., Rohit, P., et al. (2003). Mobilizing grassroot' technological innovations and traditional knowledge, values and institutions: Articulating, social and ethical capital. *Futures, 35*(9), 975–987.

Gupta, A. K., Sinha, R., Koradia, D., Prakash, T. N., & Vivekanandan, P. (2001). *Building upon grassroots' innovations: Articulating social and ethical capital*. World Social Forum Workshop, Porto Alegre, Brazil.

Hart, S., & Sharma, S. (2004). Engaging fringe stakeholders for competitive imagination. *Academy of Management Executive, 18*(1), 7–18.

Herstatt, C., & Verworn, B. (2004). The fuzzy front end of innovation. In EITIM (Ed.), *Bringing technology and innovation into the boardroom* (pp. 347–373). Houndmills: Palgrave MacMillan.

Immelt, J. R., Govindarajan, V., & Trimble, C. (2009). How GE is disrupting itself. *Harvard Business Review, 87*(10), 56–65.

Kalogerakis, K., Lüthje, C., & Herstatt, C. (2010). Developing innovations based on analogies: Experience from design and engineering consultants. *Journal of Product Innovation Management, 27*(3), 418–436.

Kaplinsky, R. (2011). Schumacher meets Schumpeter: Appropriate technology below the radar. *Research Policy, 40*(2), 193–203.

Karamchandani, A., Kubzansky, M., & Lalwani, N. (2011). Is the bottom of the pyramid really for you. *Harvard Business Review, 89*(3), 107–111.

Karnani, A. (2007). The mirage of marketing to the bottom of the pyramid: How the private sector can help alleviate poverty. *California Management Review, 49*(4), 90–111.

Kemp, R., & Rotmans, J. (2005). The management of the co-evolution of technical, environmental and social systems. In M. Weber & J. Hemmelskamp (Eds.), *Towards environmental innovation systems* (pp. 33–55). Heidelberg: Springer.

Khanna, T., & Palepu, K. (2000). The future of business groups in emerging markets: Long-run evidence from Chile. *Academy of Management Journal, 43*(3), 268–285.

Krämer, A. (2015). *Low-income consumers as a source of innovation: Insights from idea competitions in Brazilian low-income communities*. Wiesbaden: Springer Gabler.

Leff, N. H. (1978). Industrial organization and entrepreneurship in the developing countries: The Economic Groups. *Economic Development and Cultural Change, 26*(4), 661–675.

Levi-Strauss, C. (1966). *The savage mind*. Chicago: University of Chicago Press.

London, T., & Hart, S. L. (2004). Reinventing strategies for emerging markets: Beyond the transnational model. *Journal of International Business Studies, 35*(5), 350–370.

Maase, S., & Dorst, K. (2010). Emerging social entrepreneurship: Exploring the development process. In K. Hockerts, J. Mair, & J. Robinson (Eds.), *Values and opportunities in social entrepreneurship* (pp. 181–199). Hampshire: Palgrave Macmillan.

Mair, J., & Marti, I. (2007). Entrepreneurship for social impact: Encouraging market access in rural Bangladesh. *Corporate Governance, 7*(4), 493–501.

Mair, J., & Marti, I. (2009). Entrepreneurship in and around institutional voids: A case study from Bangladesh. *Journal of Business Venturing, 24*(5), 407–532.

Masse, S. J., & Dorst, K. (2007). *Exploring the development process of grassroot social entrepreneurship*. International Social Entrepreneurship Research Conference 3, Center for Corporate Values and Responsibility (CVR), pp. 1–24.

Nair, A. K., Tiwari, R., & Buse, S. (2012). *Emerging patterns of grassroot innovations – A conceptual study based on selected case studies from India*. Working paper No. 70. Institute for Technology and Innovation Management, Hamburg University of Technology, Hamburg.

OECD, & Eurostat. (2005). *Oslo manual: Guidelines for collecting and interpreting innovation data*. Paris: Organisation for Economic Co-Operation and Development (in joint publication with Eurostat).

Parayil, G. (1996). The 'Kerala model' of development: Development and sustainability in the Third World. *Third World Quarterly, 17*(5), 941–957.

Polanyi, K. (1994). *The great transformation: The political and economic origins of our time*. Boston: Beacon Press.

Praceus, S. (2014). *Consumer innovation at the base of the pyramid: Emerging patterns of user innovation in a resource-scarce setting*. Wiesbaden: Springer Gabler.

Praceus, S., & Herstatt, C. (2014). *Consumer innovation in the poor versus rich world – Some differences and similarities*. The 6th MEIDE (Micro Evidence on Innovation and Development) Conference, Cape Town (S. Africa), November 21–23, UNU-MERIT, OECD.

Prahalad, C. K., & Hammond, A. (2002). Serving the world's poor, profitably. *Harvard Business Review, 80*(9), 48–58.

Prahalad, C. K., & Hart, S. L. (2002). The fortune at the bottom of the pyramid. *Strategy + Business, 22*, 2–14.

Prahalad, C. K., & Mashelkar, R. A. (2010). Innovation's holy grail. *Harvard Business Review, 88* (7/8), 132–141.

Radjou, N., Prabhu, J., & Ahuja, S. (2012). *Jugaad innovation: Think frugal, be flexible, generate breakthrough growth*. San Francisco: Jossey-Bass.

Rao, B. C. (2013). How disruptive is frugal? *Technology in Society, 35*(1), 65–73.

Schanz, C., Hüsig, S., Dowling, M., & Gerybadze, A. (2011). 'Low cost-high tech' innovations for China: Why setting up a separate R&D unit is not always the best approach. *R&D Management, 41*(3), 307–317.

Schumacher, E. F. (1973). *Small is beautiful: A study of economics as if people mattered*. London: Blond & Briggs.

Schumann, M. (2010). *The miracle: The epic story of Asia's quest for wealth*. New York: HarperCollins.

Seelos, C., & Mair, J. (2007). Profitable business models and market creation in the context of deep poverty: A strategic view. *Academy of Management Perspectives, 21*(4), 49–63.

Seyfang, G., & Smith, A. (2007). Grassroots innovations for sustainable development: Towards a new research and policy agenda. *Environmental Politics, 16*(4), 584–603.

Smith, A. (2006). Green niches in sustainable development: The case of organic food in the United Kingdom. *Environment and Planning C: Government and Policy, 24*(3), 439–458.

Stewart, F. (1987). *Macro-policies for appropriate technology in developing countries*. Boulder, CO: Westview Press.

Tiwari, R. (2011). *'Doing well by doing good': New opportunities for Indo-German cooperation?* Berlin: OWC-Verlag für Außenwirtschaft. GermanyContact India. October, p. 17.

Tiwari, R., Fischer, L., & Kalogerakis, K. (2016). *Frugal innovation in scholarly and social discourse: An assessment of trends and potential societal implications*. Joint working paper of

Fraunhofer MOEZ Leipzig and Hamburg University of Technology in the BMBF-ITA project, Leipzig/Hamburg.

Tiwari, R., & Herstatt, C. (2014). *Aiming big with small cars: Emergence of a lead market in India*. Heidelberg: Springer.

Tiwari, R., Kalogerakis, K., & Herstatt, C. (2016). *Frugal innovations in the mirror of scholarly discourse: Tracing theoretical basis and antecedents*. R&D Management Conference, Cambridge, UK.

Vachani, S., & Smith, N. C. (2008). Socially responsible distribution: Distribution strategies for reaching the bottom of the pyramid. *California Management Review, 50*(2), 52–84.

Von Zedtwitz, M., Corsi, S., Søberg, P. V., & Frega, R. (2015). A typology of reverse innovation. *Journal of Product Innovation Management, 32*(1), 12–28.

Wood, R. C., & Hamel, G. (2002). The World Bank's innovation market. *Harvard Business Review, 80*(11), 104–113.

Woodruff, D. M. (1999). *Money unmade: Barter and the fate of Russian capitalism*. New York: Cornell University Press.

Consumer Innovation in the *Poor* Versus *Rich* World: Some Differences and Similarities

Sarah Praceus and Cornelius Herstatt

1 Introduction

Approximately one billion poor people are living at the global base of the income pyramid across various developing and underdeveloped countries (Prahalad & Hart, 2002). Their combined purchasing power of more than a billion US$ a day (Hammond & Prahalad, 2004) represents a large and so far mostly untapped market that increasingly attracts firms all over the world (Prahalad, 2012). However, serving the BoP with compatible products, services and business models requires a fundamentally different set of capabilities, resources and approaches than operating in established Western markets (Prahalad & Hart, 1999, 2002). The new product development for the BoP calls for different, BoP specific innovation focus, sources and processes (Nakata & Weidner, 2012; Prahalad, 2012; Viswanathan & Sridharan, 2012). So far research provides only very limited knowledge and practical guidance on how to innovate for the BoP (Nakata, 2012). Although literature stresses the importance of user orientation, involvement und co-creation as key success factors of innovation for the BoP (London & Hart, 2004; Viswanathan & Sridharan, 2012), even less is known with regard to indigenous or user innovation at the BoP (Nakata, 2012). Enhancing the current discussion of BoP people as consumers (Prahalad, 2010) and as producers (Hahn, 2009; Karnani, 2009; London, Anupindi, & Sheth, 2010), this paper contributes to the relatively new perception of BoP people as source of innovations (Gupta, 2006) and entrepreneurs (Christensen, Parsonsand, & Fairbourne, 2010) analyzed from a User Innovation perspective.

The paper starts with laying foundations in the fields of BoP and User Innovation and then presents the research context and methodology of the study. We will

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present first our descriptive and comparative analysis of a large Indian BoP consumer innovation sample. We will then closer analyze the effects of knowledge, context and demographic factors on innovation value and ultimately market recognition. Finally, the paper concludes with first managerial implications and suggestions for further research.

2 Background and Literature Review

2.1 Base of the Pyramid

The so-called "Base of the Pyramid" or "Bottom of the Pyramid" (BoP) describes a cross-national population group living at the lowest level of the economic or income pyramid. More than a billion people or one fifth of the world population lives from less than US$1 per day (Prahalad & Hart, 2002). The BoP business concept predominantly popularized by C. K. Prahalad (2010) emphasizes an economic point of view on the BoP as a large and so far mainly untapped market with consumers and production resources opposed to the idea of passive development aid recipients. The involvement of the private sector with its resources, know-how and skills allows to increase the quality of life through affordable products and services and to create entrepreneurial opportunities for the poor to lift themselves out of poverty (Hammond & Prahalad, 2004; Prahalad & Hart, 2002). Furthermore, the BoP is a huge market with a combined Purchasing Power of more than a billion US$ (Hammond & Prahalad, 2004) and high projected growth rates. Therefore, more and more companies seeking for new growth opportunities recognize the BoP as an attractive new market that has so far been ignored (Acosta, Kim, Melzer, Mendoza, & Thelen, 2011; London et al., 2010).

However, companies need to overcome various challenges and offer specific BoP compatible business models and product portfolios compatible in order to be successful at the BoP (Prahalad & Hart, 2000; The Economist, 2010). For example, products and services obviously need to be affordable and offered at a very low price ideally in combination with alternative payment and revenue models (Anderson & Markides, 2007). Needs, tastes and preferences of the BoP do not only differ significantly from the developed world but also within the BoP market itself, caused through the various e.g. geographic, cultural, and religious zones covered by the BoP (Banerjee & Duflo, 2007; Hammond & Prahalad, 2004). A large share of the population lives in remote rural areas or urban slums without any existing distribution or communication networks that could be used for product delivery, information and advertisement (Prahalad & Hart 1999, 2000). In addition, companies may face religious, racial and political conflicts and at same time have to cope with corruption, pirating and inefficient governmental enforcements (Anderson & Billou, 2007; Hammond & Prahalad, 2004). For many products so far unorganized or even nonexistent markets have to be created, e.g. the consumer has to informed

and educated with regard to a specific need and corresponding products (Anderson & Markides, 2007). In order to overcome these challenges and develop appropriate new products, innovation is required in all areas ranging from market creation and entire business models to product design (Prahalad & Hart, 2002; Prahalad & Mashelkar, 2010).

Innovation, however, requires detailed and in-depth information on the BoP needs and solution spaces that is difficult to access and highly sticky (Prahalad & Hart, 2002), whereby information stickiness is defined as "[...] the incremental expenditure required to transfer that unit of information to a specified location [...]" (von Hippel, 2010). Literature emphasizes the importance of user involvement and co-creation as a key success factor to access detailed information on need and solution spaces and to develop successful products (London, 2007; London & Hart, 2004; Viswanathan & Sridharan, 2012; Weidner, Rosa, & Viswanathan, 2010). In addition to a general call for research and guidelines on innovation for the BoP, a specific need for research on the BoP users' role as source and co-creator of innovations has been expressed (Nakata, 2012; Nakata & Weidner, 2012; Viswanathan & Rosa, 2010).

2.2 *User Innovation*

Empirical research proves that users of product and services often play an essential role for the development of new products and can be an important source of innovation (von Hippel, 1995). In fact, many of the most important and industry shaping product innovations that we can now buy from producers were originally initiated, invented and developed by users (de Jong & von Hippel, 2009). Shah (2000) even shows that 100 % of all first type innovations and 58 % of all major improvements relating to three different outdoor-sports activities originate from innovating users who experienced so far unmet needs. Furthermore, user innovation can be classified as a quite common phenomenon: e.g. Herstatt and von Hippel (1992) find that 36 % of industrial pipe hanger hardware users innovate; and Lüthje (2000) identifies a share of 37 % of all consumer users of outdoor-sports equipment who develop ideas for new or improved products.

In the context of user innovation, we define users as "... firms or individual consumers that expect to benefit from *using* a product or a service. In contrast, manufacturers expect to benefit from *selling* a product or a service" (von Hippel, 2010). Thus, according to this definition the term *user* embraces end consumer users as well as intermediate users who employ a producer's products and components to the creation process of another product or service (Bogers, Afuah, & Bastian, 2010) such as surgeons (Lettl, Herstatt, & Gemuenden, 2006), librarians (Morrison, Roberts, & von Hippel, 2000) or firms applying industrial instruments (von Hippel, 1976). Several studies have explored and confirmed the relevance of user innovation for the production of industrial goods (Franke and von Hippel 2003; Urban & von Hippel, 1988) and explored value and techniques of co-creation and

integration of innovating users to producers (Lilien, Morrison, Searls, Sonnack, & von Hippel, 2002; Thomke & von Hippel, 2002). Subsequently, research has been extended to innovating end consumers highlighting the importance of user innovation as source of innovation (Lüthje, 2000; Raasch, Herstatt, & Lock, 2008; Shah, 2000). User innovation research so far focuses on a relatively narrow niche of leisure and sports related consumer goods generated within a community environment (von Hippel et al., 2010). Only two very recently single broad and comprehensive studies in the UK (von Hippel et al., 2010), the US and Japan (Ogawa & Pongtanalert, 2011; von Hippel et al. 2011) examined the phenomenon across an entire consumer population and consequently opened up a new research area labeled consumer innovation (von Hippel, Ogawa, & de Jong, 2011), a term that we will adopt for this paper as well. Von Hippel et al. (2010) found user innovation to be a phenomenon of considerable size and scope with a share of 6.1 % of innovating consumers in the UK. In order to investigate generalizability there is a clearly stated need to conduct further broad consumer innovation studies in other countries (von Hippel et al., 2010) and moreover no comprehensive study on consumer innovation in developing countries and under different, resource-constraint living conditions has so far been conducted.

An unmet need is typically the trigger for a user innovation. The user expects to benefit from his solution via the use, sale or enjoyment of the development process (Bogers et al., 2010). In comparison to producer innovation user innovation is more likely to occur if need information is sticky and therefore costly to transfer (von Hippel, 1994). During the creation process a user applies his locally available solution knowledge to the development of the innovation (Lüthje et al., 2005). While addressing how producers can identify and take advantage of innovating users, literature explores which users are most likely to create commercially attractive innovations (cf. Franke & Shah, 2003; Franke, von Hippel, & Schreier, 2006; Lüthje, 2004; Morrison et al., 2000; von Hippel et al. 2011). Very limited research, however, has so far investigated the antecedents of this likelihood to create commercially attractive innovations namely demographic, contextual, knowledge-related and motivational factors (cf. Schreier & Prügl, 2008). This holds especially true regarding their influence on the quality or value of the resulting innovation.

3 Hypothesis Development

Evidence from the developed world shows that producers can profit considerably through integration of innovating users into their new product development work (cf. Herstatt & von Hippel, 1992; Lilien et al., 2002). The highly accentuated need for customer co-creation at the BoP (Viswanathan & Sridharan, 2012) also suggests a high if not even higher relevance for BoP innovations. But at least to our knowledge this has not been analyzed yet. We therefore focus here on consumer innovation at the BoP to generate insights on differences as well as communalities

to user innovation in the developed world. We will characterize innovating users, and look closer at behavioral patterns and results of their work. In order to pursue this, we analyze the antecedents of user innovation in this study. Lüthje et al. (2005) and Franke et al. (2006) suggest that users apply locally available information and resources to detecting needs and the development of appropriate solutions. Given the resource constraint living conditions at the BoP in combination with limited access to information sharing and providing infrastructure such as the internet, libraries and community memberships, a less diluted effect of knowledge, context and demographic factors on the innovativeness of BoP users can be investigated. In accordance with previous creativity and user innovation research (Amabile, 1982; Im and Workman 2004; Magnusson, 2009; Piller & Walcher, 2006) our dependent variables *creativity* and *technical elaboration* measure the value or quality of an innovation. Furthermore, innovation success and market response to an innovation is measured via the third dependent variable *market recognition*.

First we assess the effect consumer knowledge factors on the innovation quality that is creativity and technical elaboration followed by an effect analysis of innovation quality and contextual factors on market recognition.

3.1 Knowledge Related Hypothesis

Possession of knowledge does not only determine a consumer's propensity to innovate but also the quality of the developed idea (von Hippel, 1994, 2010). Successful innovations require relevant technical knowledge in order to detect technical opportunities and limitations of product ideas and subsequently to implement ideas into reality (Lüthje, 2004; Magnusson, 2009; von Hippel, 1994). Therefore, we hypothesize:

H1a Consumer's technical experience with the underlying technology is positively related to their ability to generate creative innovations

H1b Consumer's technical experience with the underlying technology is positively related to their ability to generate technically elaborated innovations

Consumers who innovate frequently gain innovation experience and draw every time on the personal knowledge pool at their disposition. Innovative creativity, however, is driven through the new combination of existing knowledge elements. If a consumer innovates on a regular basis and has already combined parts of his knowledge into an innovation, another creative and new combination of his personal knowledge pool becomes less likely (Kalogerakis, Lüthje, & Herstatt, 2010). Baldwin, Hienerth, and von Hippel (2006) observe this phenomenon regarding design spaces, which include all possible combinations of a single class of objects such as rodeo kayaks. The more designs of a given design space are explored the more the design space gets exhausted. Conversely, a consumer's innovation

experience increases his technical knowledge and experience that he employs analog to hypothesis 1b to generate his innovation. Thus, we hypothesize:

H2a Consumer's innovation experience is negatively related to their ability to generate creative innovations

H2b Consumer's innovation experience with is positively related to their ability to generate technically elaborated innovations

Evidence from studies conducted by Wuchty, Jones, and Uzzi (2007) and Schettino, Sterlacchini, and Venturini (2008) suggests that innovation quality of inventions generated by at least two innovators is higher than inventions developed by a single innovator. Cooperation does not only increase the overall technical knowledge and idea pool available to the innovation process but allows a more critical evaluation and selection of individual contributions by the innovator team. Therefore, we hypothesize:

H3a Cooperation with others during the innovation creation process increases a consumer's ability to generate creative innovations

H3b Cooperation with others during the innovation creation process increases a consumer's ability to generate technically elaborated innovations

The knowledge a consumer gains through his use experience of similar products and generally within the application area of the innovation, helps him to detect unfulfilled needs and requirements (Lüthje, 2004; Magnusson, 2009). It enables an innovator to know the performance attributes of an innovation, to generate suitable solutions and puts him into the distinctive position to evaluate whether a solution matches the requirements or not (Lüthje, 2004; Schreier & Prügl, 2008). While a user can exploit his use information to develop useful and novel ideas on performance attributes, more specifically creative ideas, we assume that a consumer's existing use experience does not influence the elaboration of its technical realization (Magnusson, 2009). We can therefore hypothesize:

H4 Consumer's use experience increases the ability to generate creative innovations

Evidence suggests education is an essential ingredient for creative performance (Amabile, 1983). A higher education increases one's general information stock and abilities required to understand and structure problems as well as subsequently to recognize opportunities and to generate adequate solutions (Shane, 2000). On the other hand, technical elaboration is expected to be positively associated with education analog to hypothesis 1b as it increases a consumer's stock of basic technical knowledge he can draw on. Von Hippel et al. (2010) emphasize the importance of education by finding that consumers with a university degree are more likely to innovate than consumers with lower education levels. Thus, we hypothesize:

H5a Consumer's level of education relates positively to the ability to generate creative innovations

H5b Consumer's level of education relates positively to the ability to generate technically elaborated innovations

3.2 Context Related Hypothesis

The innovation context describes the circumstances and conditions under which a consumer produces his innovation. Of course the BoP is special and differs dramatically from the conditions in the developed world. In our study we investigate the effect of a BoP consumer's initial motivation and impulse to innovate as well as the innovation type on the BoP market recognition. Nakata and Weidner (2012) propose that the social context plays an important role for the new product adoption, thus market recognition at the BoP. Innovations are therefore assumed to be more successful if oriented toward and inspired by greater social needs ". . .because of the group emphasis [the BoP's group-oriented social milieu], new product adoption is not motivated principally or exclusively by personal needs but rather by the welfare and preferences of the collective" (Nakata & Weidner, 2012). Furthermore, successful products for the BoP have to differ significantly from solutions for the developed world and maximize functionality and compatibility (London & Hart, 2004; Prahalad & Hart, 2000). Given that most existing products in circulation are based on developed world solutions and that the integration of many new functionalities, it requires more than just incremental changes to innovate successfully for the BoP. Therefore, we expect radically new created products to be more successful at the BoP than modified products. This leads us to hypothesize:

H6 Innovator's prosocial motivation increases the innovation's degree of market recognition

H7 New products created from scratch attain a higher degree of market recognition than product modifications

3.3 Innovation Quality Related Hypothesis

New products that embrace novel and relevant ideas as well as their high quality implementation into reality (Amabile, 1983; Mahr & Lievens, 2011) are most likely to yield market success especially at the BoP (Prahalad, 2012). Creative solutions offer significant value to customers through meaningful product differentiation and competitive advantages, which translates into new product success (Im and Workman 2004). Extreme requirements for products at the BoP with regard to e.g. adaptability, robustness, compatibility and at the same time affordability calls

for technically elaborated innovation (Nakata & Weidner, 2012; Prahalad, 2012; Prahalad & Hart, 2002). Therefore, we hypothesize:

H8 Innovation creativity relates positively to the innovation's degree of market recognition

H9 Innovation technical elaboration relates positively to the innovation's degree of market recognition

4 Methodology

For our analysis of consumer innovation at the BoP we adopt a hybrid approach (Edmondson & McManus, 2007). The approach of this paper at the intersection of a relatively well analyzed research field (user innovation) and relatively new and unexplored research areas BoP and BoP innovation includes descriptive as well as cause-and-effect analysis including hypothesis testing (Edmondson & McManus, 2007; Sekaran & Bougie, 2010). Additionally, consumer innovation studies across large population samples are still rare and the call for further large population studies including cross-validation of existing findings in another reality (Edmondson & McManus, 2007), more specifically poor and developing population groups, will be answered (von Hippel et al., 2010, 2011).

4.1 The Sample

We base our analysis on secondary data provided by the National Innovation Foundation (NIF) in India. The NIF in collaboration with the Honey Bee Network has scouted and documented more than 100,000 innovations and traditional knowledge coming from the BoP in India. An expert jury selects and awards BoP contributors on a regular basis, which are featured on the NIF website together with a detailed description of innovator and his innovations (Bhaduri & Kumar, 2011; Gupta, 2006; Sieg, 2011; Utz & Dahlman, 2007). Two examples of awarded innovations are (see, Nair, Tiwari, & Buse, 2012):

- A device developed by C. Mallesham to mechanize the process of hand winding of yarn for the traditional silk sari production relieving women from the drudgery of manual work and reducing time from 4 h to 1.5 h for one sari
- A small refrigerator created by M. Prajapati out of clay that keeps vegetables, fruits, milk and water cool without any external source of energy through a natural cooling process

Our full sample comprises 425 innovations from five award functions and embraces innovators from 22 Indian states. The award functions took place in 2001, 2002, 2005, 2007 and 2009. A total of 74 ideas were excluded after a careful

screening process because they were either traditional or community knowledge, pure abstract ideas or simply lifetime achievement awards without direct reference to any innovation. In order to retrieve information on innovator and innovation, which is only available in form of running text, we operationalized all relevant information via coding procedures into variables. Given the different degrees of descriptive detail, a reduced sample of 267 ideas is complete with regard to the set of retrieved variables and therefore, sample size by analysis depends on the variables under investigation.

4.2 Measures and Methods

Data from the website is quantified through codification (Strauss & Corbin, 1991). Following a similar procedure as Hippel et al. (2010) with their broad consumer study in the UK, we focused hereby on demographic, knowledge and context variables. With regard to the demographic variables we collect information on the innovator's *gender* (male/female), his place of *residence* (Indian state), his *age* classified into the respective age groups (10–17, 18–24, 25–34, 35–44, 45–54, 55–64, 65+) and his *profession* category (farmer, craftsman, education & health, administration, students, simple workers & unemployed). The classification was done in accordance with the guidelines of Germany's Federal Labor Agency (Bundesagentur für Arbeit, 2010) and International Labor Organization.

Knowledge and resources available to the innovator were assessed via his highest completed *education* level [illiterate, primary (level 1–5), middle (level 6–8), secondary (level 9–10), higher secondary (level 10–12), graduated, higher studies], if he possesses *technical experience* in the innovation field via his profession (Yes/No), if he is a *user* of the innovation, thus has use information (Yes/No), if he is a *serial innovator* disposing of innovation experience through more than a single innovation (Yes/No), and finally if he assesses additional knowledge through *cooperation* during the innovation process (Yes/No). Contextual factors include the creation *industry* of the innovation (agriculture, manufacturing, water & sewerage, construction, information, arts) in accordance with United Nations definitions (United Nations Statistics Division, 2012), the addressed *need* (food production, food preparation, water supply, clothing, hygiene & health, energy, transportation, household, tools & crafting, hobby & sports, other), if *prosocial motivation* was at the origin of the innovation effort (Yes/No) and lastly the *innovation type* (creation/modification). Finally, the innovative outcome is measured though the first order construct *market recognition* where an innovation gets a point for each of the fulfilled underlying drivers with possible scores from 0 to 4 [awarded (Yes/No), diffused (Yes/No), adopted (Yes/No), commercialized (Yes/No)]. Furthermore, *Creativity* and *technical elaboration* are not directly deducted from the NIF website but assessed via the Consensual Assessment Technique (Amabile, 1982).

Due to the lack of functional measures for innovative outcome, we applied the Consensual Assessment Technique (CAT) developed by Amabile (1982). CAT was

originally designed to assess creativity but beyond that, it has already been successfully used to determine product innovativeness and innovativeness of user ideas or user contributions (Magnusson, 2009; Mahr & Lievens, 2011; Piller & Walcher, 2006). Amabile found that no consistent and objective definition of creativity can be formulated but that independent judges typically recognize creativity and agree if something is creative. Therefore, we asked expert judges to apply their own, subjective definition of creativity and technical elaboration to the assessment and to evaluate every idea relative to the entire sample.

The jury individually rated every innovation from 1 to 4 (scale corresponding from 'very low' to 'very high') on the dimensions' *creativity* (composed of the notions of novelty and relevance) and *technical elaboration* as recommended by Amabile (cf. Amabile, 1982, 1996). In order to generate a relative assessment of idea quality, we select a reasonably homogenous set of ideas from the entire database. A total of 195 complete manufacturing and construction ideas are forming a comparative sample of engineering related innovations. The jury consisted in 11 higher master students with know-how and experience in engineering and product design. Analysis of inter-judge reliability via Cronbach's Alpha shows sound reliability levels for creativity (0.80) as well as technical elaboration (0.83) (Osborne, 2008). Given these reliable results we averaged individual evaluations into single scores for creativity and elaboration (cf. Magnusson, 2009). Kolmogorov-Smirnov tests (Osborne, 2008) confirm normal distribution of the two variables.

5 Findings

5.1 Descriptive Analysis and Comparison

Our descriptive analysis (Table 1) shows that out sample consists in innovations from various states across India (a total of 22 different Indian states).

The majority of innovations fall into the manufacturing (79 %) and agricultural industry (18 %). Hence, most consumers manufacture products such as machinery and tools, electrical, electronic or transportation related products, chemicals as well as pharmaceuticals or create crop and animal production related innovations. The average consumer innovator works as farmer (40 %) or craftsmen (34 %). Slightly more than half of the innovators have already innovated more than once (53 %) and possess relevant technical experience in the creation industry of the innovation (56 %). The vast majority of them with 85 %, however, is also a user of their innovation and therefore disposes of related use information (Table 2).

Comparing our BoP consumer innovation data with the outcome of the UK study (von Hippel et al., 2010), we recognize similar patterns as well as differences. Almost two third (65 %) of the BoP consumer innovation consists in creating new products from scratch whereas UK consumers focus on incremental improvements

Table 1 Distribution of descriptive information on BoP innovators and innovations

Variable	Values and percentages
Industry N = 425	Manufacturing (79 %), agriculture (18 %), construction (1 %), water and sewerage (1 %), other (<1 %)
Profession[a] N = 399	Farmers (40 %), craftsmen (34 %), education & health (13 %), students (10 %), simple workers and unemployed (5 %), administration (4 %)
Technical experience N = 394	Work experience in industry (56 %), no work experience in industry (44 %)
Serial innovator N = 437	Serial innovator (53 %), one-time innovator (47 %)
User status N = 439	User (85 %), no user (15 %)

[a]BoP comparable needs: Farmers (40 %), craftsmen (34 %), education & health (13 %), students (10 %), simple workers and unemployed (5 %), administration (4 %)

Table 2 Comparison of BoP consumer innovators and innovations with the UK (von Hippel et al., 2010)

Variable		BoP	UK	Variable		BoP	UK
Innovation type	Creation (vs. modification	65 %	33 %	Innovation sharing (in percent)	Diffused		
Cooperation	vs. development in Isolation	11 %	10 %		Adopted		
Prosocial motivation	vs. egoistic motives as initial motivation to innovate	24 %	15 %		Commercialized		
Gender	Male (vs. female)	95 %	87 %	Innovator's education level (in percent)	No education		
Needs	Craft and shop tools	7 %	23 %		Less educated		
	Sports and hobby	2 %	20 %		High school/ secondary		
	Household/ dwelling	5 %	16 %		Further qualifications		
	Transportation/ vehicle	10 %	8 %		Higher studies		
	Hygiene, health, medical	5 %	2 %	Innovator's age in percentage	10–17		
	Other[a,b]	71 %	31 %		18–24		
					25–34		
					35–44		
					45–54		
					55–64		
					65+		

N by variable varies between 74 and 104 for UK and 330 and 439 for BoP

[a]BoP non-comparable needs: Food production (41 %), food preparation (11 %), water supply (10 %), energy (4 %), clothing (2 %), other (2 %)

[b]UK non-comparable needs: Gardening (11 %), child-related (10 %), pet-related (3 %), other (7 %)

of existing products (67 %). Both consumer groups very rarely produce their innovation in cooperation with others (BoP: 11 %, UK 10 %), are less prosaically motivated but motivated by their own needs (BoP: 24 %, UK: 15 %), although BoP innovators are more prosaically motivated compared with UK consumers. The typical innovator is male in both cases, the UK (87 %) as well as the Indian BoP (95 %). Similar need categories inspire consumers to innovate: craft & shop tools, sports & hobby, household, transportation and health related needs while except for transportation (10 % of all innovations) all other categories play a minor role (19 % in total) at the BoP with significantly less importance than in the UK (69 % in total). BoP consumers primarily fulfill needs with regard to food production (42 %), food preparation (11 %) and water supply (10 %). Other important categories in the UK refer to gardening (11 %) and child related (10 %) needs. At the BoP the share of innovations diffusion (47 % vs. 33 %), adoption (32 % vs. 17 %) and commercialization (20 % vs. 4 %) is higher than in the UK. Expectedly, BoP consumer innovators are less well educated than their counterparts in the UK but surprisingly both consumer groups have comparable average ages (UK: 50 years, BoP: 47 years).[1]

5.2 *Hypothesis Testing*

We conducted two multiple linear regressions to test our earlier formulated hypothesis with regard to the knowledge effects on creativity and technical elaboration respectively and additionally an ordinal logistical regression to test hypothesis with regard to the effects on market recognition. Two control variables, gender and age, were included in all three models. We will discuss findings in the following discussion section.

The overall multiple linear regression model for creativity proves to be valid predicting a statistically significant share of the dependent variable's variance with $p < 0.01$. Hence, the multiple linear regression model explains 7 % of the variance of creativity ($R^2 = 0.113$; adjusted $R^2 = 0.071$; $F_{(9;190)} = 2.702$; $p = 0.006$).[2] Investigation of the individual regression coefficients by independent variable in Table 3 provides insights with regard to magnitude and direction of their relationships with creativity. Keeping all other independent variables controlled, three independent variables show significant associations with creativity. In line with *hypothesis 2a*, a serial innovator reaches lower creativity scores than a one-time innovator ($B = -0.0211$; $p = 0.002$). Furthermore, *hypothesis 3a* is supported as an

[1]Excluding all BoP innovators under 18 because consumers needed to be at least 18 to participate in the UK study.

[2]Statistical assumptions of linearity, homoscedasticity, normality and independence of error terms, absence of multicollinearity and influential outliers were verified, no violation of assumptions validated the regression results (Hair, Black, Babin, & Anderson, 2010).

Table 3 Coefficients of multiple linear regression model for creativity

		B	SE	β	t	p value
Intercept		2.684	.166		16.127	.000
Age		.017	.021	.064	.801	.424
Education		−.001	.023	−.004	−.053	.957
Cooperation	Cooperation (vs. solitary effort)	.232	.098	.175	2.361	.019*
Prosocial	Prosocial motivation (vs. egoistic motives)	.067	.078	.071	.854	.394
Serial	Serial innovator (vs. one-time effort)	−.211	.066	−.230	−3.207	.002**
Techn. exp.	Technical experience (vs. none)	.143	.067	.162	2.156	.032*
Type	Creation (vs. modification)	−.040	.071	−.040	−.569	.570
User	User (vs. no user)	.009	.087	.009	.103	.918
Gender	Female (vs. male)	−.165	.185	−.064	−.889	.375

$N = 200$; $R^2 = 11.3\,\%$; Adjusted $R^2 = 7.1\,\%$
*$p < 0.05$, **$p < 0.01$

innovation developed via a process including cooperation activities achieves higher creativity results ($\beta = 0.232$; $p = 0.019$) than an innovation by a single innovator. Finally disposing of innovation related technical experience results in higher creativity scores ($B = 0.142$; $p = 0.032$), which leads as to affirm ***hypothesis 1a***. Serial innovator ($B = -0.230$) is identified as the variable with the highest predictive power followed by cooperation ($\beta = -0.175$) and finally by technical experience ($\beta = -0.162$) (cf. Backhaus, 2008). No evidence can be found to support hypothesis 4 and hypothesis 5a.

The overall model for technical elaboration proves to be valid predicting a statistically significant share of the dependent variable's variance with $p < 0.01$. Hence, the multiple linear regression model explains 7 % of the variance of technical elaboration ($R^2 = 0.109$; adjusted $R^2 = 0.066$; $F_{(9;190)} = 2.572$; $p = 0.008$).

Table 4 gives on overview on the regression coefficients by independent variable. Controlling for the effects of all other independent variables, two variables show significant associations with technical elaboration. An innovator who possesses technical experience concerning the corresponding innovation will on average achieve higher technical elaboration scores than innovators who do not ($B = 0.261$; $p = 0.000$). Thus, findings support ***hypothesis 1b***. Raising the significance threshold to a significance level of $p < 0.10$, education also shows a positive association with technical elaboration in line with ***hypothesis 5b***. Thus, an increase in the innovator's highest completed education level raises the innovation's technical elaboration results ($B = 0.043$; $p = 0.080$). Standardized beta weights highlight the importance of technical experience ($\beta = 0.273$) in contrast to education ($\beta = 0.127$) (cf. Backhaus, 2008). No evidence can be found to support *hypothesis 2b* and *hypothesis 3b*.

Table 4 Coefficients of multiple linear regression model for technical elaboration

		B	SE	β	t	p value
Education		.043	.025	.127	1.762	.080†
Cooperation	Cooperation (vs. solitary effort)	.073	.107	.051	.683	.496
Prosocial	Prosocial motivation (vs. egoistic motives)	.076	.085	.075	.895	.372
Serial	Serial innovator (vs. one-time effort)	−.071	.072	−.071	−.989	.324
Techn. exp.	Technical experience (vs. none)	.261	.072	.273	3.611	.000**
Type	Creation (vs. modification)	−.078	.077	−.071	−1.017	.310
User	User (vs. no user)	−.038	.094	−.033	−.400	.689
Gender	Female (vs. male)	−.210	.201	−.076	−1.045	.297

$N = 200$; $R^2 = 10.9\,\%$; Adjusted $R^2 = 6.6\,\%$
†$p < 0.10$, **$p < 0.01$

Market recognition is measured on an ordinal scale ranging from 0 as lowest to 4 as highest value and doesn't follow a normal distribution. Given these limitations of this single dependent variable, we conducted an ordinal logistical regression (Gerpott & Mahmudova, 2006) to measure the impact of innovation quality, namely creativity and technical elaboration, as well as the context, specifically prosocial motivation and innovation type, on market recognition. User status was the only knowledge variable without any evidence for significant influence on creativity and technical elaboration. We therefore added user status as independent variable to the ordinal logistical regression model. The quality of the overall model and its goodness-of-fit with the data is appraised twofold. The likelihood method rejects on a significance level of $p < 0.001$ the null hypothesis that a baseline model and our model predict equally well market recognition (Backhaus, 2008; Norušis, 2012). Furthermore, the Pearson and deviance statistics do not reject the null hypothesis that the model fit is good ($p > 0.01$), thus are supporting model validity and quality (cf. Norušis, 2012). The Nagelkerke coefficient of determination indicates a variance explanation of approximately 19 % (cf. Gerpott & Mahmudova, 2006).[3]

The model overview in Table 5 shows parameter estimates for thresholds and factors of the ordinal logistical regression. Beta coefficients and their transformation into odds ratios for independent variables are the relevant measures to interpret the effect on the dependent variable. A positive Beta coefficient is hereby associated with an effect towards a higher category of the dependent variable whereas a negative coefficient is associated with an effect towards a lower category. Effect size in terms of direction and strength is interpreted through the odds ratio.

[3]No violations of statistical assumptions of linearity of logits, absence of multicollinearity and proportionality of odds were detected; proportionality of odds is confirmed through separate tests of parallel lines by independent variable and binary logistical regression models for each threshold.

Table 5 Coefficients of ordinal logistical regression model for market recognition

		B	SE	OR	Wald	p value
Threshold	Success = 0	−1.79	.82	–	–	–
	Success = 1	.51	.81	–	–	–
	Success = 2	1.45	.81	–	–	–
	Success = 3	2.03	.82	–	–	–
Creativity	Creativity score (standardized)	.37	.17	1.44	4.64	.03*
Technical	Technical elaboration score (standardized)	.11	.17	1.11	.40	.53
Age	Age (standardized)	.00	.14	1.00	.00	1.00
Prosocial motivation	Prosocial motivation (vs. egoistic motives)	.76	.34	2.14	5.12	.02*
User status	No user (vs. user)	1.11	.38	3.03	8.71	.00**
Type	Modification (vs. creation)	.20	.31	1.22	.43	.51
Gender	Male (vs. female)	−.02	.81	0.98	.00	.98

N = 200; Nagelkerke pseudo $R^2 = 18.7\,\%$
*p < 0.05, **p < 0.01

Creativity (B = 0.37; odds ratio = 1.44), prosocial motivation (B = 0.76; odds ratio = 2.14) and user status (B = 1.11; odds ratio = 3.03) all show a positive and significant association with market recognition and thereby support hypothesis 7 and hypothesis 6. A unit increase of creativity raises the odds to achieve a higher category of market recognition by approximately 1.5. Odds ratios for dichotomous variables are interpreted against their base category. Therefore, the odds for a prosaically motivated innovation to achieve a higher market recognition level are more than twice the odds for an egoistically motivated innovation. Conversely the odds to attain a higher market recognition category for an egoistically motivated innovation are approximately half (odds ratio = 0.47) the odds for a prosaically motivated innovation. Furthermore, the odds to achieve a higher market recognition level for innovations by non-users are more than thrice the odds of an innovation produced by a user. Conversely the odds to attain a higher market recognition category for an innovation by a user are one third (odds ratio = 0.33) the odds of an innovation produced by a non-user. Technical elaboration and innovation type as well as the control variables gender and age are not associated with market recognition and their odds ratios are close to 1 (cf. Gerpott & Mahmudova, 2006; O'Connell, 2006). Therefore, we find no evidence to support *hypothesis 7* and *hypothesis 9*.

6 Discussion

In this paper we looked closer at the phenomenon of consumer innovation at the BoP in India. Based on data of the NIF we found that most of this innovation falls into two industry fields, manufacturing and agriculture, and is conducted by male

farmers and craftsmen. In comparison to consumer innovation in the developed world represented by the UK sample, it becomes obvious that consumer innovation in both population groups follows similar patterns but also shows differences. These can be largely explained by differences of needs as well as major differences in living standards. Understandably consumers at the BoP are more concerned with basic needs and elementary products such as food, production and preparation as well as water and energy supply whereas UK consumers mostly innovate in improving existing products, for example in combination with leisure activities (von Hippel et al., 2010). Both innovator groups innovate in isolation and are predominantly motivated by their own, personal needs. While UK consumers focus on incremental innovation by modifying products, BoP consumers create new solutions. This can be explained by the resource-constraint living conditions at the BoP with a small amount of existing products affordable and available to the innovator (Viswanathan & Sridharan, 2012) as well as the need for distinct functionality (Prahalad & Hart, 2000). Consumer innovations by BoP innovators are shared more widely than in the UK. Imperfect market conditions and people's need in particular for products improving their living conditions (Nakata & Weidner, 2012; Viswanathan & Sridharan, 2012), possibly create a more welcoming environment for consumer innovation. In opposition to the UK, a higher education level does not seem to translate into a higher likelihood to innovate for the on average less educated BoP consumers.

We find that BoP innovators apply their knowledge derived from technical experience, and cooperation resources to the innovation and thereby increase the degree of creativity.

Furthermore, we can confirm our assumption that repeated innovation activity decreases the level of creativity. However, we find no evidence that being a user of the innovation and therefore possessing direct use information related positively to the degree of creativity. A plausible rationale could be that people at the BoP are embedded in strong social networks (Nakata & Weidner, 2012; Viswanathan, Sridharan, & Ritchie, 2010) allowing them to derive very detailed and in-depth information on needs and use situations substituting the advantage of direct and own information. Furthermore, basic needs satisfied through BoP consumer innovations may involve more intuitive and generic use information opposed to idiosyncratic needs from e.g. kite surfing, canyoning or sailplaning (Franke & Shah, 2003; Lüthje, 2004). Also, education does not seem to influence the level of creativity. Other drivers such as innate abilities and training (Amabile, 1983) could possibly be more important drivers for the cognitive skills required to structure and solve problems at the BoP. We find that technical experience does not only increase creativity but technical elaboration of the innovation as well. Furthermore, education is a driver for the level of technical elaboration. Conversely, innovation experience and cooperation do not seem to increase the pool of technical knowledge applied to the production of more technically elaborated innovation. The recognition of these BoP consumer innovations seems not to depend on whether it is newly created or modified product or how well the idea is technically realized but on the creativity of the innovation. Novelty and relevance

of the product, in other words the possibility to satisfy important and so far unmet needs, are in the focus even if the product is technically not perfect. Contrary to studies from user innovation in the developed world finding that being a user relates positively to the attractiveness of an innovation (Franke et al., 2006; Schreier & Prügl, 2008), not being a user and being prosaically motivated increases the innovation's degree of market recognition at the BoP. The underlying inspiration to serve "... the welfare and preferences of the collective" (Nakata & Weidner, 2012) obviously play a very important role at the BoP.

7 Conclusion

This paper contributes to the relatively new research field into user innovation patterns across a large consumer population. We analyzed the phenomenon in a new setting, more precisely a developing country among a very poor population group. We find that consumer innovation does not only exist in developed countries but with adaptation also under poor and resource-constraint living conditions. We further contribute to research on the effect of local knowledge resources on innovation quality and factors explaining the degree of BoP market recognition of consumer innovations. Limitations of our study consist in our sample based on indirect data, which is biased through the NIF collection and selection process. Furthermore, our sample concentrates on the BoP in India only. Looking forward, further research has to be conducted at the BoP in other countries to further generalize findings. Other interesting questions for ongoing research could be on how to integrate BoP consumers into the innovation process of companies, for example how can a highly-educated and internationally experienced engineer and someone from the BoP effectively and trustfully collaborate with each other and how does this joint innovation effort ultimately benefit the BoP.

Our findings hold implications for innovating firms as well. We can conclude that in order to be successful at the BoP, companies need to look for opportunities to co-create with people from the BoP. Demand for new products at the BoP is highlighted by the high degree of market recognition of innovations developed by BoP consumers themselves with an adoption rate of almost one third. Our results suggest companies should focus on useful products rather than technical breakthroughs relating to basic needs and collective welfare. Consumer innovation exists at the BoP and can be a potentially very valuable source of product innovation. Managers should therefore try to integrate innovative BoP consumers into their innovation work and to carefully explore their needs as well as concepts, prototypes or products, developed by them. These *solution spaces* can then be explored as a starting point to co-create products with BoP consumers and to test and evaluate such solutions concerning their potential to attract other BoP consumers. Low education levels should not be seen as a hurdle here, but according to our research a (minimum) level of technical capability is a useful indicator to identify promising BoP consumers who innovate.

References

Acosta, P., Kim, N., Melzer, I., Mendoza, R. U., & Thelen, N. (2011). Business and human development in the base of the pyramid: Exploring challenges and opportunities with market heat maps. *Journal of World Business, 46*(1), 50–60.

Amabile, T. M. (1982). Social psychology of creativity: A consensual assessment technique. *Journal of Personality and Social Psychology, 43*(5), 997–1013.

Amabile, T. M. (1983). The social psychology of creativity: A componential conceptualization. *Journal of Personality and Social Psychology, 45*(2), 357–376.

Amabile, T. M. (1996). *Creativity in context*. [Updated edn.]. Boulder, CO: Westview Press.

Anderson, J., & Billou, N. (2007). Serving the world's poor: Innovation at the base of the economic pyramid. *Journal of Business Strategy, 28*(2), 14–21.

Anderson, J., & Markides, C. (2007). Strategic innovation at the base of the economic pyramid. *Harvard Business Online, 49*(1), 83–88.

Backhaus, K. (2008). *Multivariate Analysemethoden. Eine anwendungsorientierte Einführung. 12*. vollst. überarb. Berlin: Springer (Springer-Lehrbuch).

Baldwin, C., Hienerth, C., & von Hippel, E. (2006). How user innovations become commercial products: A theoretical investigation and case study. *Research Policy, 35*(9), 1291–1313.

Banerjee, A. V., & Duflo, E. (2007). The economic lives of the poor. *The Journal of Economic Perspectives, 21*(1), 141–167.

Bhaduri, S., & Kumar, H. (2011). Extrinsic and intrinsic motivations to innovate: Tracing the motivation of 'grassroot' innovators in India. *Mind and Society: Cognitive Studies in Economics and Social Sciences, 10*(1), 27–55.

Bogers, M., Afuah, A., & Bastian, B. (2010). Users as innovators: A review, critique, and future research directions. *Journal of Management, 36*(4), 857–875.

Bundesagentur für Arbeit: Systematisches Verzeichnis der Berufsbenennungen. (2010). Retrieved May 9, 2012, from http://statistik.arbeitsagentur.de/Statischer-Content/Grundlagen/Klassifikation-der-Berufe/KldB2010/Systematik-Verzeichnisse/Generische-Publikationen/Systematisches-Verzeichnis-Berufsbenennung.xls

Christensen, L. J., Parsonsand, H., & Fairbourne, J. (2010). Building entrepreneurship in subsistence markets: Microfranchising as an employment incubator. *Journal of Business Research, 63*(6), 595–601.

de Jong, J., & von Hippel, E. (2009). Transfers of user process innovations to process equipment producers: A study of Dutch high-tech firms. *Research Policy, 38*(7), 1181–1191.

Edmondson, A. C., & McManus, S. E. (2007). Methodological fit in management field research. *Academy of Management Review, 32*(4), 1155–1179.

Franke, N., & Shah, S. (2003). How communities support innovative activities: An exploration of assistance and sharing among end-users. *Research Policy, 32*(1), 157–178.

Franke, N., & von Hippel, E. (2003). Satisfying heterogeneous user needs via innovation toolkits: The case of Apache security software. *Research Policy, 32*(7), 1199–1215.

Franke, N., von Hippel, E., & Schreier, M. (2006). Finding commercially attractive user innovations: A test of lead-user theory. *Journal of Product Innovation Management, 23*(4), 301–315.

Gerpott, T. J., & Mahmudova, I. (2006). Ordinale regression. *Wirtschaftswissenschaftliches Studium, 35*(9), 495–498.

Gupta, A. K. (2006). From sink to source: The Honey Bee Network documents indigenous knowledge and innovations in India. *Innovations: Technology, Governance, Globalization, 1*(3), 49–66.

Hahn, R. (2009). The ethical rational of business for the poor–integrating the concepts bottom of the pyramid, sustainable development, and corporate citizenship. *Journal of Business Ethics, 84*(3), 313–324.

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis* (7th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

Hammond, A. L., & Prahalad, C. K. (2004). Selling to the poor. *Foreign Policy, May/June*(142), 30–37.
Herstatt, C., & von Hippel, E. (1992). From experience: Developing new product concepts via the lead user method: A case study in a "low-tech" field. *Journal of Product Innovation Management, 9*(3), 213–221.
Im, S., & Workman, J. P., Jr. (2004). Market orientation, creativity, and new product performance in high-technology firms. *Journal of Marketing, 68*(2), 114–132.
Kalogerakis, K., Lüthje, C., & Herstatt, C. (2010). Developing innovations based on analogies: Experience from design and engineering consultants. *Journal of Product Innovation Management, 27*(3), 418–436.
Karnani, A. (2009, September). *Reducing poverty through employment*. Ross School of Business Working Paper #1132. University of Michigan, Ann Arbor, MI.
Lettl, C., Herstatt, C., & Gemuenden, H. G. (2006). Users' contributions to radical innovation: Evidence from four cases in the field of medical equipment technology. *R&D Management, 36*(3), 251–272.
Lilien, G. L., Morrison, P. D., Searls, K., Sonnack, M., & von Hippel, E. (2002). Performance assessment of the lead user idea-generation process for new product development. *Management Science, 48*(8), 1042–1059.
London, T. (2007). *The base-of-the-pyramid perspective: A new approach to poverty alleviation*. William Davidson Institute & Ross School of Business, University of Michigan, Ann Arbor, MI. Retrieved May 15, 2012, from http://www.pitt.edu/~mitnick/MESM10/LondonBaseofPyramidAoM08Proceedings.pdf
London, T., Anupindi, R., & Sheth, S. (2010). Creating mutual value: Lessons learned from ventures serving base of the pyramid producers. *Journal of Business Research, 63*(6), 582–594.
London, T., & Hart, S. L. (2004). Reinventing strategies for emerging markets: Beyond the transnational model. *Journal of International Business Studies, 35*(5), 350–370.
Lüthje, C. (2000). *Characteristics of innovating users in a consumer goods field-An empirical study of sport-related product consumers*. Working Paper No. 8. Institute for Technology and Innovation Management, Hamburg University of Technology.
Lüthje, C. (2004). Characteristics of innovating users in a consumer goods field: An empirical study of sport-related product consumers. *Technovation, 24*(9), 683–695.
Lüthje, C., Herstatt, C., & von Hippel, E. (2005). User-innovators and "local" information: The case of mountain biking. *Research Policy, 34*(6), 951–965.
Magnusson, P. R. (2009). Exploring the contributions of involving ordinary users in ideation of technology based services. *Journal of Product Innovation Management, 26*(5), 578–593.
Mahr, D., & Lievens, A. (2011). Virtual lead user communities: Drivers of knowledge creation for innovation. *Research Policy, 41*(1), 167–177.
Morrison, P. D., Roberts, J. H., & von Hippel, E. (2000). Determinants of user innovation and innovation sharing in a local market. *Management Science, 46*(12), 1513–1527.
Nair, A. K., Tiwari, R., & Buse, S. (2012). *Emerging patterns of grassroot innovations – A conceptual study based on selected case studies from India*. Working paper No. 70. Institute for Technology and Innovation Management, Hamburg University of Technology.
Nakata, C. (2012). From the Special Issue Editor: Creating new products and services for and with the base of the pyramid. *Journal of Product Innovation Management, 29*(1), 3–5.
Nakata, C., & Weidner, K. (2012). Enhancing new product adoption at the base of the pyramid: A contextualized model. *Journal of Product Innovation Management, 29*(1), 21–32.
Norušis, M. J. (2012). *IBM SPSS statistics 19 advanced statistical procedures companion*. Upper Saddle River, NJ: Prentice Hall.
O'Connell, A. A. (2006). *Logistic regression models for ordinal response variables*. Thousand Oaks, CA: SAGE (Quantitative applications in the social sciences, no. 146).
Ogawa, S., & Pongtanalert, K. (2011). *Visualizing invisible innovation continent: Evidence from global consumer innovation surveys*. SSRN working paper. Retrieved May 15, 2012, from http://ssrn.com/abstract=1876186

Osborne, J. W. (2008). *Best practices in quantitative methods*. Los Angeles: SAGE.
Piller, F. T., & Walcher, D. (2006). Toolkits for idea competitions: A novel method to integrate users in new product development. *R&D Management, 36*(3), 307–318.
Prahalad, C. K. (2010). *The fortune at the bottom of the pyramid. Eradicating poverty through profits* (Rev. and updated 5. anniversary ed., 2. Printing). Upper Saddle River, NJ: Wharton School Publishing.
Prahalad, C. K. (2012). Bottom of the pyramid as a source of breakthrough innovations. *Journal of Product Innovation Management, 29*(1), 6–12.
Prahalad, C. K., & Hart, S. L. (1999). Strategies for the bottom of the pyramid: Creating Sustainable Development. 2–26.
Prahalad, C. K., & Hart, S. L. (2000). *Raising the bottom of the pyramid: Strategies for sustainable growth*. Retrieved May 15, 2012, from http://www.ima.kth.se/utb/mj1501/pdf/prahalad.pdf
Prahalad, C. K., & Hart, S. L. (2002). The fortune at the bottom of the pyramid. *Strategy + Business* (26):2–14.
Prahalad, C. K., & Mashelkar, R. A. (2010). Innovation's holy grail. *Harvard Business Review, 88* (7-8), 132–141.
Raasch, C., Herstatt, C., & Lock, P. (2008). The dynamics of user innovation: Drivers and impediments of innovation activities. *International Journal of Innovation Management, 12* (3), 377–398.
Schettino, F., Sterlacchini, A., & Venturini, F. (2008, March). *Inventive productivity and patent quality: Evidence from Italian inventors*. MPRA Paper No. 7765. University of Munich.
Schreier, M., & Prügl, R. (2008). Extending lead-user theory: Antecedents and consequences of consumers' lead userness. *Journal of Product Innovation Management, 25*(4), 331–346.
Sekaran, U., & Bougie, R. (2010). *Research methods for business. A skill-building approach* (5th ed.). Chichester, NH: Wiley.
Shah, S. (2000, March). *Sources and patterns of innovation in a consumer products field: Innovations in sporting equipment*. MIT Sloan School of Management Working Paper #4105. MIT, Cambridge, MA.
Shane, S. (2000). Prior knowledge and the discovery of entrepreneurial opportunities. *Organization Science, 11*(4), 448–469.
Sieg, K. (2011). Wandern auf dem Pfad der Erkenntnis. *Flur und Furche, 1*, 18–24.
Strauss, A. L., & Corbin, J. M. (1991). *Basics of qualitative research. Grounded theory procedures and techniques*. 3. printing. Newbury Park, CA: SAGE.
The Economist (Ed.). (2010). *The world turned upside down*. A special report on innovation in emerging markets.
Thomke, S., & von Hippel, E. (2002). Customers as innovators: A new way to create value. *Harvard Business Review, 80*(4), 74–81.
United Nations Statistics Division. (2012). *International standard industrial classification of all economic activities* (Rev. 3). Retrieved May 9, 2012, from http://unstats.un.org/unsd/cr/registry/regcst.asp?cl=2
Urban, G. L., & von Hippel, E. (1988). Lead user analyses for the development of new industrial products. *Management Science, 34*(5), 569–582.
Utz, A., & Dahlman, C. (2007). Promoting inclusive innovation. In M. A. Dutz (Ed.), *Unleashing India's innovation. Toward sustainable and inclusive growth* (pp. 105–128). Washington, DC: World Bank.
Viswanathan, M., & Rosa, J. A. (2010). Understanding subsistence marketplaces: Toward sustainable consumption and commerce for a better world. *Journal of Business Research, 63*(6), 535–537.
Viswanathan, M., & Sridharan, S. (2012). Product development for the BoP: Insights on concept and prototype development from university-based student projects in India. *Journal of Product Innovation Management, 29*(1), 52–69.
Viswanathan, M., Sridharan, S., & Ritchie, R. (2010). Understanding consumption and entrepreneurship in subsistence marketplaces. *Journal of Business Research, 63*(6), 570–581.

von Hippel, E. (1976). The dominant role of users in the scientific instrument innovation process. *Research Policy, 5*(3), 212–239.
von Hippel, E. (1994). Sticky information and the locus of problem solving: Implications for innovation. *Management Science, 40*(4), 429–439.
von Hippel, E. (1995). *The sources of innovation* [Nachdr.]. New York: Oxford University Press.
von Hippel, E. (2010). *Democratizing innovation*. Merzig: Creative Commons.
von Hippel, E., de Jong, J., & Flowers, S. (2010, September). *Comparing business and household sector innovation in consumer products: Findings from a representative study in the UK*. MIT Sloan School of Management Working Paper. MIT, Cambridge, MA.
von Hippel, E., Ogawa, S., & de Jong, J. (2011). The age of the consumer-innovator. *MIT Sloan Management Review: MIT's Journal of Management Research and Ideas, 53*(1), 27–35.
Weidner, K. L., Rosa, J. A., & Viswanathan, M. (2010). Marketing to subsistence consumers: Lessons from practice. *Journal of Business Research, 63*(6), 559–569.
Wuchty, S., Jones, B. F., & Uzzi, B. (2007). The increasing dominance of teams in production of knowledge. *Science, 316*(5827), 1036–1039.

Lessons from Low-Cost Healthcare Innovations for the Base-of the Pyramid Markets: How Incumbents Can Systematically Create Disruptive Innovations

Aditi Ramdorai and Cornelius Herstatt

1 Introduction

The healthcare industry today is at a crossroads and every nation in the world faces healthcare challenges. Rich countries like the USA and Germany are battling soaring costs for healthcare and the long-term demographic challenges of an aging population, whereas poor countries like India are struggling to provide quality healthcare to millions.

Frugal innovations in healthcare are emerging from India, ranging from low-cost healthcare delivery by hospitals like Aravind Eye Care that provides cataract surgery to around 300,000 patients at a cost of US$18 per patient (Rangan and Thulasiraj, 2007) to product innovations such as the Jaipur Foot, a low-cost prosthesis (Prahalad, 2004). Frugal innovations are characterized by their focus on affordability and retaining key functionalities of products/services (Prahalad & Mashelkar, 2010; Tiwari & Herstatt, 2012). These low-cost healthcare innovations not only provide access to millions who previously could not afford the product or service, but also have the potential to contribute to health care cost containment in developed markets and 'disrupt' developed markets (Christensen, Grossmann, & Hwang, 2008; Howitt et al., 2012).

Disruptive innovations, in contrast to sustaining innovation, initially offer lower performance in the key performance attribute but offer a secondary performance attribute, making it appealing to an emerging or a less demanding market segment (Christensen & Bower, 1996). Disruptive innovations are typically simpler, more convenient and more affordable (Christensen & Raynor, 2003). Disruptive innovations create growth potential for companies while opening up access to products and services that were previously beyond peoples' reach (Christensen, 1997;

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Christensen & Raynor, 2003; Hart and Christensen, 2002). Low-income markets or Base-of-the-Pyramid [BOP] markets present new opportunities to Multi-National Corporations [MNCs] (Prahalad, 2004) and scholars are calling MNCs to leverage BOP markets to create disruptive innovations (Hart and Christensen, 2002). The healthcare industry is especially ripe for disruptive innovations because it has mostly focused on creating products and services for the Top of the Pyramid, to help solve problems that have not been solved before, and has not focused on making healthcare affordable and accessible (Christensen, Bohmer, & Kenagy, 2000).

Addressing the vast, fast-growing, four-billion-people-strong segment poses unique challenges to MNCs and also requires new thinking in the field of international strategy (Ricart, Enright, Ghemawat, Hart, & Khanna, 2004). Companies seeking to serve the BOP segments have to deal with market creation issues, working in informal economies with institutional voids and typically with broader and diverse set of partners (London & Hart, 2010) as well as internal organizational barriers (Halme, Lindeman, & Linna, 2012; Olsen & Boxenbaum, 2009). This is why MNCs have either failed to successfully enter BOP markets (Jaiswal, 2008) or have largely ignored them (Prahalad & Lieberthal, 2003). Similarly, established incumbents generally fail to successfully commercialize disruptive innovations. Their internal processes and values force them to focus on their existing customers, thereby ignoring projects targeted at new emerging markets that lack a customer base (Christensen & Bower, 1996).

An exception to this is the American incumbent GE Healthcare[i], which has been creating several frugal innovations targeted at emerging markets for the past years (Immelt & Govindrajan, 2009). In this research, we will look at organizational structures and processes that GE Healthcare has in place, which enables it to create disruptive innovations systematically. With this we hope to contribute towards building disruptive innovation theory (Christensen, 2006), where questions pertaining to selective success and failure of incumbents to create disruptive innovations remain unanswered (Danneels, 2004). Literature on disruptive innovations recommends incumbent firms to create a separate entity for commercializing disruptive innovations (Christensen & Bower, 1996). However, scholars have been calling upon firms to explore new markets and exploit existing opportunities simultaneously (Tushman & O'Reilly, 1996).

The ability to successfully drive disruptive innovations from within the organization will be analyzed through the lens of organizational ambidexterity. Ambidexterity is the ability of organizations to successfully balance exploration and exploitation. The manifestation of this act of balancing exploitation and exploration is the companies' ability to initiate multiple innovation streams, in this case sustaining innovations and disruptive innovations (Danneels, 2004; Tushman, Smith, Wood, Westerman, & O'Reilly, 2010). Key proponents of organizational ambidexterity, O'Reilly and Tushman, consider it a "solution to the innovator's dilemma" (O'Reilly & Tushman, 2008: 202), however present their thesis only conceptually. This is a general gap in the research of organizational ambidexterity, as noted by scholars of organizational ambidexterity where consensus exists on the

need for ambidexterity, but the underlying mechanisms and the 'how' remain undertheorized (Gupta, Smith, & Shalley, 2006). This work will look at the mechanisms of ambidexterity at GE Healthcare to help explain its ability in successfully hosting sustaining and disruptive innovations from within its boundaries.

The next section will focus on the theoretical background of this research, explaining in greater detail the concept of disruptive innovation and BOP research. The next section describes the research methodology and research question. Section 4 narrates the empirical data from the GE Healthcare case study after which we analyze the main findings and close with a conclusion.

2 Theoretical Background

2.1 Disruptive Innovations

Disruptive innovation, pioneered by Christensen through a series of scholarly work (Christensen & Bower, 1996; Christensen & Rosenbloom, 1995) and popularized by his seminal book, 'The Innovator's Dilemma' (Christensen, 1997), is considered by practitioners and researchers as "a powerful means for developing and broadening new markets" (Govindarajan & Kopalle, 2006: 190). According to the theory, there are two types of innovations, sustaining and disruptive. To attain growth, companies improve product/service features that their mainstream customers appreciate through sustaining innovations.

Sustaining innovations thus improve the product along the primary performance dimension, which established customer segments value, in an evolutionary or radical manner. Disruptive innovations, however, initially appear inferior from the perspective of mainstream customers but are appealing to emerging customers in low-end or new markets as they perform better on an alternative dimension. As these innovations improve over time, they overtake the existing technologies, by satisfying current market needs.

Christensen, in a sequel, replaced the term disruptive technology with disruptive innovation to include service and business model innovations (Christensen & Raynor, 2003). In this book, the authors further categorized disruptive innovations into two types: low-end disruption and new-market disruption. In case of low-end disruptions, the initial customers of the disruptive technology are price-sensitive customers at the low end for whom the low performance is acceptable. Low-end disruptions occur when current technologies are over-priced because their performance overshoots the performance expected by the market. Thus lower-priced alternatives with 'good-enough' performance have a chance to disrupt the existing technology. Alternatively, new-market disruptions "compete against non-consumption" as these enable new groups of people to begin using these

products that previously lacked the resources or skills to use them (Christensen & Raynor, 2003: 45).

Along with wide spread praise, the disruptive innovation theory by Christensen has also attracted criticism (Danneels, 2004; Tellis, 2006). The main criticism revolves around the lack of a comprehensive definition of disruptive innovation and predictive use of the theory. However, this theory is still evolving and significant opportunities exist to contribute to theory building (Christensen, 2006).

2.1.1 Disruptive Innovations and Base of the Pyramid Markets

Base of the Pyramid refers to the lowest socio-economic segment in the world. The World Resource Institute defines the BOP segment as people with an annual income in 2005 PPP terms of less than US$3260 (Hammond, 2010). Since roughly over a decade, companies have shown growing interest in serving the BOP markets. Proponents C.K. Prahalad and Stuart Hart (2002) argued that MNCs the world over should create products and services for the four billion strong low income markets, that MNCs traditionally have tended to ignore. The authors positioned this approach as having two key advantages: Firstly, it meant creating new profitable revenue streams for MNCs as they enter largely un-tapped markets. Secondly, they viewed it as a new market-based approach to poverty alleviation.

The BOP market is in no way homogenous and large populations, e.g. about 80 % of Asia falls into this category (Hammond, 2010). The 'bottom billion' (Collier, 2007) or the poorest one billion people of the world live in subsistence and cannot be considered a "market" for MNCs (Jaiswal, 2008). However, there are still large parts of low-income segments, which are growing and have considerable purchasing power that can be of interest to MNCs. These segments that make up the mass markets of countries like India and China have been neglected by MNCs until recently, who have chosen to concentrate on the small number of elite in these countries (Prahalad & Lieberthal, 2003). The BOP approach, targets these unaddressed markets and is recognized as a key emerging frontier of international business strategy research as it requires fundamental rethinking (Ricart et al., 2004).

The BOP market is an ideal ground for potentially disruptive innovations (Hart & Christensen, 2002; Prahalad, 2012). One of the characteristics of disruptive innovation is that it attracts non-consumers or low-end customers that are satisfied with "good-enough" performance. BOP markets have vast populations of people with limited or no access to services and products who are willing to adopt affordable products with acceptable performance (Hart & Christensen, 2002).

Disruptive innovations initially take root in nascent segments and non-mainstream markets (Christensen, 1997). The BOP markets are nascent markets for MNCs and were, until recently, ignored by them since people from the BOP don't have the kind of buying power that developed markets do (Prahalad & Lieberthal, 2003).

Disruptive innovations are typically simpler and are offered at a lower price (Christensen, 1997; Govindarajan & Kopalle, 2006). Creating products and services

that are simple and affordable to low-income segments is most crucial for adoption and success in the BOP (Anderson & Billou, 2007; Prahalad, 2004). Such models created for the low-end can be profitably applied in the high-end as well (Hart, 2010). Thus products and services that succeed in BOP markets could be disruptive to dominant products and services in the higher-end of emerging markets as well as developed markets. These three attributes of the BOP mentioned above make BOP an ideal market for launching disruptive innovations, namely, vast numbers of non-consumers, disregard by MNCs and need for simple and affordable products.

2.1.2 Challenges in Commercializing Disruptive Innovations

Prior research points to how established firms stumble in the face of technological change (Foster, 1986; Henderson & Clark, 1990; Tripsas & Gavetti, 2000; Tushman & Anderson, 1986). Technological discontinuities that were competence destroying (Tushman & Anderson, 1986) or 'architectural innovations' (Henderson & Clark, 1990) presented established companies with challenges that led to serious shifts in the industry. Disruptive innovations present another manifestation of this phenomenon, but have different characteristics and other reasons why established firms fail to commercialize them (Christensen & Bower, 1996).

Two inherent qualities of disruptive innovations differentiate them from other discontinuous innovation.

1. Lack of financial attractiveness: Christensen argues that disruptive innovations appear financially unattractive for companies to pursue (Christensen, 2006), relative to their mainstream investments for three main reasons:
   I. Profit margins for disruptive innovations are typically lower (Christensen, 1997)
   II. Companies are unable to correctly estimate the size of the market for disruptive innovations since these innovations create completely new markets (Christensen & Raynor, 2003).
   III. Companies tend to pursue large markets. Initially markets for disruptive innovations are much smaller than mainstream markets and cannot provide volumes that make the business interesting for companies (Christensen, Craig, & Hart, 2001).
2. Incompatibility with existing value network: Christensen uses the concept of value networks to explain attacker's advantage in commercializing disruptive innovations (Christensen & Rosenbloom, 1995). Value networks are defined as "the collection of upstream suppliers, downstream channels to market, and ancillary providers that support a common business model within an industry" (Christensen, 1997). Disruptive innovations do not fit into the embedded value networks of the organization and new market disruptive innovations typically create new value networks with new performance attributes (Christensen & Raynor, 2003).

These inherent qualities of disruptive innovation make them unattractive for established firms and they often fail to commercialize disruptive innovations (Christensen & Bower, 1996).

Two underlying mechanisms have been identified by scholars as an explanation for this failure:

Resource Allocation Processes

Christensen in one of his works (Christensen & Bower, 1996) argues that established firms fail to allocate resources to disruptive innovations because they do not address their current customer base. He bases this argument on resource dependence theory by Pfeffer and Salancik (1978), where Christensen posits that firms are governed by their resources and the sources of their resources, namely their existing and most profitable customers. Christensen elaborates this view with his resource, process, and value [RPV] theory (Christensen & Overdorf, 2000). Christensen argues that an incumbent's values and processes tend to favor sustaining innovations and this is where they invest their resources, because disruptive innovations have inherent qualities, stated above, that make them unattractive to incumbents.

Inadequate Market-Facing Organizational Competency

Henderson added to the disruptive innovation theory by suggesting that another reason for companies to be unable to develop disruptive innovations is the lack of marketing competency (Henderson, 2006). Exploring new, disruptive markets requires a major change in patterns of behavior and search (Danneels, 2002). The lack of this competence in companies focused on their current customers, hinders companies from identifying emerging customer trends peripheral to their current business (Henderson, 2006).

Christensen and other authors (Christensen, 2006; Danneels, 2004) have pointed out examples of established players that have successfully developed disruptive innovations. In Christensen's research on the disk drive industry, he shows that incumbents who maintained their dominance through the disruptive change, did so by spinning off the sub-unit developing the 5.25-inch drive (Christensen & Bower, 1996). Thus, Christensen's recommendation for established players is to set up autonomous units or spin-offs to incubate disruptive innovations (Christensen & Bower, 1996; Christensen & Raynor, 2003).

In contrast to this recommendation, other scholars promote organizational structures that are loosely coupled with each other and enable organizations to simultaneously host evolutionary and revolutionary innovations from within (Tushman & O'Reilly, 1996). Thus, questions remain on what makes some incumbents successful while others fail and whether companies always need to spin-off their disruptive projects (Danneels, 2004). Although a spin off can successfully protect projects, it

also isolates it from crucial company resources and capabilities and the ability for the company to learn (McDermott & OConnor, 2002). This is why authors O'Reilly and Tushman (2008: 202) posit that "ambidexterity is one solution to the innovator's dilemma". The concept of ambidexterity will be explained in detail in the next section.

2.2 Organizational Ambidexterity

Organization ambidexterity [OA] is an organizations' ability to successfully explore and exploit simultaneously. Researchers have diversely defined OA and its importance has been noted across different fields of management research, including strategic management, innovation management, organization learning and organizational behavior (Simsek, 2009). We operationalize ambidexterity as the ability of organization's to simultaneously host different innovation streams (Tushman et al., 2010), specifically in our case sustaining and disruptive innovations (Danneels, 2006; Simsek, 2009).

Research points to two forms of ambidexterity, structural ambidexterity, which is achieved by creating separate structures for the different kinds of activities and contextual ambidexterity, which resides in an individual's ability to allocate time between exploration and exploitation (Raisch, Birkinshaw, Probst, & Tushman, 2009). As this work concerns mechanisms at an organizational level, we will focus on structural ambidexterity. The main proponents of this school are O'Reilly and Tushman (see, e.g., O'Reilly & Tushman, 2004; Tushman & O'Reilly, 1996; Tushman et al., 2010). Structural ambidexterity is achieved through distinct units within the organization held together by a common strategic intent, an overarching set of values, and a leadership team that can manage differentiated sub-units with clearly defined interfaces that leverage existing assets (O'Reilly & Tushman, 2008). Research shows two key components are necessary for achieving structural ambidexterity. First, structural differentiation of the different activities in distinct units ensures that exploratory units enjoy required freedom and flexibility, while exploitative units can carry on with their ongoing business (Jansen, Tempelaar, Bosch, & Volberda, 2009). However, to reduce the risk of isolation, targeted integration mechanisms between these units are necessary (Sirmon, Hitt, & Ireland, 2007). Second, the role of the top management is crucial for managing the contradictions arising from managing innovation stream (Smith & Tushman, 2005).

While several works have confirmed the business performance enhancement through ambidexterity (Gibson & Birkinshaw, 2004; He & Wong, 2004), there remains a gap in understanding of the mechanisms by which organizations achieve ambidexterity, as Gupta et al. (2006: 697) noted, "although near consensus exists on the need for balance, there is considerably less clarity on how this balance can be achieved".

Few works have empirically studied organization designs required to deal with multiple innovation streams, with the exception of (O'Reilly & Tushman, 2004;

Tushman et al., 2010). The results from analyzing innovation episodes within 13 business units was the nature of ambidextrous organizational design-high structural differentiation of exploitative and exploratory units with targeting structural linkage (Tushman et al., 2010). In studying the cases of USA Today and Ciba vision, the authors O'Reilly and Tushman (2004) also identified the need for an overarching vision that permits the otherwise contradictory units to coexist. However, these case studies explore incremental vs. architectural innovations (Henderson & Clark, 1990) or discontinuous innovations, which involve fundamental competence destroying technological changes (Tushman & Anderson, 1986) and do not deal with disruptive innovations. As shown in Sect. 2.1.2, disruptive innovations have certain inherently unfavorable characteristics specific to them. Thus empirically exploring the role of ambidexterity in hosting disruptive innovations is still an open field (Danneels, 2004).

3 Research Question and Methodology

3.1 Research Question

This research brings together three fields in management research, namely BOP research, disruptive innovation theory and organizational ambidexterity. Analysis of strategy for MNCs in low-income markets is an emerging field of international strategy research (Ricart et al., 2004). Some of the most important aspects of products developed for BOP markets is the need for extreme affordability and adaptation to local needs (London & Hart, 2004; Prahalad, 2004; Tiwari & Herstatt, 2012). By developing disruptive innovations to seize the opportunities of the BOP, companies could potentially "give themselves a chance for sustained corporate growth while also helping to lift the poor out of poverty" (Hart and Christensen, 2002: 56).

However, questions regarding how large companies can successfully develop disruptive innovations from within their boundaries remain (Danneels, 2004). Authors O'Reilly and Tushman posit that "ambidexterity is one solution to innovator's dilemma" (O'Reilly & Tushman, 2008: 202), however fail to answer the 'how'.

This research will try to answer this question by analyzing the case of GE Healthcare and its innovations for the Indian mass market. GE Healthcare is one of the few MNCs committed to developing products for low-income markets and has been developing several products over the last few years (Immelt & Govindrajan, 2009).

Thus the key research question is:

What organizational structures and processes would enable incumbent firms to systematically create disruptive innovations for the BOP markets?

3.2 Methodology

Exploratory case study methodology has been chosen for this research. Exploratory case study method is considered apt when insufficient theory exists in the area and a deep understanding into the "how and why" is required (Yin, 1994). Single case study research can richly describe the existence of a phenomenon (Siggelkow, 2007) and extend and refine theory (Eisenhardt, 1989).

Secondary data, including company press releases, annual reports, and primary data in the form of interviews as well as internal company documentation have been analyzed. In total 11 interviews were conducted with senior management at GE Healthcare India involved in low-cost innovations, including senior executives. The interviews lasted between 30 and 60 min and were semi-structured. Most interviews were conducted in person and some follow-up interviews were conducted over the telephone. All interviews were recorded and transcribed. Notes of the meeting and impressions, over and above the interviews were written the same day, conforming with the "24-hour rule" (Yin, 1994).

Once transcribed, the interviews and secondary data were coded using content analysis principles with the software MAXQDA. This enabled us to code key passages, add memos to codes and sort codes. We continuously sought to sort and match codes with theory. This iterative comparison between emergent theory and case study data led to additional memos and new insights. At the end of the transcription and content analysis process, memos and codes were categorized into conceptual clusters, e.g. challenges in commercialization or enablers of low-cost innovations.

4 Empirical Data

4.1 GE Healthcare Case Study

GE Healthcare is a division of the American conglomerate, General Electric. GE Healthcare had revenues of US$18.3 billion in 2012 with about 48,000 employees worldwide.[1] GE Healthcare's main revenue streams are medical equipment and services in medical imaging, diagnostics, IT and patient monitoring systems.[2]

[1] GE.com website investor relations.

[2] www.gehealthcare.com

4.1.1 Early Successes in Frugal Innovations

GE established the Jack F. Welch Technology Center [JFWTC] in Bangalore in 2000 to capitalize on the R&D talent available in the country (GE, 2010b). It is GE's largest R&D center and the first one to be built outside the USA. Healthcare is one of the focus areas of the R&D center and was established as a center of software excellence. The engineering teams at the JFWTC, working together with GE's global teams, were solely focused on developing GE's premium products.

Around 2001, a lead engineer in GE's cardiology team wondered why none of GE's products, like the ECG device that his team was working on was not available in Indian clinics, beyond the high-end hospitals in India's tier 1 cities. The glaring answer was the high price tag of GE's premium products. It was apparent that GE would not be able to penetrate these emerging markets with its premium products and would need to develop products especially for these markets. Even the Indian sales teams were demanding low-cost products.

The team in India tried to push the idea for a low-cost ECG device for India and India-like markets, but only after 3 years did they receive a positive response. A leader at the global level bought into the idea and allocated an engineering team in Bangalore to develop a low-cost ECG device. He also brought in technology experts from Germany to help the Indian team with knowledge transfer. The answer was the MAC 400, which was priced at about US$1000, compared to premium segment ECGs that cost about ten times as much.

The value proposition of the MAC 400 was not only the cost advantage but also portability and robustness to work in an environment with power fluctuations and dust. Portability was an important feature as doctors in India, especially in tier 3 cities and rural areas have multiple practices and travel to smaller clinics in more remote regions. The cost advantage was achieved by creating a smaller device that retained only key functionalities. Standard and commercially available subsystems were chosen, e.g. a standard, off-the-shelf charging system used for mobile phones was used instead of a custom-made power supply system and more commonly used printer systems were chosen, like those used for bus ticketing systems. The next version, the MACi [I stands for India], with a price tag of US$535, was launched in 2009. This had an even more cost optimized design than the MAC 400, reduced printer size. Despite being such frugal products, the MAC 400 and MACi run the Marquette 12SL analysis program that runs on all high-end ECG devices. This way the clinical efficacy of the device is not compromised on. As noted by the GE senior executive responsible for the MACi and MAC 400 development:

> One of the fundamental things is that value product does not mean old technology. But many companies do this. They would sell the last generation products cheaper in emerging markets. That is nonsense. In our case, the value product means high-tech engineering but cost optimized

The MAC 400 and MACi were considered breakthrough at GE. It was not only breakthrough because GE had managed to develop such a low-cost ECG device, but it was also breakthrough in terms of the value network GE created to sell these

products. GE's portfolio until then only had expensive US$10,000+ and its sales, servicing teams were built for such a high-end product portfolio.

4.1.2 Raising the Stature of Everything Global

These initial successes in product development led to major shifts within GE by 2009. In the letter to the shareholders, as part of the 2009 annual report, GE's Chairman announced a push for reverse innovation (as explained in Sect. 3.1) to capture new opportunities by "taking the low-cost healthcare devices designed in India and China and marketed in the developed world". GE also announced the Healthymagination initiative in May 2009, with the commitment to invest US$6 billion in the next 6 years to develop products with a goal "to provide better health for more people at lower cost" (GE, 2010a). The Healthymagination initiative was a key component in the GE's 2009 Renewal Model with a focus on "creating market solutions for societal problems".

In late 2009, GE also decided to give India its own Profit and Loss [P&L] responsibility. Traditionally, GE's regional business leaders reported to their respective GE product business leaders. Under the new structure, the business unit leaders reported to John Flannery, the then CEO of GE India, who would in turn report to GE's Vice Chairman. This was done to ensure India had the empowerment to develop products for its own markets. Jeff Immelt, Chairman of GE in the official press statement (Mahajan-Bansal & Goya, 2009) described it as:

> With an integrated team, we can develop products and services designed specifically to meet local needs and, potentially, for export to other markets

This was the first time a country, other than the USA had its own P&L. This also meant it was in charge of its own growth strategy and its own budgeting processes. Following this, GE China also got a similar status. In 2010, GE established the Global Growth Organization to oversee operations in high-growth markets. Thus GE continued to push its emerging markets strategy by "raising the stature of everything global in GE" (Lemer & Crooks, 2010).

4.1.3 Pushing Further Down the Pyramid

In India, a new range of products in infant-care was launched under the brand of Lullaby. The Lullaby warmer was launched first in 2009 at a price tag of US$3000 about 60–70 % lower than premium segment warmers. Next in the range, the Lullaby LED Phototherapy [LED PT] Device, developed in India for India-like markets was launched in 2011. The LED PT's value proposition of low Total Cost of Ownership [TCO], energy savings, ease of use and serviceability, made it a runaway success not only in India but also outside India.

Even with the new range of Lullaby infant care products, the Maternal and Infant Care [MIC] team in India realized that the US$3000 warmer could sell in top-end

clinics in the metros, but could not impact the broader issue of infant mortality rates [IMR] of the country. They realized that with their product line they were serving countries like USA and Western Europe or even the top-end of the developing world that did not have a problem of IMR. The real issue of infant mortality was in poor regions of Asia and Africa. In their current markets, the aim of infant care was saving premature babies born too early, e.g. at 24 weeks whereas in countries like India, the issue was solving even more basic problems of survival. As the MIC Marketing executive put it:

> In the current state of the portfolio, we had some fantastic incubators and warmers, which are best in class. . .. but the products are made for those markets where the core issue of IMR is under control, whereas in countries like India, IMR is very high. We needed something, which is at a price point that can make an impact to the IMR

The MIC India team is currently working on a range of products that caters to segments in Tier-2 and Tier-3 cities and villages, mostly local clinics and government hospitals. These hospitals, MIC India's research showed, currently have low quality local warmers that are often broken or overused or use 200-W bulbs to keep babies warm. The MIC team aims to sell its new range of cost-effective products to these segments and push towards selling to clinics that have not adopted any warmers yet.

To cater to segments further down the pyramid, i.e., home births that occur outside a hospital or clinic that represent about 51 % of births in rural India (Chandramouli, 2011), the MIC India team has partnered with Embrace. Embrace is a non-profit organization that has developed an innovative, low-cost baby warmer priced at US$250 that looks like a sleeping bag for a baby. This is portable and does not require a continuous supply of electricity.

The MIC team is now working on an end-to-end solution that not only includes products at significantly lower price points but also a go-to-market strategy that includes collaborations with the government and NGOs. This new approach is highlighted in this quote from the MIC Marketing executive:

> We have dropped our—what should I say, reluctance—and we are more than willing to form partnerships with Embrace and to work with East Meets West to address the BOP market. So these are the different efforts of establishing a performance [value] segment. And my role is to facilitate the creation of low-cost value products in all these different ways. . .so it is a very concerted strategy

GE Healthcare is partnering with East Meets West [EMW], an international development agency focused on neonatal health, to distribute and service GE Healthcare's infant care products in developing and rural regions. While GE provides its products, servicing and technical expertise, EMW provides monitoring and training for the medical personnel. The MIC Team in India is also starting a concerted effort to work with government as they realize that only through such partnerships can they have an impact on the IMR.

4.2 Characteristics of the Value Segment Products

The value proposition of the value segment products at GE Healthcare go beyond cost-effectiveness. Products developed for the BOP and in general for emerging markets need to be well adapted to local needs (London & Hart, 2004). GE Healthcare's value products fit this mantra, as supported by this quote by the CTO of the GE Healthcare India talking about the considerations behind the MACi:

> [In places where the MACi was to be deployed], there was no technician who knew where the leads had to be attached to get a reliable ECG so ease-of-use became an important criterion, as important as cost. Most of our devices sit in air conditioned rooms like this, they are plugged into the wall with back-up power. Then you look at places [where MACi was to be deployed] that get three hours of power a week. So that became another consideration. If the patient cannot get to where the ECG machine is because it is 50–100 kilometers away, the ECG machine has to get to the patient. So something that can be carried around. While the first thing on the surface always seems to be cost, that is really not the whole story and sometimes not even half the story. In fact, most of what is in the MACi has nothing in common with most of the ECG machines we have except for the algorithms and the software, which is kind of the legacy that we have and that we built over a period of time

The other "half of the story" of GE Healthcare's value segment products entails other product characteristics summarized in this section:

1. Low complexity: The value segment products are stripped of non-essential features and target satisfying critical user needs. The products would compromise on unused features or even on convenience in order to keep the complexity and hence the cost of the product low. In case of the MACi, the team decided to build a single-channel ECG without a display, which meant that it would be more inconvenient for doctors to read the ECG in comparison to 3-channel digital displays, but the information would be the same.
2. Ease of Use: In most cases, the technicians operating medical devices in Indian clinics are minimally trained, especially in more remote regions. To make sure they can properly operate the devices, ease of use is an important aspect in product development. The MACi is designed with a minimum number of buttons and its regular usage requires only the on/off button. Similarly, the MIC team on one of its immersive market research field trips evidenced how a baby died because the nurse thought that the warmer was on when only its observation lamp was lit. This had a deep impact on the team and it decided to make its products "absolutely foolproof". The engineering lead of the MIC team recalled this incident and said:

   > See it is very easy for me to say at least this basic knowledge should be there with the nurse, or that we should train them. . . but now we say we need to make the product foolproof for untrained people too

3. Reliability and Serviceability: Products sold to remote parts of India would be difficult to service because of poor infrastructure to reach there. Keeping this in mind, GE's products are also designed for serviceability by ensuring those parts

that breakdown most often are done without or extra components are sold along with the product. In general, the engineering teams try to minimize the number of parts, especially the number of movable parts.

4. Environmental fit: BOP products generally have to function amidst harsh conditions: high levels of dust and humidity, large fluctuations of voltage, etc. Besides this, hospitals are generally not equipped with high-quality infrastructure. An example is the lack of wall oxygen supply in most hospitals, which is recommended for resuscitation [breathing] equipment for premature babies. To counter this, GE Healthcare's resuscitation device, currently under development in India, will work under either condition: one in case there is a wall oxygen supply available and in another case where the equipment is connected to an external oxygen cylinder. The device is able to function even with power breakdowns and time lags. As an executive of the MIC segment put it:

> So this is the environment in which we work. Now, you cannot try to say, okay, get me reliable power and I'll give you a product, that doesn't work... then you're not in the game and you'll continue to create products that don't work. So now when you have [these conditions], you need to come up with some other innovative way of doing things

5. Local use cases: Doctors in India apply this medical equipment for different use cases. For instance, in India several hospitals and clinics conduct large scale screening camps, often for free, in rural areas or even urban areas to pull in customers. Thus the MACi is designed in such a way that it can take 500 ECG's in a single charge. Also its requirement for portability came up because doctors in India sometimes are required to travel between clinics.
6. Cost-effectiveness: The basic requirement of these products, "the right to play" is to make value segment products affordable for the market. This does not mean a 20 % or 30 % reduction in cost but more drastic, between 70 % and 90 % reduction. If one compares the MACi and premium ECG devices sold in developed markets, there is difference of a factor of 20 in price. Not just the initial investment but the Total Cost of Ownership must be kept low.
7. Clinical efficacy: In all GE Healthcare's products, clinical efficacy is not compromised. All products go through rigorous certification processes just like premium segment products do. The MAC 400 and MACi run the same Marquette 12SL analysis program as the high-end ECG devices to interpret the ECG. This is the core of their technology, built on several years of testing and experience. Similarly, the MIC segments products all have high clinical efficacy but are geared towards saving late-stage premature babies vs. the premium segment incubators that are designed to save extremely premature babies.

In some cases, designing for one feature brings advantages in cost at the same time. For instance, in case of the LED PT, the team decided early on to do away with the cooling fan, which was a feature in previous generations of PT devices. This decision was taken in order to ensure reliability of the product as the fan system is very susceptible to breakdowns. Thus the team designed the product with vents and natural airflow. This had the positive side effect of removing complexity and cost simultaneously.

These characteristics are very much in line with the characteristics of frugal innovations identified by authors Tiwari and Herstatt (2012). In addition to those points, clinical efficacy and product adaptation towards local use cases are additional characteristics that GE's frugal medical technology developed for India have.

4.3 How Are Value Segment Products Potentially Disruptive

As seen in the section above, GE Healthcare's value segment products trade-off features and convenience for price. With drastic price reductions, these products can be sold to new segments that were previously not using the product or using only a poor substitute. Value segment products have other features that make it attractive for mass markets in emerging economies, such as ruggedness, reliability and fit to the environment. Thus, besides price, the new performance attributes of these value segment are also in some cases, portability, reliability and ease of use.

There is also emerging evidence of better versions of some of the value segment products being sold in more mature markets, e.g. the MAC 800, a later version of the MAC 400 is selling in the USA and Western European markets in emergency situations like in an ambulance (Immelt & Govindrajan, 2009). Also a significant portion of Lullaby range warmers and LED PT device are selling in more developed markets. These warmers and PT devices could potentially enable hospitals to purchase multiple units rather than just a few units traditionally purchased only for the Neo-Natal Intensive Care Units.

While it is true that these low-cost devices open up new markets, e.g. in rural India, question does remain as to what extent these low-cost devices will disrupt existing markets. Disruption is a process and not an event (Christensen, 2006) and the evolution of the healthcare industry in developed markets and other factors will play a role in this disruption process.

5 Analysis

5.1 Overcoming Innovator's Dilemma

In Sect. 2.1.2 the inherent qualities that make disruptive innovations unattractive for established firms were described, along with the underlying organization's mechanisms that prevent them from investing in disruptive innovations. This section will elaborate on how GE Healthcare is countering these mechanisms with structures and routines that enable it to systematically invest and commercialize disruptive innovations.

5.1.1 Dedicated Processes

GE has created dedicated processes by putting new structures in place to allocate resources to disruptive projects. The main structure is the GE India P&L. Until 2009, GE Healthcare was organized along product groups, where each product group was responsible for its P&L. In late 2009, GE introduced its "one GE" strategy in India, where it gave GE India its own P&L. This also meant own control of budget processes. As John Flannery, the previous CEO of GE India put it in an interview to a newspaper:

> The change to direct reporting is monumental as it fundamentally changes in many ways the business operations. . .The decision making is faster and so is spotting opportunities and acting upon them. India for a lot of MNCs is 3–5% of business, but for myself and the team here it's 150% of our business. So, the sense of urgency is very different in that context (Times, 2010)

GE India has control of budget and product development for the local market. Thus if opportunities for the BOP are identified, those projects get funded from GE India directly, rather than having to apply for funding at the headquarters.

GE India reports into the Global Growth Organization [GGO], headed by John Flannery, the Vice-Chairman of GE. The GGO was setup to empower the emerging markets with resources and give it more autonomy to make decisions. The GGO is responsible for funding "In Country for Country" [ICFC] programs. This stands for products designed and developed in a country for that country. The program manager for ICFC programs in India summarized the advantages of these structures appropriately:

> What that gives you is the ability to seek funding for opportunities that are highly relevant in the Indian marketplace. So you go to John and tell him, "Here's this market opportunity". If I look at the overall number, it may not get prioritized within the Healthcare business because it's still a small number. It's an infant market. We need to create this market, grow this market. Whereas for India, it's all the more relevant because [GE's operations in] India can grow only if we invest the kind of money that we need for such products that are extremely relevant and designed solely for Indian requirements

GE Healthcare India has setup a unique role of a program manager for ICFC programs who pivots between GE Healthcare India and the GGO. He is responsible for ensuring ICFC project ideas from India get appropriate access to funding from the GGO. In a broad sense he is the ambassador for frugal innovations from India to the GGO or GE's Headquarters. He described his role as:

> On one hand I work with healthcare folks [in India] to determine what the market needs are, what the commercial pain points are, what the product portfolio gaps are. I the go back to GGO and explain to them why these are the gaps, [and] why we need the money to fill these gaps

Thus GE Healthcare India has put one person in charge of the process, who ensures the disruptive projects for the Indian market get the resources they need.

5.1.2 Reconfigured Values

The Healthymagination initiative has brought the need to improve access and affordability of healthcare to the forefront. To quote Immelt, the Chairman of GE in the letter to their investors:

> This commitment has transformed our entire approach to health—from the way we motivate and engage employees and consumers, to the way we collaborate with partners and develop new products. Today, healthymagination serves as a rallying cry for meaningful innovation to address the world's biggest health issues. It's a call for better products at more price points in more regions. . . In short, it's a call for better health worldwide. (GE, 2011)

GE has been able to operationalize the Healthymagination vision by changing its innovation process. Cost, access and quality are now the evaluation criteria in the companies' New Product Introduction [NPI] process. The value propositions of new product introductions are evaluated against the three axes of cost, quality and access. As the erstwhile CEO of GE Healthcare Systems, Omar Ishrak noted about the Healthymagination initiative[3]:

> All new products must be designed in a way that a value proposition for those products must be considered during the initial phase of design..and by value proposition, we mean that whether that product is going to provide an improvement in cost to the health care system, . . . whether it will increase access, . . .or whether it will improve quality. So every new product will have to be gauged and assessed as to what value it will provide in terms of cost, quality, and access

5.1.3 Dedicated Resources

GE's Healthymagination initiative has also set aside US$3 billion out of the total US$6 billion commitment to launch products that improve cost, access and quality of healthcare. This involves not just in-house development but also acquisition or partnerships with external companies. Thus the Healthymagination initiative also provides dedicated funds for disruptive innovation ideas that might come from within or outside the firm. Projects like the cooperation with Embrace fall into this category. The Healthymagination initiative is also monitored via a neutral third party, the Oxford Analytica to track how its initiatives deliver on its commitments. Moreover, GE India and GGO, with their mandate to increase GE's presence in emerging markets, have dedicated budget for developing products for the local markets.

By dedicating resources, processes and reconfiguring values to accommodate disruptive innovations within its organizational structures, GE Healthcare is combating the tendency of resource allocation processes within established companies to ignore disruptive innovations as explained in Sect. 2.1.2. GE has also taken

[3]Online Interview http://www.ge.com/audio_video/ge/health/healthymagination_vision.html

proactive steps to counteract the lack of market-facing organizational competency, Henderson's explanation to incumbent failure (Henderson, 2006). This is elaborated in the next section.

5.1.4 Building Capability

GE has built local capabilities for product development within the value segments. Besides the engineering capability that it already had in place through the R&D center, GE Healthcare has created teams with product management, upstream marketing and market research skills in key emerging markets such as India for certain business areas. For instance, in the MIC space, there are product managers in India, China, Latin America and Middle East. The MIC space in India has a complete marketing and product development team involved in all aspects from market research, development as well as managing local partnerships and government engagement. The importance of this was emphasized by the MIC value segment leader:

> So this is one of the most important things- setting up the organizations such that the team has the empowerment to do things, the team has experienced people to do it, and the team has the right people sitting here to actually identify what exactly the need [of the local market] is. So you need qualified people who have different skill sets. You can't just run this whole thing with an R&D/engineering mindset

5.2 Combating the Unfavorable Characteristics Disruptive Innovations

This section describes the approaches GE Healthcare India has taken to overcoming the innovator's dilemma, structured along the unfavorable characteristics of disruptive innovations as described in Sect. 2.1.2.

Financial Unattractiveness There is a large chasm between developed markets and BOP markets, especially in terms of informal economies (Banerjee & Duflo, 2007), and institutional voids (Khanna & Palepu, 1999). These new environments pose new risks to MNCs and are thus sometimes viewed financially unattractive to companies, just like in the case of disruptive innovations. Even at GE before 2009, proposals for these low-cost innovations were often met with fear of cannibalization and dragging down profit margins (Immelt & Govindrajan, 2009).

In terms of internal product development processes, GE Healthcare India is substantially diverging from the norm by building some of the lowest cost equipment within GE Healthcare, in some cases about 80–90 % cheaper than the high-end products in their portfolio. In order to manage risks involved in the development and commercialization process, GE Healthcare has begun to assess many of

these market risks and technical risks upfront. This approach is summarized well by this quote by the MIC value segment leader:

> So what we are trying to do is, try to move risks up to the front of the program, do things as early as possible. . .Can we find out the customer needs before even we embark on a New Product Introduction [NPI], which means can we fund a small team to go and identify needs even though it's not part of any NPI process, so that once a need is identified then we can put it to the NPI process very quickly. Can we mitigate technology risks earlier in the process as a separate activity, not as part of the NPI process itself. . . . So, for example, can we get a heater head at 20% of the cost of the current heater head? . . .So all of those [go to market] strategies have to be thoroughly thought of. So the entire supply chain piece, the entire commercialization piece, the service piece. . . all this has to form the go/no go for the product development

GE Healthcare exploits these innovations by selling them in less price-sensitive markets around the world at a higher price. Many of GE's ICFC are being sold outside India, for instance in Eastern Europe, Middle East and Latin America. The MIC value segment leader explains the success of selling its products outside India:

> If you can succeed with decent margins in an extremely price sensitive market like India then when you go outside India you can potentially extract more value and get a better margin profit

This is one of the basic tenants of reverse innovation, taking innovations first adopted by emerging markets to more mature markets (Govindarajan & Ramamurti, 2011). GE Healthcare with its disruptive innovations wins by keeping the cost low and exploiting higher margins when selling these products in more mature markets.

Incompatible Value Networks As explained in Sect. 2.1.2, disruptive innovations do not fit into the embedded value networks of the organization and new market disruptive innovations typically create new value networks (Christensen & Raynor, 2003). GE Healthcare faced—and is still facing—similar challenges of embedding their low-cost innovations into their existing value network. This quote from the MIC Marketing executive summarized the problem well:

> Today we sell premium products to premium hospitals. . . . Now once you decide to go to the bottom of the pyramid, once you decide to serve primary healthcare it's a completely different ball game. So it means you're going to the rural areas, you're going to mom and pop sort of entrepreneurs. . .

Or this quote by the GE executive responsible for the MAC 400 and MACi:

> We thought we could use our distributors. But when we asked them they said 'No, I can't send my guy to the villages for the small margin of 80 USD. I have my rep in Mumbai and I have him sell big equipment. That gives me much more money'. They refused to do that [sell the low-cost ECG devices]

Besides the distribution channel, GE Healthcare had to learn to work with different types of customers, including the Government in different countries because they mainly procure equipment for primary health centers in remote parts of countries.

This required GE Healthcare to find a more holistic approach to serving the BOP markets. The MIC value team has defined its vision as "making an impact on Infant Mortality Rate". This vision, rather than a one-dimensional mandate to create products for the BOP, makes them take a more holistic approach. This affects their go-to-market strategy, e.g. partnering with NGOs such as East meets West to provide a more comprehensive support to providers and also how they develop their products, e.g. by making sure their products really fit the unique needs of the BOP.

GE Healthcare is also innovating on other business process fronts, e.g. providing financing to purchase equipment by tying up with local banks to ensure doctors in rural areas, who are generally managers/entrepreneurs of their practice, have access to loans. They are learning from, and partnering with distribution channels of other industries like pharmaceutical industry and consumer goods like blood pressure monitors to build a distribution network for their low-cost products.

5.3 Ambidexterity in Action at GE Healthcare

These innovations represent emerging market opportunities, where companies need to diverge from the ongoing business and invest into exploration. As literature points out, it is important for companies to balance exploitation and exploration, i.e. to be ambidextrous. This section describes how GE Healthcare achieves ambidexterity and how it hosts sustaining and disruptive innovation streams within its boundaries.

5.3.1 Structural Differentiation and Integration

GE Healthcare has adopted an ambidextrous design to balance its exploitation and exploration activities (O'Reilly & Tushman, 2004). The existing high-end product segments serving developed markets are organized under the "premium segment" whereas the emerging-market products developed to make technology affordable are organized under the "value segment". The premium segment caters to product development for GE Healthcare's existing high-margin customers, which represents sustaining innovations. The value-segment caters to product development for low-income markets, representing disruptive innovations.

These two segments are managed by the manager of that product segment within GE Healthcare. The value segment leader is typically based in an emerging market, e.g. India, China. The main task of the value segment leader is to develop and market value products in emerging markets and globally. The segment leader has functions related to product development reporting to him, e.g. marketing, engineering. Local sales teams who sell the products are organized regionally.

This organizational design ensures that the value segment leader is empowered to develop products for BOP markets. The CTO of GE Healthcare described this empowerment:

> Each of these businesses today inside of the company has a general manager for value and that person, even though their business might be one-twentieth of the premium business, they [the value segment general manager and the premium segment general manager] are peers and at the same level of the staff

While structural differentiation is necessary to clearly delineate exploration from exploitation, organizations run the risk of isolating explorative activities and under-utilizing existing assets. Thus structural differentiation needs to be combined with targeted integration activities (Jansen et al., 2009; O'Reilly & Tushman, 2008). With the ambidextrous design, GE Healthcare ensures integration through the ambidextrous manager who is responsible for both segments (Tushman et al., 2010). The premium segment and the value segment also share a common CTO and key product development decisions go through him. These managers need to ensure that newly created value segments can leverage the knowledge and expertise that exists within the company. As the MIC engineering leader described the integration:

> It's extremely important that you don't lose the global connect. . .You have to leverage the existing platform; otherwise it's completely inefficient. . .So, for example, the heating system [in the baby warmer], we do leverage a premium platform for our heating because that is very crucial [part] and we have 30 years of experience in heating. . . Of course, we have reduced cost, we have changed the material, [etc]

As seen in the Fig. 1, the organizational design of GE Healthcare is very similar to the ambidextrous organization described by O'Reilly and Tushman (2004). The crucial difference here is that all functions related to product development fall under these segments whereas sales is a regional function and does not fall under this matrix.

Not only is there empowerment through product-based segmentation, i.e. premium and value segments, but also through regional segmentation. As shown above, GE Healthcare achieves structural ambidexterity by putting in place a differentiated structure with integrative mechanisms, as well as dedicated resources with necessary competencies and dedicated processes to ensure disruptive innovations streams can simultaneously be hosted along with existing sustaining innovation streams.

5.3.2 Overarching Vision

Research points out the need for strategic intent to pursue exploratory units as well as an overarching vision across the exploration and exploitation units (O'Reilly & Tushman, 2011). GE's strategic intent of being a global organization legitimizes the need to create strong local capabilities in emerging markets. At the same time, the Healthymagination initiative provides a common vision for across GE Healthcare. Healthymagination is a commitment by GE Healthcare made over a 6-year period "to reduce costs, improve quality and expand access of healthcare for millions of people" (GE, 2009).

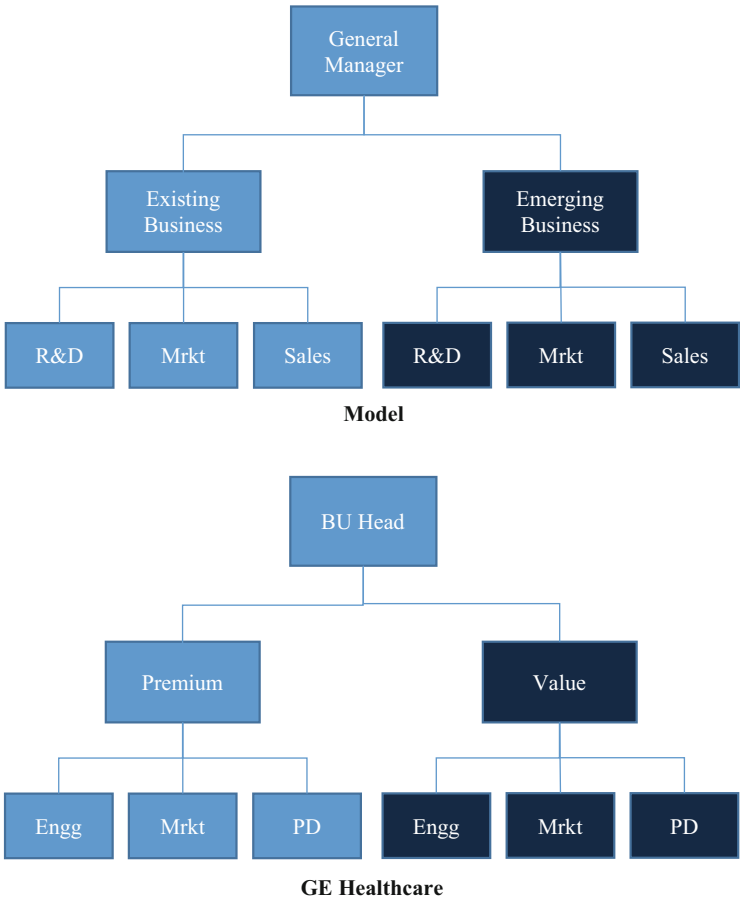

Fig. 1 Comparison of ambidextrous organizational design by O'Reilly and Tushman (2004) and GE Healthcare's organizational design

These three Healthymagination pillars have resulted in a reconfiguration of values within the company. GE Healthcare has traditionally been a technology leader in its industry, selling the most advanced equipment. Improving the quality of healthcare is what GE Healthcare historically has been innovating towards. With the goals of improving access and decreasing cost, the initiative explicitly aims at shifting GE Healthcare's focus towards low-income emerging markets. The Healthymagination initiative is thus able to create an overarching vision for units serving existing developed markets as well as new emerging markets within GE Healthcare.

6 Conclusion

Companies are increasingly looking at creating new markets for their products in low-income markets in emerging economies (Prahalad & Hart, 2002). However, serving these markets pose new challenges to MNCs from developing affordable, "good enough" products to commercializing these innovations. This article explores GE Healthcare's ventures into serving low-income markets in India with disruptive innovations. In particular, we explore organizational conditions that have enabled this incumbent to successfully and systematically develop and commercialize potentially disruptive innovations to serve BOP markets.

We see that GE Healthcare's ambidextrous structure creates the right conditions for it to host disruptive and sustaining innovation streams within its boundaries. The structural separation of premium and value segments as well as the overarching Healthymagination vision of improving quality as well as cost and access to healthcare gives value segment products legitimacy within the organization. Thus the two elements of ambidexterity of differentiated and integrated structures as well as an overarching vision have been shown to be helpful. In addition, as shown in this case, it is necessary to create measures to protect disruptive innovations within the boundaries of the organization, namely by creating dedicated processes and resources for disruptive innovations, reconfiguring values to help prioritize disruptive innovations and building capabilities for exploring these new markets. The Healthymagination initiative has reconfigured the values of GE Healthcare, right down to what products GE Healthcare brings to the market. GE has also ensured dedicated resources, processes and capabilities for enabling disruptive innovations, through the Healthymagination commitment, GGO and GE India P&L.

GE Healthcare's changes in its organizational design have laid the foundations to help it systematically create potentially disruptive innovations. GE Healthcare has adopted a permanent ambidextrous design by separating all its product units into premium and value segments. This fixed structure is part of GE Healthcare's organization, as opposed to transitional organizational structures put in place for temporary innovation episodes (Tushman et al., 2010).

Thus, this work contributes to emerging disruptive innovation theory, by exploring organizational designs required by incumbent firms to deal with strategic challenges associated with disruptive innovations in the context of BOP markets. It also contributes to organizational ambidexterity theory by providing substantial empirical evidence from the GE Healthcare case to show how a company has adopted an ambidextrous design to deal with hosting contradictory innovation types.

Companies like GE Healthcare are leading the way to create disruptive innovations in medical technology focused on the BOP markets. These disruptive innovations have the potential to not only make quality healthcare accessible to those who previously could not afford it, but also have the potential to be a solution to the global health care crisis.

References

Anderson, J., & Billou, N. (2007). Serving the world's poor: Innovation at the base of the economic pyramid. *Journal of Business Strategy, 28*(2), 14–21.

Banerjee, A. V., & Duflo, E. (2007). The economic lives of the poor. *Journal of Economic Perspectives, 21*(1), 141–167.

Chandramouli, K. (2011). *Family welfare statistics in India*. New Delhi: Ministry of Health and Family Affairs.

Christensen, C. M. (1997). *The innovator's dilemma: When new technologies cause great firms to fail*. Boston: Harvard Business School Press.

Christensen, C. M. (2006). The ongoing process of building a theory of disruption. *Journal of Product Innovation Management, 23*(1), 39–55.

Christensen, C. M., Bohmer, R., & Kenagy, J. (2000). Will disruptive innovations cure health care? *Harvard Business Review, 78*(5), 102–112.

Christensen, C. M., & Bower, J. L. (1996). Customer power, strategic investment, and the failure of leading firms. *Strategic Management Journal, 17*(3), 197–218.

Christensen, C., Craig, T., & Hart, S. (2001). The great disruption. *Foreign Affairs, March/April*, 80–95.

Christensen, C., Grossmann, J. H., & Hwang, H. (2008). *The innovator's prescription: A disruptive solution for health care*.

Christensen, C., & Overdorf, M. (2000). Meeting the challenge of disruptive change. *Harvard Business Review, March–April*, 67–76.

Christensen, C. M., & Raynor, M. (2003). *The innovator's solution: Creating and sustaining successful growth*. Boston: Harvard Business Press.

Christensen, C. M., & Rosenbloom, R. S. (1995). Explaining the attacker's advantage: Technological paradigms, organizational dynamics, and the value network. *Research Policy, 24*(2), 233–257.

Collier, P. (2007). *Bottom billion*. Wiley Online Library.

Danneels, E. (2002). The dynamics of product innovation and firm competences. *Strategic Management Journal, 23*(12), 1095–1121.

Danneels, E. (2004). Disruptive technology reconsidered: A critique and research agenda. *Journal of Product Innovation Management, 21*, 246–258.

Danneels, E. (2006). Dialogue on the effects of disruptive technology on firms and industries. *Journal of Product Innovation Management, 23*(1), 2–4.

Eisenhardt, K. M. (1989). Building theories from case-study approach. *Academy of Management Review, 14*, 532–550.

Foster, R. N. (1986). *The attacker's advantage*. New York: Summit Books.

GE. (2009). Michael Barber named Vice President, healthymagination. *GE News Center*.

GE. (2010a). *GE Healthymagination Annual Report 2009*.

GE. (2010b). GE's technology center celebrates ten years of innovation in India. *GE News Center*.

GE. (2011). "GE Healthymagination Annual Report 2010".

Gibson, C. B., & Birkinshaw, J. (2004). The antecedents, consequences and mediating role of organizational ambidexterity. *Academy of Management Journal, 47*, 209–226.

Govindarajan, V., & Kopalle, P. K. (2006). The usefulness of measuring disruptiveness of innovations ex post in making ex ante prediction. *Journal of Product Innovation Management, 23*(1), 12–18.

Govindarajan, V., & Ramamurti, R. (2011). Reverse innovation, emerging markets, and global strategy. *Global Strategy Journal, 1*(3–4), 191–205.

Gupta, A. K., Smith, K. G., & Shalley, C. E. (2006). The interplay between exploration and exploitation. *Academy of Management Journal, 4*, 693–706.

Halme, M., Lindeman, S., & Linna, P. (2012). Innovation for inclusive business: Intrapreneurial Bricolage in multinational corporations. *Journal of Management Studies, 49*(4), 743–784.

Hammond, A. (2010). *The next 4 billion: Market size and business strategy at the base of the pyramid*. Washington, DC: World Resource Institute.

Hart, S. (2010). Taking the green leap to the base of the pyramid. In T. London & S. Hart (Eds.), *Next generation business strategies for the base of the pyramid*. Upper Saddle River, NJ: Pearson Education.

Hart, S., & Christensen, C. (2002). The great leap. *MIT Sloan Management Review, Fall*, 51–56.

He, Z. L., & Wong, P. K. (2004). Exploration vs. exploitation: An empirical test of the ambidexterity hypothesis. *Organization Science, 15*(4), 481–494.

Henderson, R. (2006). The innovator's dilemma as a problem of organizational competence. *Journal of Product Innovation Management, 23*(1), 5–11.

Henderson, R. M., & Clark, K. B. (1990). Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms. *Administrative Science Quarterly, 35*, 9–30.

Howitt, P., Darzi, A., Yang, G. Z., Ashrafian, H., Atun, R., Barlow, J., et al. (2012). Technologies for global health. *The Lancet, 380*(9840), 507–535.

Immelt, J., & Govindrajan, V. (2009). How GE is disrupting itself. *Harvard Business Review*, 1–11.

Jaiswal, A. K. (2008). The fortune at the bottom or the middle of the pyramid? *Innovations: Technology, Governance, Globalization, 3*(1), 85–100.

Jansen, J. J. P., Tempelaar, M. P., van den Bosch, F. A. J., & Volberda, H. W. (2009). Structural differentiation and ambidexterity: The mediating role of integration mechanisms. *Organization Science, 20*(4), 797–811.

Khanna, T., & Palepu, K. (1999). The right way to restructure conglomerates in emerging markets. *Harvard Business Review, 77*(4), 125–134.

Lemer, J., & Crooks, E. (2010). *Rice to lead GE in emerging markets*. New York: Financial Times.

London, T., & Hart, S. (2004). Reinventing strategies for emerging markets: Beyond the transnational model. *Journal of International Business Studies, 35*(5), 350–370.

London, T., & Hart, S. (Eds.). (2010). *Next generation business strategies for the base of the pyramid*. Upper Saddle River, NJ: Pearson Education.

Mahajan-Bansal, N., & Goya, M. (2009). Jeff Immelt: India will be a centrepiece in our growth. *Forbes India*.

McDermott, C. M., & OConnor, G. C. (2002). Managing radical innovation: An overview of emergent strategy issues. *Journal of Product Innovation Management, 19*(6), 424–438.

O'Reilly, C., & Tushman, M. (2004). The ambidextrous organization. *Harvard Business Review, 82*(4), 74–81.

O'Reilly, C. A., & Tushman, M. L. (2008). Ambidexterity as a dynamic capability: Resolving the innovator's dilemma. *Research in Organizational Behavior, 28*, 185–206.

O'Reilly, C. A. I., & Tushman, M. L. (2011). Organizational ambidexterity in action: How managers explore and exploit. *California Management Review, 53*(4), 5–22.

Olsen, M., & Boxenbaum, E. (2009). Bottom-of-the-pyramid: Organizational barriers to implementation. *California Management Review, 51*(4), 100–125.

Pfeffer, J., & Salancik, G. (1978). *The external control of organizations: A resource dependence perspective*. New York: Harper & Row.

Prahalad, C. K. (2004). *The fortune at the bottom of the pyramid: Eradicating poverty through profits*. New Delhi: Wharton School Publishing.

Prahalad, C. K. (2012). Bottom of the pyramid as a source of breakthrough innovations. *Journal of Product Innovation Management, 29*(1), 6–12.

Prahalad, C. K., & Hart, S. (2002). The fortune at the bottom of the pyramid. *Strategy + Business*, 1–24.

Prahalad, C. K., & Lieberthal, K. (2003). The end of corporate imperialism. *Harvard Business Review, August*, 109–118.

Prahalad, C. K., & Mashelkar, R. (2010). Innovation's holy grail. *Harvard Business Review, July–August*, 132–142.

Raisch, S., Birkinshaw, J., Probst, G., & Tushman, M. L. (2009). Organizational ambidexterity: Balancing exploitation and exploration for sustained performance. *Organization Science, 20* (4), 685–695.

Rangan, V. K., & Thulasiraj, R. D. (2007). Making sight affordable. *Innovations, Fall*, 35–49.

Ricart, J. E., Enright, M. J., Ghemawat, P., Hart, S. L., & Khanna, T. (2004). New frontiers in international strategy. *Journal of International Business Studies, 35*(3), 175–200.

Siggelkow, N. (2007). Persuasion with case studies. *Academy of Management Journal, 50*(1), 20–24.

Simsek, Z. (2009). Organizational ambidexterity: Towards a multilevel understanding. *Journal of Management Studies, 46*(4), 597–624.

Sirmon, D. G., Hitt, M. A., & Ireland, R. D. (2007). Managing firm resources in dynamic environments to create value: Looking inside the black box. *Academy of Management Review, 32*(1), 273–292.

Smith, W. K., & Tushman, M. L. (2005). Managing strategic contradictions: A top management model for managing innovation streams. *Organization Science, 16*(5), 522–536.

Tellis, G. J. (2006). Disruptive technology or visionary leadership? *Journal of Product Innovation Management, 23*, 34–38.

Times, T. E. (2010). We'll now produce what India wants: John Flannery, GE India. *The Economic Times*.

Tiwari, R., & Herstatt, C. (2012). Assessing India's lead market potential for cost-effective innovations. *Journal of Indian Business Research, 4*(2), 97–115.

Tripsas, M., & Gavetti, G. (2000). Capabilities, cognition, and inertia: Evidence from digital imaging. *Strategic Management Journal, 21*(10–11), 1147–1161.

Tushman, M. L., & Anderson, P. (1986). Technological discontinuities and organizational environments. *Administrative Science Quarterly, 31*(3), 439–465.

Tushman, M. L., & O'Reilly, C. A. (1996). Ambidextrous organizations. *California Management Review, 38*(4), 8–30.

Tushman, M., Smith, W. K., Wood, R. C., Westerman, G., & O'Reilly, C. (2010). Organizational designs and innovation streams. *Industrial and Corporate Change, 19*(5), 1331–1366.

Yin, R. K. (1994). *Case study research*. Thousand Oaks, CA: Sage.

Part III
Connecting Frugal Innovations with Analogies and Disruption

Developing Frugal Innovations with Inventive Analogies: Preliminary Evidence from Innovations in India

Rajnish Tiwari, Katharina Kalogerakis, and Cornelius Herstatt

1 Introduction

In the past few years we have seen the emergence of an innovation paradigm that, in a nutshell, emphasizes the need to develop "good enough" products with a strong focus on core functionalities and a radically reduced cost-structure. Such products are often known as "frugal innovations" and are predominantly, though not exclusively, found in the fast growing markets of emerging economies like India and China (Basu, Banerjee, & Sweeny, 2013; Bound & Thornton, 2012; Prahalad, 2012; Prahalad & Mashelkar, 2010; Tiwari & Herstatt, 2012b). Rapidly growing middle classes in largely unsaturated markets of emerging economies are turning these countries into "lead markets" for "low cost, high quality" products (Tiwari & Herstatt, 2014), which in the form of "reverse innovations" are increasingly reaching markets in the industrialized nations (Govindarajan & Trimble, 2012).

India has been at the forefront of such innovations (Tiwari, Fischer, & Kalogerakis, 2016; Tiwari & Herstatt, 2012a). A comparative study of frugal and standard (non-frugal) entry-level products in the Indian market across 13 different product categories by Rao (2013) revealed that frugal products reduced costs anywhere between 58 % and 97 %. Another study of the healthcare sector in India and the USA by Govindarajan and Ramamurti (2013) showed a cost-difference of over 80 % after incorporating the wage differentials. Such radical reduction in cost structure while maintaining the necessary quality standards raises the question: How are innovators of frugal products and services able to manage this seeming paradox?

A close scrutiny of several frugal products reveals that they tend to make use of inventive analogies by transferring solutions from one industry domain to the other

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or by transferring solutions from nature. For example, an Indian doctor successfully pioneered the use of "sterilized mosquito nets as a low-cost substitute for the expensive commercial meshes" for repairing hernias; this solution is "around 4000 times cheaper than imported mesh" and has proven its technological performance in a long-term study (Lacey, 2013). Another example is delivered by a low-cost artificial heart that is reportedly under clinical trial at Indian Institute of Technology (IIT) in Kharagpur. It uses an analogy from the multi-chamber, fault-resistant heart structure of cockroaches to develop robust and affordable solutions for as low as approx. $2000 (Economist, 2009b; Mukherjee Pandey, 2009).

These examples suggest that inventive analogies (Gick & Holyoak, 1980; Kalogerakis, Lüthje, & Herstatt, 2010) might constitute a promising approach for developing solutions that can ensure "affordable excellence" (Mashelkar, 2014). Nonetheless, neither the use of inventive analogies nor their impact on results in frugal innovation projects has been properly researched in the innovation management literature. According to Kalogerakis, Lüthje, and Herstatt (2010: 427): "The scarce literature on analogies in the context of new product ideation hardly addresses the possibility of using analogies to lower development costs or to cut development time."

This research gap is intriguing as it can, in turn, have some interesting implications for analogy research itself. So far, an efficiency effect of analogies was mostly attributed to within-industry analogies. However, some examples indicate that by using cross-industry analogies the cost-structure of products can be massively reduced. Apart from the use of mosquito net to repair hernia we can observe the transfer of the principles of mass production to heart surgeries that have reduced their costs to a fraction. Inspired by the success of no-frills business models such as Wal-Mart and Ryanair, "Narayana Hrudayalaya", an Indian hospital chain that conducts more than 11,000 heart surgeries a year has reduced operation costs to less than 1400€ per operation while complying with the highest industry standards (Bound & Thornton, 2012). The case of "Mitti Cool", a fridge made of clay and based on the principle of natural evaporation is another example of bionic analogies that can be used to develop frugal innovations. For further details, see chapter "Emerging Patterns of Grassroots Innovations: Results of a Conceptual Study Based on Selected Cases from India" of this contributed volume authored by Nair, Tiwari and Buse.

Therefore, this paper focuses on the process and the outcome of the application of inventive analogies in frugal innovation projects. Based on three explorative case studies from India, the process of using inventive analogies is analyzed in regard to a systematic approach and openness towards external solutions. Furthermore, the impact of different types of inventive analogies on the efficiency of the development process and development costs is investigated.

This paper is structured on the following lines: After a brief introduction, a theoretical fundament is laid, where the relevant concepts of frugal innovations and inventive analogies are introduced. This section also derives the research questions and presents a research model. The following section contains information on the research approach taken and introduces the objects of investigation. Thereafter, we

present our findings for the research questions and summarize the paper with some final conclusions.

2 Theory and Research Questions

2.1 Characteristics of Frugal Innovation

Frugal innovations are an emerging phenomenon, and scholarly research on their causes, effects and characteristics is still in a nascent stage. Not surprisingly, a host of terms has been employed by scholars to describe innovative products and services that seek to radically lower the costs and target price-sensitive customers (cf. Baker, Miner, & Eesley, 2003; Basu et al., 2013; Gupta, 2010; Prahalad, 2005; Radjou, Prabhu, & Ahuja, 2012; Tiwari & Herstatt, 2012b). For the purpose of this paper we use a definition proposed by Tiwari and Herstatt (2014: 30) that considers frugal innovations as:

> [...] new or significantly improved products (both goods and services), processes, or marketing and organizational methods that seek to minimize the use of material and financial resources in the complete value chain (development, manufacturing, distribution, consumption, and disposal) with the objective of significantly reducing the total cost of ownership and/or usage while fulfilling or even exceeding certain pre-defined criteria of acceptable quality standards.

Frugal innovations are characterized by an enhanced need to offer an attractive value proposition (cf. Rogers, 2003) to ensure diffusion. Firms offering frugal products and services are often competing not merely against a traditional rival but also against "non-consumption" since the potential customer might not be possessing means for buying the product or service on offer and/or (access to) the necessary infrastructure for using it. This value proposition may be achieved by the following (Tiwari & Herstatt, 2014):

- Reduced overall cost of ownership: It is not just the price point at the time of purchase, which is a crucial success factor for frugal innovations. Rather, it is the significantly reduced total cost of ownership that is achieved by the low costs of usage, maintenance and repair from acquisition till disposal. For example, in terms of the automobile industry it is not just the low price of a vehicle but also the high mileage and the low costs of repair that positively affect a purchasing decision in the price-sensitive segments of small cars.
- Robustness: Frugal innovations are often targeted at customers living in rural and semi-urban areas in developing economies. The products need to cope with various infrastructural shortcomings such as voltage fluctuation, abrupt power-cuts, dust, and extreme temperatures. Practices of planned obsolescence (Economist, 2009a; Slade, 2007) that seek to intentionally limit the life-span of a product without simultaneously reducing the associated costs for the customer are incompatible with frugal innovations.

- User friendliness: Many (potential) buyers of frugal products have no prior, first-hand experience of using similar products. Companies cannot presume a significant level of familiarity on the consumer side in dealing with their products. Frugal products therefore need to be easy-to-use and fault resistant.
- Economies of Scale: Finally, the need for significant cost reduction, and the thin profit margins almost necessarily associated with frugal products necessitate access to voluminous business to reduce unit costs of development and production.

2.2 *Characteristics of Inventive Analogies*

Innovations are, to a large extent, based on already existing knowledge. Even radical or breakthrough innovations often result out of new combinations of known technologies. This perspective on the development of innovations can be related to the view of Schumpeter (1934) who defined innovation as a process of newly combining available resources. Hence, one challenge in the process of innovation is the detection of new connections between knowledge from by then separate domains.

The transfer of knowledge from one context to another can be fostered by the use of inventive analogies. In the process of an inventive analogical transfer existing solution elements from a familiar conceptual domain (the base) are used to solve a given problem or engineering challenge at hand (the target). This kind of analogical transfer leads to innovation, if disparate pieces of knowledge are combined in a novel way (Gick & Holyoak, 1980; Holyoak, 2005; Ward, 1998).

Inventive analogies can be categorized depending on the conceptual distance between the source and target domain of the analogy. A general and widespread distinction is made between near analogies and far analogies (Gick & Holyoak, 1980; Keane, 1987; Vosniadou, 1989; Ward, 1998). Generally, near analogies only lead to rather incremental innovations, whereas far analogies have the potential to initiate radical and breakthrough innovations (Dahl & Moreau, 2002; Perkins, 1997).

In their empirical study, Kalogerakis et al. (2010) specified the rather vague classification of near and far analogies. They distinguish between analogies within one product category, analogies between different product categories and analogies stemming from a non-product domain. A product category is defined as all products that belong to the same use context, for example sports equipment, medical equipment or furniture (Kalogerakis et al., 2010). An approach to measure the conceptual distance between different industries based on the NACE industry-classification did not lead to convincing results (Enkel & Gassmann, 2010). Overall, a further significant refinement of analogy-distance in the context of new product development is still missing. Based on current research in this context, a distinction between (1) near analogies as analogies of the same broad product category or industry, (2) far analogies as analogies across broad product categories

or industries and (3) far analogies as bionic analogies seems reasonable (Bonnardel & Marmèche, 2004; Dahl & Moreau, 2002; Herstatt & Kalogerakis, 2005; Kalogerakis et al., 2010).

In some professional domains the use of inventive analogies is a widespread practice. Empirical studies show that industrial design and engineering consultancies often use analogies in the process of product development. Especially, if they have clients from diverse domains, they are in a privileged position to transfer knowledge between industries based on analogies (Hargadon, 2002; Kalogerakis et al., 2010; Lüthje, Kalogerakis, & Schulthess, 2010). From this context it is known, that the inspiration to discover a useful analogy, often stems from knowledge that is already available within the company. The use of local knowledge is for companies that possess knowledge in many diverse domains an efficient way to develop new solutions (Kalogerakis et al., 2010).

However, other people that are not used to solve creative problems from different domains usually have more trouble identifying relevant far inventive analogies. Especially the detection of far analogies based on structural similarities is more difficult if these cannot rest upon own experiences (Blanchette & Dunbar, 2000). Furthermore, functional fixedness can hinder the search for analogies. This psychological phenomenon was first described by Duncker (1945). Functional fixedness occurs if knowledge about the regular use context of a product or technology inhibits the developer to find other applications of the product or technology. Derived from this phenomenon, another problem arises: Engineers who have a profound knowledge in only one single domain experience difficulties to see the usefulness of solutions from other domains for their specific problems. Therefore, a systematic approach expanding the search space to external knowledge often is an inevitable course of action to succeed in detecting far inventive analogies.

2.3 Research Questions

Frugal innovations are characterized by a massive cost reduction of a product—not only concerning costs of acquisition, but also costs of usage, maintenance and disposal. Therefore, the concept of "total costs of ownership" (TCO) receives a critical importance for frugal innovations. Simultaneously, frugal innovations need to fulfil certain standards of robustness, user friendliness and quality. In order to reach these aims, more often than not, radically new solutions are required. However, financial resources for development and manufacturing are strictly limited. As shown in the preceding sections of this paper, inventive analogies seem to help in reaching these conflicting goals.

First, the question arises if premises of using inventive analogies in frugal innovation projects differ from its application in normal innovation projects. So far, the process of finding relevant inventive analogies in frugal innovation projects is still unclear. Industrial engineering and management consultants working for

clients from diverse industries frequently apply inventive analogies based on knowledge already available with them (Hargadon, 2002; Hargadon & Sutton, 1997; Kalogerakis et al., 2010). A systematic search for unknown sources of analogies outside the own knowledge base is not reported. Results from other empirical studies suggest that generally only few companies apply systematic search and idea generation methods in the front end of innovation (Barczak, Griffin, & Kahn, 2009). Application of creativity methods is mostly limited to simple ad-hoc brainstorming sessions. Due to the special requirements of frugal innovations, it can be expected that frugal innovation development teams are more open to external knowledge and realise the need of systematic search processes compared to "normal" innovation projects. This leads to the first two research questions:

- Q1a: Are systematic methods applied in frugal innovation projects to find inventive analogies?
- Q1b: Are developers of frugal innovations more open to external solutions from other domains?

Second, the benefit of different kinds of inventive analogies in frugal innovation projects needs further investigation. Research in inventive analogies suggests that within-industry analogies, cross-industry analogies and bionic analogies have differing effects on the newness of results and the efficiency of the development process. Whereas many researchers analyzed creativity effects of inventive analogies (Chan et al., 2011; Dahl & Moreau, 2002; Kalogerakis et al., 2010; Ward, 1998), evidence about efficiency effects is still sparse. However, Majchrzak, Cooper, and Neece (2004) show how organizational pressure concerning very restricted development time and cost inspired NASA researchers to use inventive analogies. Only by looking for reusable technological solutions from other domains, they could reach their development goals. Similarly, industrial designers and engineers reported in a study from Kalogerakis et al. (2010) that only by using inventive analogies, many of their development projects could be accomplished within the limited time and financial resources given by their clients. This leads us to two additional research questions

- Q2a: Are inventive analogies used in frugal innovation projects to increase process efficiency?
- Q2b: Are inventive analogies used in frugal innovation projects to decrease development costs?

A corresponding research model is given in Fig. 1. It shows how process factors might have an effect on the use of different kinds of inventive analogies. The application of inventive analogies in turn is supposed to lead to efficiency effects: increased process efficiency and decreased development time. Finally, a positive impact on the aspirated goals of frugal innovation projects is expected.

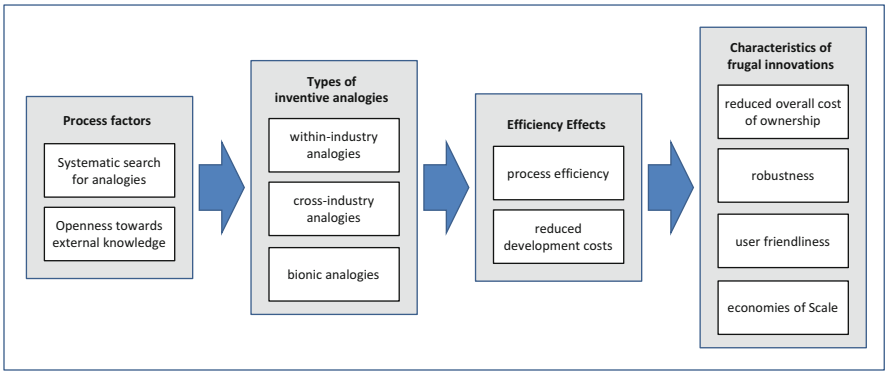

Fig. 1 Proposed research model connecting inventive analogies with frugal innovations

3 Research Approach

3.1 Methodology

This paper is based on three case studies of successful frugal innovations from India, which has been identified as a lead market for frugal products and services (Tiwari & Herstatt, 2014). The case study method has been selected since the phenomenon under question is still at a nascent stage and the study has an explorative character (Eisenhardt, 1989; Greenstein & Polsby, 1975). Furthermore, the study intends to not only concentrate on the "what" aspects of the phenomenon but also, and especially so, it seeks to generate preliminary insights on the "how" and "why" aspects of the usage of inventive analogies in the product development process of frugal innovations (cf. Yin, 2003). The study is based on an extensive literature review of published information in scholarly journals, company publications and news media. The cases have been identified based on the authors' preceding studies of frugal innovations that have included interviews with concerned officials at the respective firms (see e.g. Ramdorai & Herstatt, 2013; Tiwari & Herstatt, 2012b, 2014). The key selection criterion was the potential to generate preliminary insights and the availability of information.

3.2 Objects of Investigation

- Tata Ace: The "Tata Ace" is a small commercial vehicle (SCV) from the stable of India's Tata Motors Limited (TML). It was first launched in 2005 and has a payload capacity of 0.75 tons. TML conceptualized the Ace as a competitor to the 3-wheeled commercial vehicles and went on to create a new product category of SCVs that was not existent in India's automobile market till then. The development budget of the Ace was fixed at a maximum of INR 2.2 billion

(approx. $49 million in then exchange rates), which was less than one-tenth of what MNCs then typically spent on a similar project (Palepu & Srinivasan, 2008). The Ace was targeted at price-sensitive buyers, costing INR 225,000 (about $4000 in then exchange rates), which was at least 50 % less than any other 4-wheeled commercial vehicle in India (Freiberg, Freiberg, & Dunston, 2011; Palepu & Srinivasan, 2008). The Ace fulfils the requirements of a frugal product and was conceived as a "cheap, nasty and rugged vehicle for India" (Palepu & Srinivasan, 2008), with low-cost and low-maintenance features that can ideally be used on India's narrow and crowded roads within towns, as well as for long highway journeys (Khanna & Palepu, 2010; Singh & Chaudhuri, 2009).

- Tata Nano: The "Tata Nano" is one of the best known (radical) frugal innovations from the product portfolio of TML and has been promoted in the press as "the cheapest car of the world" (Schuster & Holtbrügge, 2011). It was launched for a price of INR 100,000 (approx. $2200 in then exchange rates) in March 2009 (Palepu, Anand, & Tahilyani, 2011). The driving force behind the development of the Nano was the vision of Ratan Tata, then Head of the Tata Group, to provide a safe and affordable medium of transport to millions of Indian (lower) middle class families that often use a 2-wheeler for transporting a family of 4–5 members including children. An affordable car should provide better comfort and increase traveling safety while providing protection against natural elements such as rains or extreme weather conditions (Tiwari & Herstatt, 2012b). The Nano was a unique project as the maximum retail price of the end product was already fixed by the highest level of management at INR 100,000 which was less than 50 % of a standard entry-level product thereby forcing the developers to employ target costing in the development process. Despite its development in a strongly resource-constrained atmosphere the Nano fulfils all prescribed safety norms in India and was developed in an "open innovation" project that included several global automotive suppliers (Chacko, Noronha, & Agrawal, 2010).
- GE's MAC 400: The "MAC 400" is an electrocardiogram device (ECG) from the product portfolio of US-based multinational General Electric (GE). This ECG was developed at GE's Jack F. Welch Technology Centre in Bangalore in India (Govindarajan & Trimble, 2012; Ramdorai & Herstatt, 2013). The MAC 400 enables radical cost reduction for its users: Whereas a standard ECG device costs $15,000 and more, the MAC 400 was launched in India's domestic market for about one-tenth of that price (Jana, 2009). Furthermore, it is a robust device that is equipped with ultra-portability (Ramdorai & Herstatt, 2013): It weighs only 1.3 kg and can run on battery (GE Healthcare, 2010). The reduced need for electricity makes it suitable for usage in rural and semi-urban areas with poor infrastructure. In 2009 a next generation version the "MACi" was introduced in the Indian market that reduced the price once more substantially to $535 (Ramdorai & Herstatt, 2013). Another variant the "MAC 800" which is endowed with more features is sold in western countries such as Germany and the USA and is reportedly used for doctors on ambulant emergency duty (Govindarajan & Trimble, 2012).

4 Findings

4.1 Systematic Search for Analogies

The case studies provide ground for assumption that development teams of frugal innovation projects apply systematic methods to find inventive analogies. In all cases a deliberate attempt to actively seek and employ inventive analogies could be observed. This was mostly motivated by the restrictive development budgets and the resultant pressure to achieve process efficiency and reduce development costs. The management expected from its product developers a substantial reduction in cost/price of the products targeted at price-sensitive customers. Development budgets were as low as one-tenth of comparable projects in the developed world.

While developing the Tata Ace, TML's management intentionally created strong resource constraints to induce the developers into searching for existing solutions and technologies that could meet the set performance criteria and reduce the development costs. A similar approach can also be observed in the development of the Tata Nano. In the words of Chacko et al. (2010: 124):

> Much of the creativity that characterized the Nano project involved taking existing, patented components and technologies and rejigging them to the small car's advantage.

Another example of systematic use of inventive analogies is provided by TML's search for inspirations in the Tata Nano project:

> He [Ratan Tata] was also keen that the group explores every avenue in the development process, even the most unconventional, suggesting, for instance, that they look at furniture catalogues before deciding how the car's seating could be styled and positioned. The message was unambiguous: break out of the mold. (Chacko et al., 2010: 16)

Ratan Tata, whose vision behind the Nano drove the entire project, wished to create a car around a scooter and motivated his team to explicitly seek insights from the 2-wheeler segment (Chacko et al., 2010). At GE, too, product developers searched extensively for existing, proven technologies both within and outside the firm to reach strong cost reduction requirements set by the management for the MAC 400:

> [Davy] Hwang and [Oswin] Varghese [project leaders] also kept costs low by studying other products. From the team responsible for GE's portable ultrasound machine, they learned about a low-cost source for [a] technology which can cut plastic mold prototypes far earlier in the process than usual. That let them get feedback from doctors before changes got costly. (McGregor & Kripalani, 2008)

These examples confirm that (successful) innovators seem to apply systematic methods in frugal innovation projects to find inventive analogies.

4.2 Openness of the Development Process

In all the analyzed cases product developers displayed a remarkable openness for external solutions, both from outside the boundaries of their own firms as well as from other domains. One example is provided by the Tata Nano project where this openness for external knowledge was not just passively present, but was actively fostered and is well documented:

> [Sam] Johnny's immediate task was to scout for information on engines and transmission systems. The internet was an important source for data and he frequently found himself spending his after-office hours in cyber cafes. Johnny and his colleagues—there were some 10 people in the small-car team then—looked at small cars and small engines from around the world, with new and old technology, proprietary and those for sale. Calls were made and contact established with engine vendors in, among other places Australia, Italy and the United States. (Chacko et al., 2010: 18 f.)

The Warwick Manufacturing Group of the School of Engineering at Britain's University of Warwick was involved in the development of the Nano. Seven suppliers of construction material including GE, DuPont and Reliance, made several experiments on behalf of and together with TML to test various materials and their possible use in automobiles. GE even stationed three engineers at TML for the duration of 6 months to carry out various experiments at TML. The Nano team considered even solutions from 2- and 3-wheeler industries that would make the final product look totally different from a conventional car.

> Although Ratan Tata had already described the Nano to the press as something that would look like a real car, [. . .] No idea was off the table. All ideas were considered worthy of discussion. (Freiberg et al., 2011: 48)

Also at GE, this practice was followed; even though taking recourse to external knowledge meant nothing less than breaking a taboo since the company had till then pursued a strong in-house policy (Govindarajan & Trimble, 2012). Within the GE concern too, concerted and proactive efforts were made to benefit from existing technologies in different business divisions of the company (Immelt, Govindarajan, & Trimble, 2009). This indicates an important role of cross-divisional innovations within big corporate houses (Grote, Herstatt, & Gemünden, 2012).

These examples confirm the proposition that developers of frugal innovations appear to be open to external solutions from other domains.

4.3 Effects of Inventive Analogies on Process Efficiency

The case studies demonstrate that the use of inventive analogies helped increase process efficiency. While developing the Ace, TML intentionally and proactively created synergies to its small passenger car the Indica. For example, the Indica's engine was enhanced and upgraded for use in the Ace. Additionally, the Ace was designed in a way that about 40 % of its components are shared with other TML

models (Palepu & Srinivasan, 2008). This sharing led on the one hand to significant synergies in procurement and maintenance. On the other hand, TML could utilize existing production processes and facilities for the new platform. Buoyed by the success of the Ace, TML decided to exploit analogies even further by transferring the Ace platform from commercial goods sector to commercial passenger vehicles. Two years after launching Ace, in 2007 TML introduced the "Tata Magic", a minivan for transporting 7–8 passengers in rural areas where narrow roads restrict movement of passenger buses (TML, 2013b). In the meantime an even smaller variant the "Tata Iris" has been launched to commercially carry 4–5 passengers (TML, 2013a).

In case of the Nano, too, many ideas were generated and implemented by using within-industry analogies that led to faster development and reportedly even enabled better performance:

> Tata Motors engineers say the car's body is stronger than that of a conventional car due to it being a combination of monocoque and the space frame that motor cycles employ. (Chacko et al., 2010: 126)

Even component suppliers of the Nano are reported to have used such (within-industry) analogies. For example, German component supplier Bosch reportedly adapted a motorcycle starter to supply for the Nano and helped remove several ounces of weight from the generator (Sehgal, Dehoff, & Panneer, 2010) while reducing development costs and time.

The use of analogies to increase process efficiency is, however, not limited to within-industry analogies alone. In case of GE's MAC 400 we can also observe the use of cross-industry analogies to increase similar results. Developers at GE took recourse to analogies from other industries like telecommunication and transport while developing the MAC 400. They searched and identified relevant knowledge from non-related fields. For example, they integrated in the MAC 400 compatibility to commercial available mobile phone batteries. It helped not only to reduce the costs of development for GE but also costs of usage for the user; besides ensuring portability of the equipment. Similarly, the MAC 400 was equipped with a printer that is typically used in India to sell tickets in buses in local public transport or in cinema halls. This mass-product with proven utility and robust features (dust & temperature tolerance) could enhance these attributes of the MAC 400 as well (Govindarajan & Trimble, 2012; McGregor & Kripalani, 2008; Ramdorai & Herstatt, 2013).

The examples above confirm that the use of inventive analogies can increase process efficiency, e.g. reducing development time, in frugal innovation projects.

4.4 Effects of Inventive Analogies on Development Costs

In all the products examined in this study the usage of analogies led to a significant reduction in the costs of development. Use of cross-industry analogies enabled

GE's developers to reduce costs by 90 % while allowing new features like portability. Similarly, the development of the Tata Ace would not have been possible for one-tenth of costs in comparable projects without taking recourse to the various within-industry analogies described in Sect. 4.3.

This can be demonstrated using the case of the Nano as one detailed example. The development team of the Tata Nano extensively explored possible use of analogies from TML's own commercial vehicles division as well as from the 2-wheeler and 3-wheeler industries to reduce the Nano's costs (Chacko et al., 2010; Freiberg et al., 2011). In words of Freiberg et al. (2011: 48), it was "the cost imperative [that] drove the design team to keep looking for solutions coming out of the world of scooters".

From the very beginning options were explored to use engineering plastics and other new materials from the chemical industry instead of steel (Freiberg et al., 2011) to reduce development and manufacturing costs. According to Chacko et al. (2010: 6):

> There was a host of ideas flying about, [...] among them a car created by engineering plastics and new materials, the use of aerospace adhesives instead of welding, and making one part perform multiple functions.

Various external partners from several industries brought in their know-how in the development of the Tata Nano. Especially some chemical firms worked very closely with TML to enable fundamentally new solutions. The examples above endorse the proposition that frugal innovators employ inventive analogies to reduce development costs.

5 Conclusion

Successful frugal innovations usually can be characterized as breakthrough innovations. Traditional approaches of product development for emerging economies have built upon stripping down of features or replacing high quality material with cheaper substitutes. These practices are generally insufficient to reach radically reduced cost structures while at the same time ensuring robustness, user friendliness and a good-enough quality.

The results of this study show that development teams are willing to follow untrodden paths in order to create successful frugal products targeted at highly price-sensitive customers. Strict target costing objectives in conjunction with inspirations derived from conceptual solutions and/or proven technologies from other industry domains can enable frugal innovators to achieve the conflicting development goals of "affordable excellence". Hence, inventive analogies seem to be essentially important in the development process of frugal products.

The cases analyzed in this study deliver some valuable insights for intentional and systematic use of inventive analogies in frugal innovation projects. The research model and the interdependences presented in Fig. 1 seem to have been

confirmed by our case studies. Altogether three propositions for product development in emerging economies can be derived:

- Actively and systematically searching for inventive analogies in other industry domains is an essential step to the successful development of frugal innovations.
- The openness of the management as well as of the development team towards external solutions from other domains is a necessary premise to find and apply inventive analogies for frugal products.
- Inventive analogies, especially cross-industry analogies but also within-industry analogies, can substantially reduce development costs and time.

Generally speaking, it seems recommendable that firms aspiring to serve unsaturated, price-sensitive markets of emerging economies should make systematic use of inventive analogies for developing products that have a better fit to market demand. These products would be characterized not only by their affordability but also by a high value proposition enabled by radically new innovations. For analogy research, too, there seems to be a potentially significant insight from the frugal context: The willingness of product developers to systematically search and effectively utilize external solutions, especially from non-related industry domains, appears to correlate with the level of resource constraints. Moreover, the use of inventive analogies does not have to be restricted to the ideation phase. The cases analyzed here provide preliminary evidence that the use of analogies can extend to product development and market introduction phases.

Finally, it may be noted that the results of this study are based upon three case studies of successful frugal products from India. Therefore, the findings are based upon qualitative analyses from a rather small sample and still need to be verified in different contexts. Further research should explore the phenomenon of inventive analogies in a greater variety of frugal development cases. Additionally, it would be interesting to deepen insights of the process of analogy-usage by conducting specific interviews with involved engineers.

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References

Baker, T., Miner, A. S., & Eesley, D. T. (2003). Improvising firms: Bricolage, retrospective interpretation and improvisational competencies in the founding process. *Research Policy, 32*, 255–276.

Barczak, G., Griffin, A., & Kahn, K. B. (2009). Trends and drivers of success in NPD practices: Results of the 2003 PDMA best practices study. *Journal of Product Innovation Management, 26*, 3–23.

Basu, R. R., Banerjee, P. M., & Sweeny, E. G. (2013). Frugal innovation: Core competencies to address global sustainability. *Journal of Management for Global Sustainability, 2*, 63–82.
Blanchette, I., & Dunbar, K. (2000). How analogies are generated: The roles of structural and superficial similarity. *Memory and Cognition, 28*(1), 108–124.
Bonnardel, N., & Marmèche, E. (2004). Evocation processes by novice and expert designers: Towards stimulating analogical thinking. *Creativity and Innovation Management, 13*(3), 176–186.
Bound, K., & Thornton, I. (2012). *Our frugal future: Lessons from India's innovation system*. London: NESTA.
Chacko, P., Noronha, C., & Agrawal, S. (2010). *Small wonder: The making of the nano*. Chennai: Westland Ltd.
Chan, J., Fu, K., Schunn, C., Cagan, J., Wood, K., & Kotovsky, K. (2011). On the benefits and pitfalls of analogies for innovative design: Ideation performance based on analogical distance, commonness, and modality of examples. *Journal of Mechanical Design, 133*(8), 81004–81005.
Dahl, D. W., & Moreau, P. (2002). The influence and value of analogical thinking during new product ideation. *Journal of Marketing Research, 34*(1), 47–60.
Duncker, K. (1945). On problem solving. *Psychological Monographs, 58*(Whole No. 270).
Economist. (2009a). *Idea: Planned obsolescence*. Retrieved October 17, 2013, from http://www.economist.com/node/13354332
Economist. (2009b, June 4): Monitor: On the pulse. *The Economist*, London.
Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of Management Review, 14*(4), 532–550.
Enkel, E., & Gassmann, O. (2010). Creative imitation: Exploring the case of cross-industry innovation. *R & D Management, 40*(3), 256–271.
Freiberg, K., Freiberg, J., & Dunston, D. (2011). *Nanovation: How a little car can teach the world to think big and act bold*. Nashville, TN: Thomas Nelson.
GE Healthcare. (2010). *MAC 400 resting ECG analysis system*. Retrieved October 12, 2013, from http://healthymagination.me/en/about/gehealthtech.php?id=85&cat_id=7
Gick, M. L., & Holyoak, K. J. (1980). Analogical problem solving. *Cognitive Psychology, 12*(3), 306–355.
Govindarajan, V., & Ramamurti, R. (2013). Delivering world class healthcare, affordably: Innovative hospitals in India are pointing the way. *Harvard Business Review, 91*(11), 1–7.
Govindarajan, V., & Trimble, C. (2012). *Reverse innovation: Create far from home, win everywhere*. Boston: Harvard Business Review Press.
Greenstein, F. I., & Polsby, N. W. (Eds.). (1975). *Strategies of inquiry* (Handbook of political science). London: Addison-Wesley.
Grote, M., Herstatt, C., & Gemünden, H. G. (2012). Cross-divisional innovation in the large cooperation: Thoughts and evidence on its value and the role of the early stages of innovation. *Creativity and Innovation Management, 21*(4), 361–374.
Gupta, A. K. (2010). Grassroot green innovations for inclusive, sustainable development. In A. López-Carlos (Ed.), *The innovation for development report 2009–2010: Strengthening innovation for the prosperity of nations* (pp. 137–146). Hampshire: Palgrave Macmillan.
Hargadon, A. (2002). Brokering knowledge: Linking learning and innovation. *Research in Organizational Behaviour, 24*, 41–85.
Hargadon, A., & Sutton, R. I. (1997). Technology brokering and innovation in a product development firm. *Administrative Science Quarterly, 42*(4), 716–749.
Herstatt, C., & Kalogerakis, K. (2005). How to use analogies for breakthrough innovations. *International Journal of Innovation and Technology Management, 2*(3), 331–347.
Holyoak, K. J. (2005). Analogy. In K. J. Holyoak & R. G. Morrison (Eds.), *The Cambridge handbook of thinking and reasoning* (pp. 117–142). Cambridge: Cambridge University Press.
Immelt, J. R., Govindarajan, V., & Trimble, C. (2009). How GE is disrupting itself. *Harvard Business Review, 87*(10), 56–65.

Jana, R. (2009, March 31). P&G's trickle-up success: Sweet as honey (Slide show: Trickle-Up Innovation – GE Healthcare MAC 400). *Business Week*. Retrieved October 12, 2013, from http://images.businessweek.com/ss/09/04/0401_pg_trickleup/5.htm

Kalogerakis, K., Lüthje, C., & Herstatt, C. (2010). Developing innovations based on analogies: Experience from design and engineering consultants. *Journal of Product Innovation Management, 27*(3), 418–436.

Keane, M. T. (1987). On retrieving analogues when solving problems. *Quarterly Journal of Experimental Psychology, 39A*, 29–41.

Khanna, T., & Palepu, K. G. (2010). *Winning in emerging markets: A road map for strategy and execution*. Boston: Harvard Business Press Books.

Lacey, A. (2013, September 13). *A novel use for mosquito nets*. Retrieved April 14, 2013, from http://www.bbc.com/news/health-23944195

Lüthje, C., Kalogerakis, K., & Schulthess, M. (2010). *Knowledge and inventive analogies: An empirical investigation of industrial designers*. EURAM 2010, Rom.

Majchrzak, A., Cooper, L. P., & Neece, O. E. (2004). Knowledge reuse for innovation. *Management Science, 50*(2), 174–188.

Mashelkar, R. A. (2014, March 20). *Accelerated inclusive growth through inclusive innovation*. Retrieved April 14, 2013, from http://www.oecd.org/sti/inno/Session_3_Mashelkar_Keynote.pdf

McGregor, J., & Kripalani, M. (2008, April 16). *GE: Reinventing tech for the emerging world*. Retrieved October 12, 2013, from http://www.businessweek.com/stories/2008-04-16/ge-reinventing-tech-for-the-emerging-world

Mukherjee Pandey, J. (2009, March 19). An artificial heart for Rs 1 lakh, courtesy IIT-Kgp. *The Times of India*. Retrieved October 20, 2013, from http://articles.timesofindia.indiatimes.com/2009-03-19/india/28012456_1_total-artificial-heart-human-trials-heart-muscles

Palepu, K. G., Anand, B., & Tahilyani, R. (2011). *Tata Nano – The people's car, Case 9-710-420*. Boston: Harvard Business School.

Palepu, K. G., & Srinivasan, V. (2008). *Tata Motors: The Tata Ace, Case 9-108-011*. Boston: Harvard Business School.

Perkins, D. N. (1997). Creativity's camel: The role of analogy in invention. In T. Ward, S. Smith, & J. Vaid (Eds.), *Creative thought* (pp. 523–538). Washington, DC: American Psychological Association.

Prahalad, C. K. (2005). *The fortune at the bottom of the pyramid: Eradicating poverty through profits*. Upper Saddle River, NJ: Wharton School Publishing.

Prahalad, C. K. (2012). Bottom of the pyramid as a source of breakthrough innovations. *Journal of Product Innovation Management, 29*(1), 6–12.

Prahalad, C. K., & Mashelkar, R. A. (2010). Innovation's holy grail. *Harvard Business Review, 88*(7/8), 132–141.

Radjou, N., Prabhu, J., & Ahuja, S. (2012). *Jugaad innovation: Think frugal, be flexible, generate breakthrough growth*. San Francisco: Jossey-Bass.

Ramdorai, A., & Herstatt, C. (2013). *Lessons from low-cost healthcare innovations for the Base-of the Pyramid markets: How incumbents can systematically create disruptive innovations*. Working Paper No. 74. Institute for Technology and Innovation Management, Hamburg University of Technology, Hamburg.

Rao, B. C. (2013). How disruptive is frugal? *Technology in Society, 35*(1), 65–73.

Rogers, E. M. (2003). *Diffusion of innovations*. New York: Free Press.

Schumpeter, J. A. (1934). *The theory of economic development*. New Brunswick, NJ: Transaction Publishers.

Schuster, T., & Holtbrügge, D. (2011). Tata Nano: The car for the bottom-of-the-pyramid. In J. Zentes, B. Swoboda, & D. Morschnett (Eds.), *Fallstudien zum Internationalen Management: Grundlagen – Praxiserfahrungen – Perspektiven* (pp. 83–102). Wiesbaden: Gabler.

Sehgal, V., Dehoff, K., & Panneer, G. (2010). The importance of frugal engineering. *Strategy + Business, Summer*(59), 1–5.

Singh, S. K., & Chaudhuri, A. (2009). The reality of India: Folding constraints into business strategy. *Journal of Business Strategy, 30*(4), 5–16.

Slade, G. (2007). *Made to break: Technology and obsolescence in America*. Cambridge, MA: Harvard University Press.

Tiwari, R., Fischer, L., & Kalogerakis, K. (2016). *Frugal innovation in scholarly and social discourse: An assessment of trends and potential societal implications*. Joint working paper of Fraunhofer MOEZ Leipzig and Hamburg University of Technology in the BMBF-ITA project, Leipzig/Hamburg.

Tiwari, R., & Herstatt, C. (2012a). Assessing India's lead market potential for cost-effective innovations. *Journal of Indian Business Research, 4*(2), 97–115.

Tiwari, R., & Herstatt, C. (2012b). Frugal innovation: A global networks' perspective. *Die Unternehmung, 66*(3), 245–274.

Tiwari, R., & Herstatt, C. (2014). *Aiming big with small cars: Emergence of a lead market in India*. Heidelberg: Springer.

TML. (2013a). *Tata Magic Iris: About us*. Retrieved October 12, 2013, from http://www.magiciris.tatamotors.com/iris/about-us.aspx

TML. (2013b). *Tata Magic: About us*. Retrieved October 12, 2013, from http://www.magiciris.tatamotors.com/magic/about-us.aspx

Vosniadou, S. (1989). Analogical reasoning as a mechanism in knowledge acquisition: A developmental perspective. In S. Vosniadou & A. Ortony (Eds.), *Similarity and analogical reasoning* (pp. 413–437). Cambridge: Cambridge University Press.

Ward, T. B. (1998). Analogical distance and purpose in creative thought: Mental leaps versus mental hops. In K. Holyoak, D. Genter, & B. Kokinov (Eds.), *Advances in analogy research* (pp. 221–230). Sofia: New Bulgarian University Press.

Yin, R. K. (2003). *Case study research: Design and methods*. Thousand Oaks, CA: SAGE.

Made in India for the World: An Empirical Investigation into Novelty and Nature of Innovations

Daniel Tobias Hagenau and Rajnish Tiwari

1 Introduction

For several years, there has been an increasing technology- and market-driven shift of innovation activities from established, developed markets towards emerging economies such as India (Gerybadze & Merk, 2014; Herstatt, Tiwari, Buse, & Ernst, 2008; Kumar & Puranam, 2012; UNCTAD, 2005). Many large western companies establish R&D facilities in developing countries, realizing how quickly local educational standards are catching up to western structures and how quickly local markets grow at all levels of the economic pyramid. Nearly 70 % of researching Fortune 500 companies conduct at least part of their R&D in India (Herstatt et al., 2008). With well above two million graduates a year, India and China are creating an impressive resource pool for further R&D investments (Knowledge@Wharton, 2005). At the same time, local markets are growing rapidly and multinationals begin to understand the potential of as yet untapped segments. C.K. Prahalad estimated the combined purchasing power at the "Bottom of the Pyramid"[1] to be roughly US$3 trillion p.a. (Prahalad & Hart, 2002). Countries like India also have a large and growing middle class (Ablett et al., 2007).

In this context, a special interest has arisen in innovations that not only thrive under the still restricted resource pools in developing markets but make special use

[1]Part of the population with less than US$1500 p.a. at purchasing power parity at their disposal; roughly four billion people worldwide (Prahalad & Hart, 2002).

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of their 'frugality'. Concepts like "Gandhian", "Reverse" or "Frugal" Innovation are used to describe products and services specifically tailored to the needs of developing countries such as India or China and their large rural population (Immelt, Govindarajan, & Trimble, 2009; Prahalad & Mashelkar, 2010; Sehgal, Dehoff, & Panneer, 2010). C.K. Prahalad describes in his 2010 article 'Innovation's Holy Grail' how "affordability and sustainability replace abundance and premium pricing as drivers for Innovation" in developing countries (Prahalad & Mashelkar, 2010). Due to limited infrastructure, financial resources and education, the distribution, (interface-)design and cost-structure are of higher importance than in developed countries (Wooldridge, 2010). Instead of simply cutting costs and offering technologically outdated products from western markets at lower prices, true innovation in terms of technology and process are necessary in order to satisfy the demands of developing markets (Tiwari & Herstatt, 2012b). Stripping products of non-essential features and applying sophisticated technologies in order to reduce costs and adopt products to local environments makes the difference between failure and success of such innovations (Immelt et al., 2009; Nakata, 2012; Sehgal et al., 2010). As a result, innovations developed under the severe constraints described above can result in out-of-the-box solutions that might not have been possible in more developed environments (Gibbert, Hoegl, & Välikangas, 2007). Because of these special properties, some studies find promising potential in frugal innovations as lower-price alternatives for established markets (Tiwari & Herstatt, 2012b) as well as the seeds for disruptive innovation (Hart & Christensen, 2002), which may prove to the origin of industry-changing innovations (Christensen & Raynor, 2003).

While numerous case studies exist on frugal innovations in varying industries and their transfer potential (e.g. Immelt et al., 2009; Tiwari & Herstatt, 2012a, 2012b; Wooldridge, 2010) there exists to the authors' knowledge little quantitative research on such innovations, their potential and their corporate and social context. Such research may help in better understanding the factors involved in successful frugal innovation and deliver an empirical basis to the alleged promise emerging nations are showing in this area.

This study aims at providing an initial quantitative evaluation of innovations being developed for an emerging market (India), by both local and foreign innovators. In order to do so, a database of 178 innovations has been created from online news-reports that were published between January 1st 2010 and December 31st 2011. The initial focus is put on three distinct areas, necessary to derive further additions to the data sample and meaningful research questions building upon this study and its database. They are:

1. What industry and company structures are the primary sources of innovation within an emerging market such as India?
2. Who (in terms of company origin) is the primary driver of innovation and where (in terms of R&D location) are innovations being developed?
3. What types of innovations arise from an emerging market such as India?

The paper is structured on the following lines: In order to consistently classify the recorded innovations, Sect. 2 of this study develops an innovation typology based on existing literature on the subject. Section 3 then introduces the data sample and remaining criteria used for analysis and conducts the actual data evaluation. Section 4 concludes the paper with a discussion of the results, practical implications and avenues for future research.

2 Innovation Typology

In order to derive meaningful consequences from raw-data on individual innovations, these have to be categorized into consistently applicable sub-groups. The settings and chosen sources of this study require classification criteria that (a) enable the uniform, consistent categorization of large data samples with limited access to background information and (b) relate to the success of the innovation and the circumstances of its development (cf. Christensen & Raynor, 2003: 73). As Garcia and Calantone (2001) show, a variety of classification themes (typologies) of innovations are being used in current research applying similar terminologies (such as 'radical' or 'breakthrough' innovation) but differing definitions and classification criteria making an intuitive understanding and comparison difficult. In order to design the classification used for this study and future studies building upon its database as transparent and comparable as possible, the following sections draw upon the work of Garcia and Calantone (2001) as well as other widely accepted publications on innovation typology, such as the Oslo Manual, in creating a transferrable innovation typology in accordance with the classification criteria.

2.1 Defining Innovation

One of the first comprehensive definitions of innovation has been created by Joseph A. Schumpeter in 1934, highlighting many of the aspects that are still considered to be the basis of modern understanding of innovations; among them the introduction of a new good or its quality, production method, new market, source of supply, or industrial organization (Schumpeter, 1934). In more recent times, strongly referencing Schumpeter and his seminal work, one of the most widely accepted definitions of the term innovation has been grafted by the Organization of Economic Co-operation and Development's (OECD) and Eurostat known as the "Olso Manual" (OECD & Eurostat, 2005) for collecting and interpreting innovation data:

> An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations.

Due to its wide acceptance and application as well as its extensive documentation, this definition will be assumed and used throughout this study.

To be highlighted in this context is the aspect of the implementation, a mere concept or idea as such is not yet considered to be an innovation. Within this study only such cases are considered for the data sample that fulfill this basic definition of innovation.

2.2 Types of Innovations

The Oslo Manual identifies four distinct types of innovations (OECD & Eurostat, 2005). They are:

1. **Product Innovations:** involve significant changes in the capabilities of goods or services or the creation of completely new goods or services.
2. **Process Innovations:** represent significant changes in production and delivery methods.
3. **Organizational Innovations:** refer to the implementation of new organisational methods. These can be changes in business practices, in workplace organisation or in the firm's external relations.
4. **Marketing Innovations:** involve the implementation of new marketing methods. These can include changes in product design and packaging, in product promotion and placement, and in methods for pricing goods and services.

When implementing this framework it is important to notice that the four available types of innovation are not mutually exclusive for any given good or service. When introducing a new product to a market, this can (and often does) involve several types of innovation. The following example illustrates one such instance.

In 2010 a Chinese manufacturer introduced a new kind of ceramic tiles, made from the exhaust of coal power plants (Veach, 2010). The tiles are especially resistant to environmental influences. The manufacturing process had never been used before and therefore needs to be classified as a process innovation. At the same time, the special attributes of the tiles make them a product innovation in themselves.

Another difficulty can be the classification of marketing innovations vs. product innovations. In 2010, the Indian TV-Channel 'Zing' rebranded its entire identity, including channel-logo, colours and themes as a continuous ad for the product launch of a new toiletry product brand (Chakrabarty, 2010). This had never been done before and hence classifies as an innovation—but is it a marketing innovation by the toiletry brand 'Lux', or a product innovation by the Bollywood-channel 'Zing', whose business model is based on the sales of advertisement? Since the responsible innovator, addressing his customers with a new channel, is the initiator (in this example 'Lux'), such cases are considered to be marketing innovations by the producing firm.

2.3 Degree of Novelty

Even though the degrees of Innovations (also degree of novelty or newness) is covered in the OECD's Oslo manual, Garcia and Calantone (2001) show in their thorough literature review on innovation typology how different interpretations and operationalizations of these concepts can lead to very different classification results. By introducing a comprehensive framework they offer a toolbox for grouping innovations by their degree of novelty using two levels of evaluation:

1. **The macro level:** evaluating the impact on an entire industry
2. **The micro level:** evaluating the impact on a particular firm

On both levels, the novelty/discontinuity of the technology and of the market are evaluated on a yes/no basis, thus reducing the classification of an innovation's novelty to several binary choices. This facilitates the individual assessment but requires additional information for each decision, as described in the following sections.

2.3.1 Newness of a Technology

Technology in this study's context is defined as extending beyond engineering and manufacturing. It is the process by which an organization transforms inputs such as capital, labour, materials and information into outputs (products and services) of greater value (Christensen, 1997).

The question to ask when assessing the newness of a technology to a firm (micro-level) is therefore: *"Has Company A used the same or a very similar technology earlier in order to provide a product or service to a customer?"* In addition, this question needs to be considered with respect to the type of innovation to be evaluated (product, process, marketing or organization). For marketing innovations for instance, the technology used for specific marketing purposes needs to be considered instead of the technology used in the actual product or service.

On the macro-level the according question to ask is: *"Has this or a very similar technology been used before by any company within the same industry?"* Important to note is the focus on a specific industry, not the worldwide usage of a technology. Garcia and Calantone (2001) show that this distinction is reasonable for a useful classification framework, since innovations on a worldwide scale, with worldwide impact are extremely rare. As a consequence, the direct transfer of a technology from one industry to another is to be considered as a discontinuity on a macro-level.

2.3.2 Newness of a Market

Similar considerations are necessary for the market and marketing factors. First of all, a market is not to be understood in a regional sense. Launching an already

established product, marketing method or organizational structure to the same customer segment in a new country does not imply new market/marketing know-how. Instead, market is to be understood in the sense of a new customer segment that has new needs and/or requires new access channels to be reached (Christensen & Raynor, 2003; Garcia & Calantone, 2001; OECD & Eurostat, 2005).

On a micro-level this implies the question: *"Has Company A addressed this or a very similar customer segment before?"* One might add *"with this or a very similar product"* since a company can address different needs of a customer segment with different products. Say, a company has been selling agricultural tools to farmers and now introduces information services on weather conditions and agricultural best-practices; this definitely involves new marketing know-how—even though the part of the population addressed is very similar. By entering a different industry (agricultural tools vs. information services), the company also changes its market segment. Note, that the marketing process involved in addressing a market segment plays no role in the evaluation of the newness of the market. A marketing innovation therefore does not necessarily imply a market/marketing discontinuity on a micro- or macro-level.

On a macro-level the according question is: *"Has this or a very similar customer segment ever been addressed (by this industry)?"* Considering above mentioned example, a company that has been offering information services to farmers in developed countries and now (as the first company in the industry) starts offering these same services to rural farmers in India, introduces market discontinuities in both micro- and macro-levels, since needs and access channels of this new customer segment are very much different from the original segment. Therefore the move to a new regional market can also imply new market/marketing know-how (Fig. 1).

By thus evaluating the four factors described above, innovations are placed into three distinct categories (Garcia & Calantone, 2001):

1. **Incremental Innovations:** can be defined as products that provide new features, benefits, or improvements to the existing technology in the existing market. They will only occur on the micro level.
2. **Really New Innovations:** are moderately innovative products. On a macro level, a really new product will result in a market discontinuity or a technological discontinuity but not both.

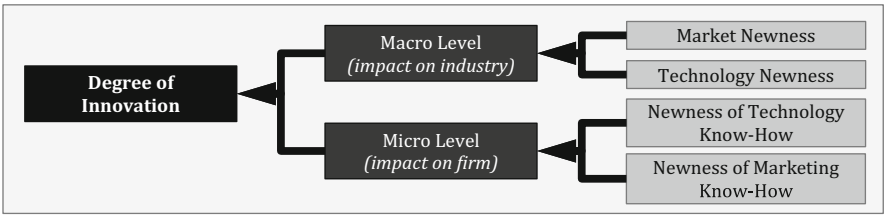

Fig. 1 Framework 'Degree of Innovations' (adapted from Garcia & Calantone, 2001)

3. **Radical Innovations:** often do not address an existing demand but instead create a demand previously unrecognized by the consumer. They result in macro level discontinuities for both technology and market.

2.4 Disruptive Potential

In his 1997 book 'The Innovator's Dilemma', Harvard Professor Clayton Christensen introduced the notion that traditional innovation typologies do not serve as an adequate judge of the likelihood of success of the innovation. Neither do they provide reliable guidance for managerial action during innovation processes, according to Christensen (1997). He hence introduces an alternative variant of innovation typology titled *"principles of disruptive innovation (Christensen, 1997)"*.

These principles include two broad variants of innovations, namely

1. **Sustaining innovations:** improving the performance of established products according to the measurement criteria of their most important customers and
2. **Disruptive innovations:** generally underperforming existing technologies according to established performance criteria but introducing features valued by new or fringe markets.

Developed by start-ups or independent divisions and ripened in emerging market segments, disruptive innovations gradually become competitive in the initial markets and finally have the potential to fully substitute established technologies (Christensen, 1997). Disruptive innovations tend to be cheaper, simpler, smaller, or more convenient to use than established solutions (Christensen, 1997). This definition is similar to how (Tiwari & Herstatt, 2012b) define 'frugal innovation'. A connection between the two classes of innovations is possible and shall be investigated further.

In order to take into consideration the potential difference between more traditional typologies as described in Sect. 2.3 and Christensen's proposal, the above model is appended by two additional evaluation criteria. In 2003, Christensen and Raynor extended the model of disruptive innovations by subdividing disruptive innovation into *"new-market disruption"* and *"low-end disruption"* also providing simple-to-integrate litmus tests for checking specific innovations for their disruptive potential (Christensen & Raynor, 2003):

New-Market Disruption

- Is there a large population of people who have not had the money, equipment, or skill to do this thing for themselves, and as a result have gone without it altogether or have needed to pay someone with more expertise to do it for them?
- To use the product or service, do customers need to go to an inconvenient, centralized location?

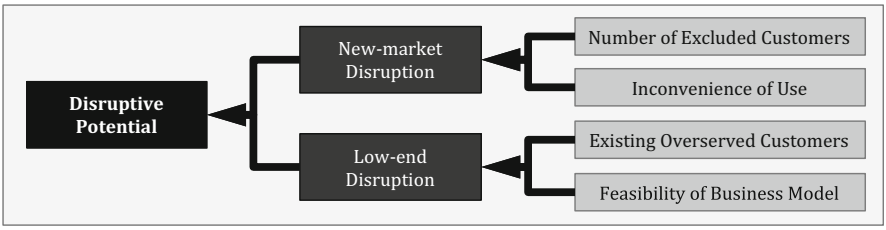

Fig. 2 Framework 'Disruptive Potential' (adapted from Christensen & Raynor, 2003)

Low-End Disruption

- Are there customers at the low end of the market who would be happy to purchase a product with less (but good enough) performance if they could get it at a lower price?
- Can we create a business model that enables us to earn attractive profits at the discount prices required to win the business of these overserved customers at the low end?

The resulting process for checking an innovation's disruptive potential is depicted in Fig. 2. Accordingly, an innovation can have the potential to become a new-market disruption, a low-end disruption or both.

2.5 Innovation Typology: Process Approach

Combining the individual classifications described in the previous sections, a process for consistently classifying innovations has been derived and depicted in Fig. 3. It will be applied throughout the following sections of this study.

3 Empirical Study

3.1 Data Description

The online service 'Google Alerts' has been used to gather daily reports on several key words for this study. The key words were: 'India + Innovation', 'India + R&D', 'Offshoring + India' as well as their german translations 'Indien + Innovation', 'Indien + F&E', and 'Offshoring + Indien'. Across the study's timeframe between January 1st 2010 and December 31st 2011 this query resulted in a total of well above 1200 online-news reports that have been evaluated for references to innovations introduced in India. A total of 178 innovations have been identified. They were described in 69 individual publications primarily encompassing newspapers (such as Wall Street Journal and Times of India), innovation-oriented news portals

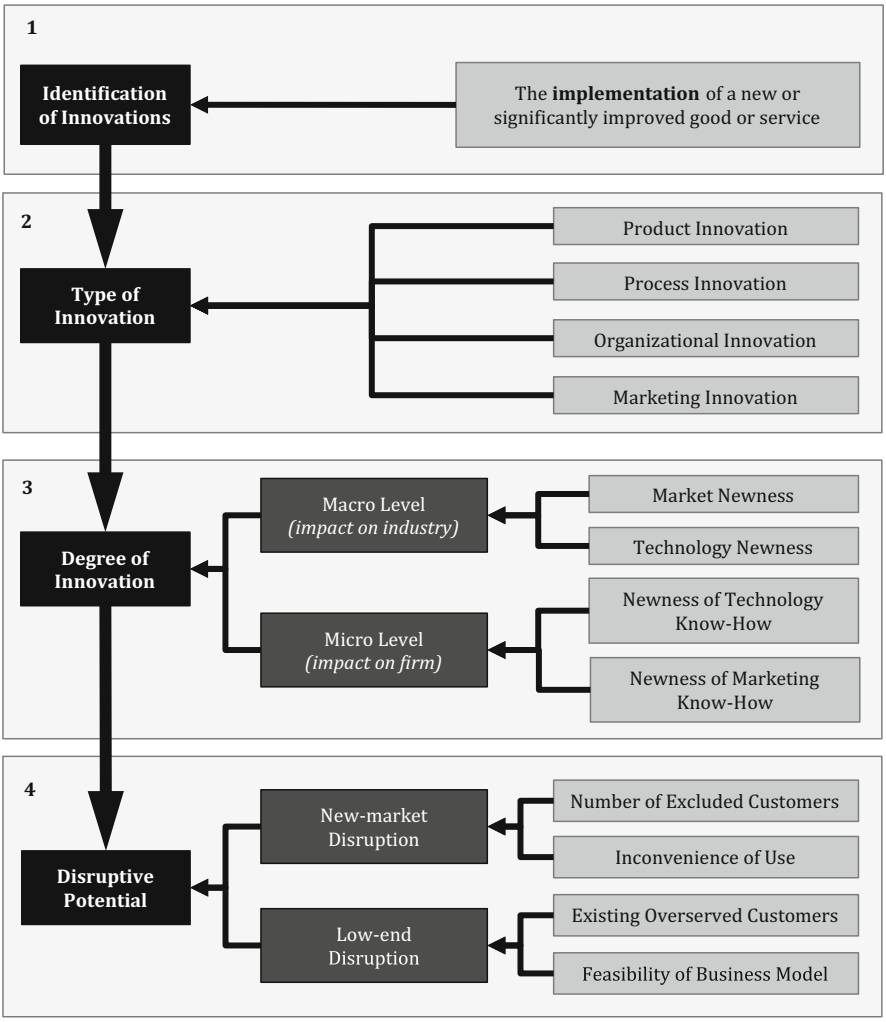

Fig. 3 Process 'Classifying Innovations'

(such as afaqs.com and siliconindia.com) as well as press archives (such as indiaPRwire.com and PR.com). The news reports were evenly spaced across the entire 2-year time frame of the study. Wherever such data was available, the innovations have been catalogued according to the 38 criteria shown in Table 1. In order to properly classify the innovation itself, a typology as described in chapter "Frugal Innovation: An Assessment of Scholarly Discourse, Trends and Potential Societal Implications" has been applied using criteria 19 through 29. Building upon these direct criteria, further aggregation and evaluation has been conducted as described in Sect. 3.2ff. Additionally, company data has been recorded from

Table 1 Cataloguing criteria used for this study

Innovator's description	1	Innovator's name	Describing the innovator
	2	NACE level 1	
	3	NACE level 2	
	4	NACE level 3	
	5	Origin (country)	
	6	Origin (classification)	
	7	R&D location (country)	
	8	R&D location (classification)	
	9	Revenues	Company classification
	10	No of employees	
	11	Year of foundation	
	12	Legal form	
	13	Company classification	
Innovation's description	14	Product name	General description
	15	Product category	
	16	Short description	
	17	B2C/B2B	
	18	Innovative effect	
	19	Type of innovation	
	20	Market discontinuity	Degree of novelty
	21	Technology discontinuity	
	22	New market know-how	
	23	New technology know-how	
	24	Technology score	
	25	Market score	
	26	Novelty	
	27	Potential new-market disruption	Disruptive potential
	28	Potential low-end disruption	
	29	Disruption result	
	30	Localization	Innovative effect
	31	Additional features/performance	
	32	Lower cost	
	33	Simplified use	
	34	Easier availability	
	35	Other	
Other	36	Comment	
	37	Hyperlink	
	38	Date	

publicly available data sources such as annual reports and press releases where available. The full dataset as been submitted with this study. An excerpt containing key criteria for all records is included in the appendix.

3.1.1 Innovator's Description

In order to investigate connections between the innovator's background, origin, and structure and the resulting innovations, several criteria relating to the innovating company or individual have been recorded.

General Information (Criteria 1–8)

Apart from the innovator's name, his industry has been recorded according to the second revision of the European standard for statistical classification of economic activity in its second iteration (NACE v.2) (Eurostat, 2008) with a detail of up to three levels. This facilitates a flexible aggregation of innovators into sub-sectors and their individual evaluation.

Furthermore, the innovators' countries of origin have been recorded. The seat of a company's headquarters was considered to be decisive. In a very similar fashion, the country where a major proportion of R&D related to the innovation in question has been conducted was included wherever possible. Since the differences and similarities between developed regions of the world (including Europe, North America, Japan, and Australia) and developing regions (with a focus on India) were of special interest to this study, an aggregation of both the innovators' countries of origin and their R&D locations has been conducted into these two categories.

Company Classification (Criteria 9–13)

For relating innovative capacities and patterns to company size, a standardized classification scheme has been applied in accordance with the European Union's standard for business classification (Eurostat, 2011). For a more uniform classification one additional range "very large" has been added above 10 billion euros in revenues or 10,000 employees. Companies and innovators have been assigned the next higher category as soon as one of the two criteria was fulfilled (Table 2).

In addition to a classification of company size, the legal form has been recorded as one of *public*, *private*, *NGO*, or *cooperative*. Where available, the year of the company's foundation has been included as well.

3.1.2 Innovation's Description

The following criteria include the innovation typology process developed in Sect. 2 and complement it with specific product information, wherever such was available from the data sources.

Table 2 Company classification scheme in accordance with (Eurostat, 2011)

Class	Yearly revenues (euros)[a]	No of employees
Micro		<10
Small	<1 mn	10–49
Medium	1 mn to 49 mn	50–249
Large	50 mn to 10 bn	250–10,000
Very large	>10 bn	>10,000

[a]Based on average exchange rates over the fiscal year in question

General Information (Criteria 14–17)

The general section encompasses the innovations' product name (where applicable) as well as a more general categorization and short description, giving the researcher a short impression of the kind of product/service the innovation in question belongs to (The name could e.g. be '*ClimaCon'*, which is of the category 'a*pparel'* and has the description '*temperature regulating clothes'*). In addition, the target group has been identified as one of B2B or B2C, discerning end-consumers from business customers.

Innovative Effect (Criteria 18 and 30–35)

Some studies attribute special importance to certain innovative effects (such as cost reduction) expected in above average quantities of innovations of certain typologies and origins (e.g. disruption and simplified usage (see Christensen, 1997) or innovations of Indian origin and reduced cost of ownership (see Tiwari & Herstatt, 2012a)). In order to inspect such correlations, every innovation in the dataset has been evaluated with respect to its innovative effect. The qualitative effect has been recorded in continuous text as mentioned in the sources. It has furthermore been classified into the following categories as described in several descriptive studies and reports (e.g. Christensen, 1997; OECD & Eurostat, 2005; Tiwari & Herstatt, 2012b; Utterback & Abernathy, 1975):

- **Additional features—**Existing functionality is extended and/or supplemented. New functionality is added to the product or service.
- **Lower cost—**Life-cycle cost for the direct consumer is reduced. The origin can lie anywhere along the supply chain.
- **Simplified use—**The use of the product/service has been simplified through interface design or modification of working principles.
- **Localization—**Existing or new functionality is adapted to special regional circumstances or tastes.
- **Easier availability—**Access to the product or service has been simplified. Access is provided to consumers previously excluded by limited technological, infrastructural or regional provisions.
- **Other**

Innovation Typology (Criteria 19–29)

Type, degree of novelty and disruptive potential has been evaluated according to the process developed in Sect. 2.

Other (Criteria 36–38)

For each recorded innovation, the date of the according source-report has been recorded as well as the hyperlink of the source-report and additional comments. While the according hyperlink may not be available forever, each source-report has been separately documented and archived for future reference.

3.2 Data Evaluation

From the large variance of available evaluation criteria, three areas of primary interest have been chosen for this initial study.

In order to answer more detailed research questions in subsequent studies and prioritize future additions to the data sample, the focus for this initial study has been put on answering the three questions

1. What types of innovations arise from an emerging market such as India?
2. Who (in terms of company origin) is the primary driver of innovation and where (in terms of R&D location) are innovations being developed?
3. What industry and company structures are the primary sources of innovation within an emerging market such as India?

3.2.1 Industry Distribution and Company Classification

Within the study's sample there is a strong concentration of innovations in the NACE level 1 industry clusters C (manufacturing, 60 %) and J (information and communication, 34 %). Furthermore, a majority of innovations belong to NACE level 2 clusters C26 (manufacture of computer, electronic and optical products, 20 %) and J62 (computer programming, consultancy and related activities, 21 %). This corresponds to existing studies, claiming that India has become a growing hub for software innovation and development of computers and electronics (Ernst, Dubiel, & Fischer, 2009; Vardi, 2010) as well as to recent data on telecom penetration (above 70 %) and rising engineering exports (US$4.95 billion to US $68.8 billion from 1997 to 2011) (RBI, 2011; TRAI, 2011). For a complete

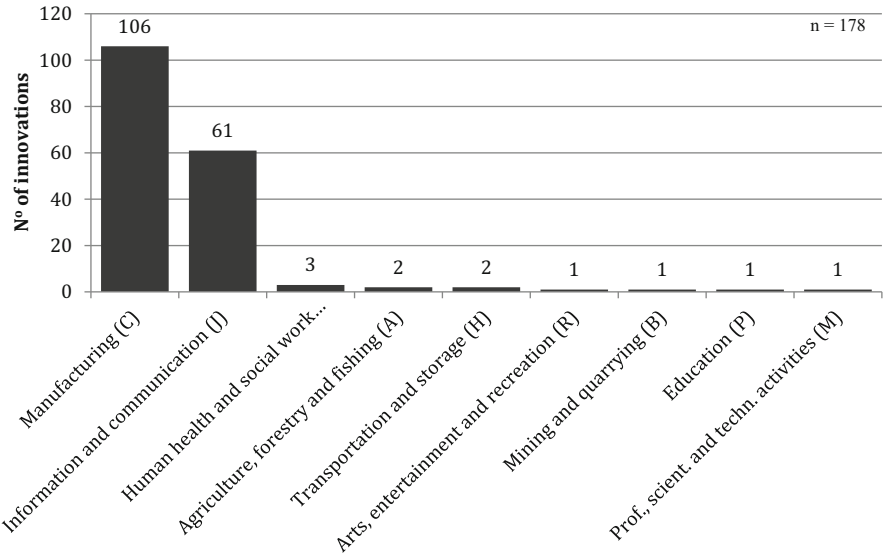

Fig. 4 Number of innovations by NACE level 1 cluster

overview of industries represented within the sample see Figs. 4 and 5 and corresponding supplementary legend in Table 3.

Accordingly, the top five industry clusters (NACE level 2) account for more than 62 % of all innovations within the sample. Within these five clusters the distribution of innovative effects differs (as shown in Fig. 6). While cluster 62 (programming etc.) has a large share of innovations with added functionality as well as increased availability, cluster 26 (manufacturing of electronics etc.) has a much larger share of innovations reducing cost. This may indicate the increased use of information technology and adapted software in supply chains distributed across rural environments, solving some of the inherent distribution challenges described by previous case studies (see e.g. Gradl, Herrndorf, Knobloch, and Sengupta (2010), Mahajan and Ramola (1996) from the financial services sector). At the same time similar forces may be behind the focus on cost-reduction within the engineering sector, where the superb cost of highly engineered products until now hinders their widespread distribution.

Within the study's sample are 148 individual innovators. Eliminating direct corporate branches and similar associations leaves 141 individual companies and innovators. 51 % of all innovators fall into the category 'very large' or 'large' which together account for 63 % of all innovations. When considering the total number of innovations, these two categories are also the most innovative measured in number of innovations per company—as is to be expected considering the significant difference in workforce and financial resources involved in the classification scheme (see Fig. 7).

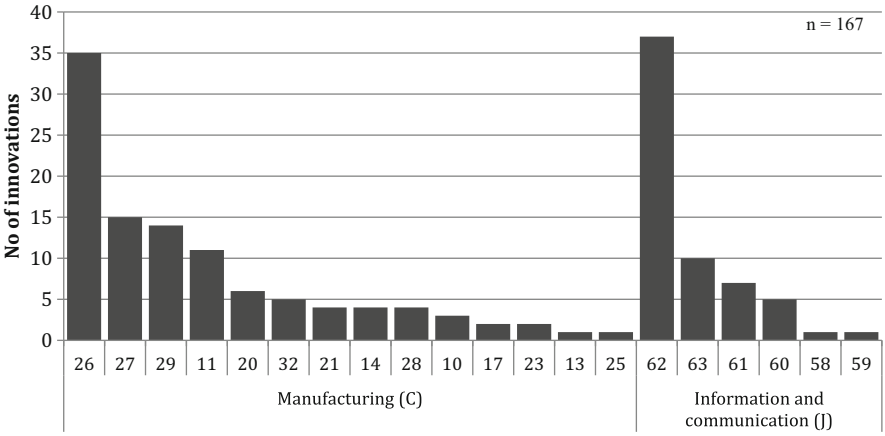

Fig. 5 Number of innovations in NACE clusters C and J by NACE level 2 clusters (for the legend see Table 10)

Table 3 Relevant excerpt from the NACE classification of industrial activity (based on Eurostat, 2008, p. 55ff.)

C	*Manufacturing*
10	Manufacture of food products
11	Manufacture of beverages
13	Manufacture of textiles
14	Manufacture of wearing apparel
17	Manufacture of paper and paper products
20	Manufacture of chemicals and chemical products
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
23	Manufacture of other non-metallic mineral products
25	Manufacture of fabricated metal products, except machinery and equipment
26	Manufacture of computer, electronic and optical products
27	Manufacture of electrical equipment
28	Manufacture of machinery and equipment n.e.c.
29	Manufacture of motor vehicles, trailers and semi-trailers
32	Other manufacturing
J	*Information and communication*
58	Publishing activities
59	Motion picture, video and television programme production, sound recording and music publishing activities
60	Programming and broadcasting activities
61	Telecommunications
62	Computer programming, consultancy and related activities
63	Information service activities

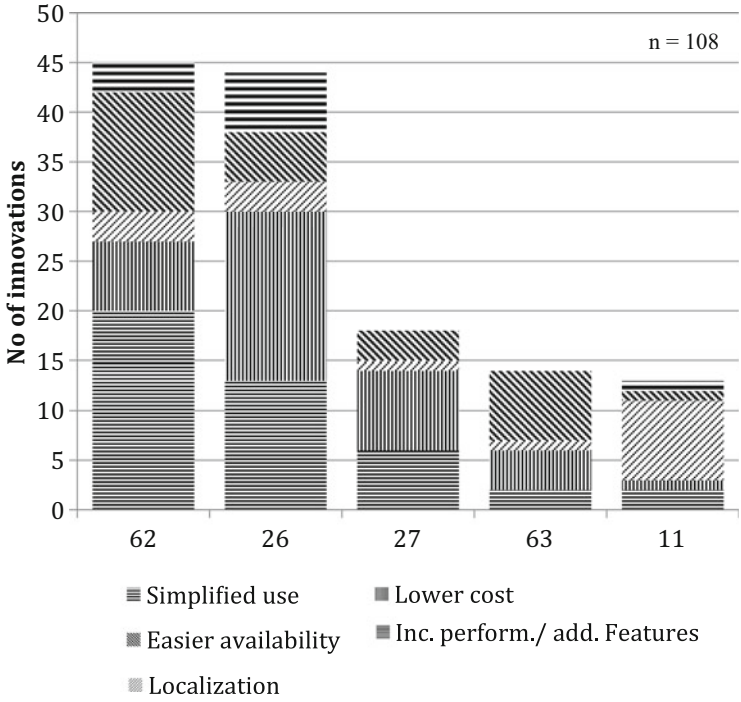

Fig. 6 Number of innovations in TOP 5 NACE (L2) clusters by impact

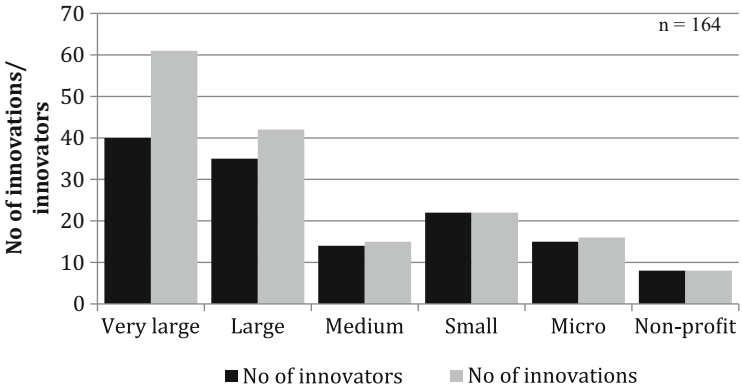

Fig. 7 Number of companies and innovations by company size in sample

However, a further examination of the disruptive potential and degree of novelty of the innovations reveals that the difference in the absolute number of potentially disruptive innovations is much smaller across company sizes than for incremental and sustaining innovations. Hence the *relative* number of radical and disruptive innovations is much higher for the smaller company sizes (e.g. in the extreme: 0.44

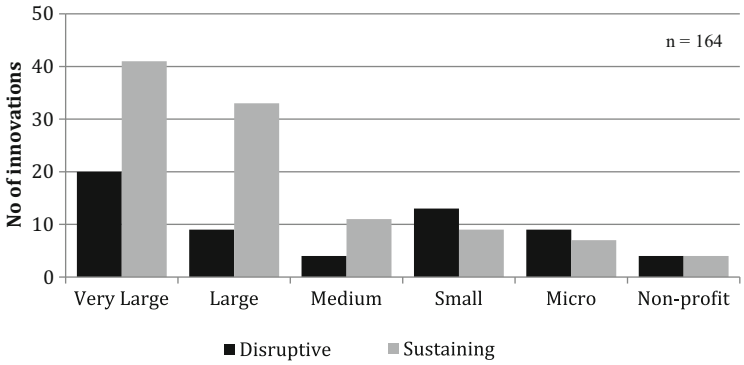

Fig. 8 Number of innovations by disruptive potential and company size

radical innovations per micro-innovator vs. 0.08 per very large-innovator; see Figs. 8 and 9 for details). This supports the claim that potentially disruptive and/or radical innovations flourish more easily within smaller organizations (Christensen & Raynor, 2003). It thereby also suggests that start-ups and grassroot innovators (31 within the sample, all local in origin) account for a relatively large portion of these innovations, highlighting their importance for the innovation climate in an emerging market such as India. Consequently, scholars arguing for the importance of social capital and knowledge of local conduct in the frugal innovation process (e.g. Subramaniam & Youndt, 2005; Tiwari & Herstatt, 2012b) may find support in this result.

3.2.2 Influence of Innovator's Origin and R&D Location

Within the given sample a majority of innovations (71 %) stem from Indian innovators and have been developed within India. A second large block (21 %) originates in companies from the developed world but has also been developed in India. Table 4 shows an overview of the number of innovations within the sample by their innovator's origin and their R&D location.

When looking at the timeline of innovations (shown in Fig. 10) and their share by country of origin, the average share of Innovations by Indian companies increases slightly over the 24 month timeframe of the study.

Tables 5 and 6 show the distribution of the degree of novelty by R&D location for Indian innovators and those from developed countries, respectively. While the share of really new innovations developed in India is much larger for innovators from the developed world (50 %) than for Indian innovators (34 %), the reverse is true for radical innovations that make up a share of 17 % of all innovations by Indian companies and entrepreneurs but only 2 % of those by companies from developed countries.

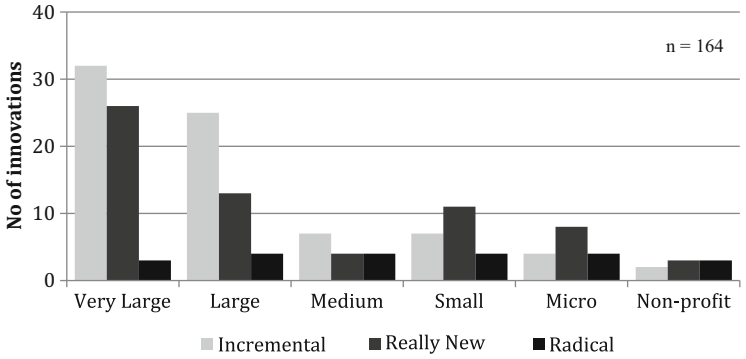

Fig. 9 Number of innovations by degree of novelty and company size

Table 4 Number and share of innovations in sample by innovator's origin and R&D location

	R&D location			
Innovator's origin	Developed world	India	RoW	Grand total
Developed world	7 (4 %)	35 (21 %)	0 (0 %)	42 (25 %)
India	2 (1 %)	117 (71 %)	0 (0 %)	119 (72 %)
RoW	0 (0 %)	1 (1 %)	3 (2 %)	4 (2 %)
Grand total	9 (5 %)	153 (93 %)	3 (2 %)	165 (100 %)

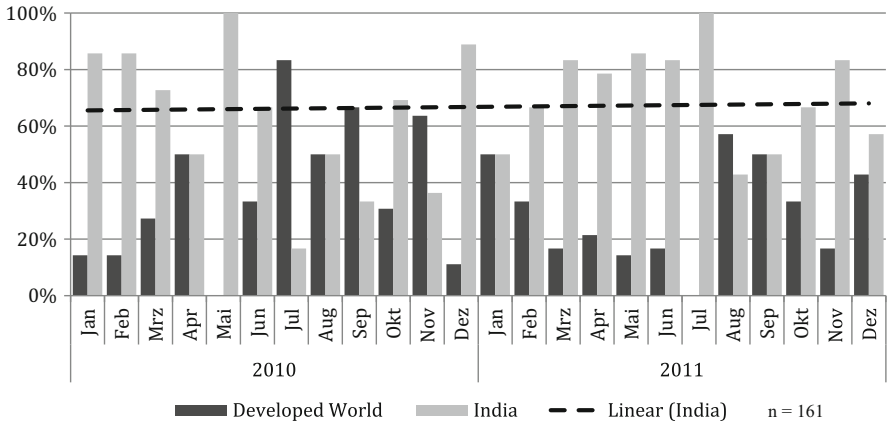

Fig. 10 Timeline of the share of innovations by the innovator's origin. (For reasons of simplicity only India and developed world are shown in the figure. The four innovations originating in the rest of the world (RoW) have been omitted. Due to their wide spread across the depicted timeframe, they do not change its appearance perceptibly)

In order to gain a deeper understanding of the kind of innovations developed within the sample, Tables 7 and 8 evaluate the technology score of the innovations in a similar fashion as above. This evaluation reveals, that the share of high-

Table 5 Number and share of innovations by Indian companies by their R&D location and degree of novelty

	Degree of novelty			
R&D location	Incremental	Really new	Radical	Grand total
Developed world	2 (2 %)	0 (0 %)	0 (0 %)	2 (2 %)
India	56 (47 %)	41 (34 %)	20 (17 %)	117 (98 %)
Grand total	58 (49 %)	41 (34 %)	20 (17 %)	119 (100 %)

Table 6 Number and share of innovations by companies from developed countries by their R&D location and degree of novelty

	Degree of novelty			
R&D location	Incremental	Really new	Radical	Grand total
Developed world	1 (2 %)	5 (12 %)	1 (2 %)	7 (17 %)
India	13 (31 %)	21 (50 %)	1 (2 %)	35 (83 %)
Grand total	14 (33 %)	26 (62 %)	2 (5 %)	42 (100 %)

Table 7 Number and share of innovations by Indian companies by their technology score and R&D location

	Technology score			
R&D location	0	1	2	Grand total
Developed world	0 (0 %)	2 (2 %)	0 (0 %)	2 (2 %)
India	25 (21 %)	37 (31 %)	55 (46 %)	117 (98 %)
Grand total	25 (21 %)	39 (33 %)	55 (46 %)	119 (100 %)

Table 8 Number and share of innovations by companies from developed countries by their technology score and R&D location

	Technology score			
R&D location	0	1	2	Grand total
Developed world	3 (8 %)	0 (0 %)	4 (10 %)	7 (17 %)
India	18 (43 %)	9 (21 %)	8 (19 %)	35 (83 %)
Grand total	21 (50 %)	9 (21 %)	12 (29 %)	42 (100 %)

technology innovation (causing a technology discontinuity on a macro level) of innovations developed within India is more than twice as high (46 %) for Indian innovators as it is for their counterparts from the developed world (19 %). This result could be an indication that, while companies from developed countries continue to expand their R&D facilities within the emerging markets, their most sophisticated technology oriented R&D is still conducted elsewhere, presumably within their home-markets. At the same time, Indian companies concentrate also their most advanced technology development in India.

This observation poses the question of the development of technology oriented innovations in India over time, i.e. has foreign innovators' trust in technology oriented R&D within India risen over the past years. As several current studies

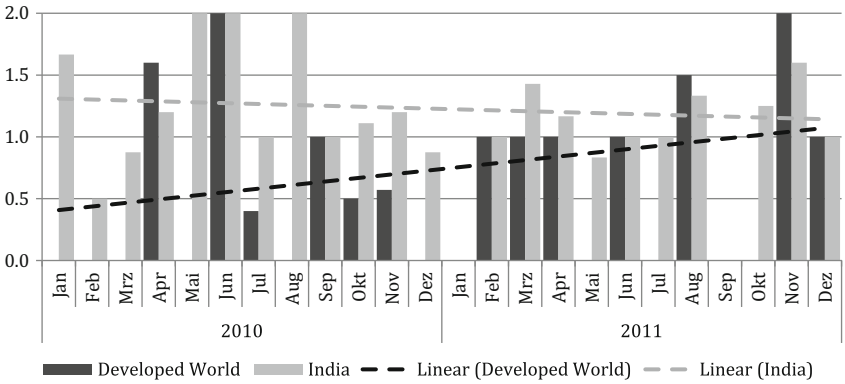

Fig. 11 Average technology score by innovator's origin

(see Herstatt et al., 2008) suggest, the average technology score of innovations by companies from developed countries has risen considerably across the study's timeframe, pointing towards increased availability of according infrastructure and technology distribution as well as increased outsourcing activities in technology oriented areas (e.g. Tiwari & Herstatt, 2012a). However, the average technology score of innovations by Indian innovators has decreased slightly, very much in contrast to the studies and suggested trends mentioned above. This poses the question, whether there is an actual decrease in technology oriented innovation underlying this apparent tendency or whether an above average increase in less technology heavy innovation causes the phenomenon (see Fig. 11).

Indeed, Fig. 12 shows a slight increase in innovations with technology score 2 by Indian innovators. The overall decrease in the average technology score is caused by a decrease in innovations with a technology score of 1 (technology discontinuity on a micro-level). In essence, this may imply the move from innovations that are merely technologically new on a micro-level, towards more globally revolutionary R&D conducted by Indian innovators.

Finally, the number and share of innovations with disruptive potential varies only slightly between Indian innovators (34 %) and those from developed countries (45 %) as shown in Tables 9 and 10. This may be an indication that the unique circumstances within emerging economies resulting in a special composition of innovations apply similarly to indigenous and foreign innovators. However, the influence of 'social capital' in the emergence of innovations tailored to emerging markets (see Subramaniam & Youndt, 2005) needs to be further investigated.

3.2.3 Innovation Typology

Of the 178 innovations within the sample, 83 (47 %) have been rated as incremental innovations. Accordingly, just under half of all recorded innovations happen solely on the micro-level and hence require the firm to develop new technology- and/or

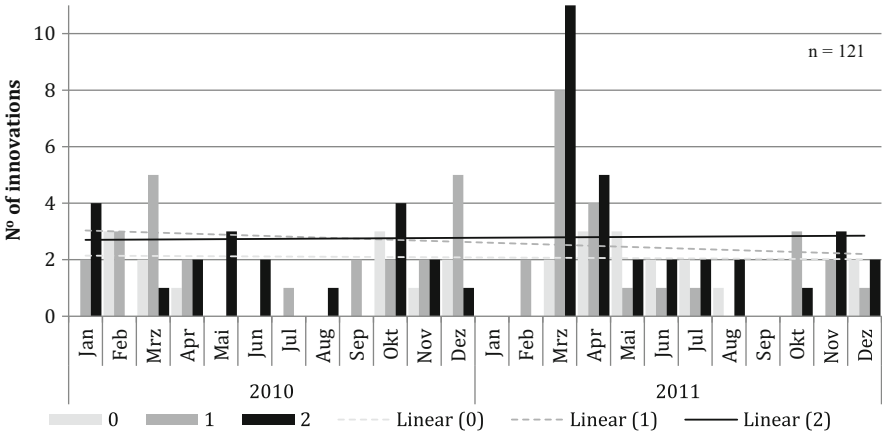

Fig. 12 Timeline: number of innovations by Indian companies by their technology score. (The considerable spike in Mach 2011 results from in-depth media coverage of a nation-wide Indian innovation contest conducted by the National Association of Software and Services Companies (NASSCOM))

Table 9 Number and share of innovations by Indian companies by R&D location and disruptive potential

	Disruptive potential		
R&D location	Yes	No	Grand total
Developed world	0 (0 %)	2 (2 %)	2 (2 %)
India	40 (34 %)	77 (65 %)	117 (98 %)
Grand total	40 (34 %)	79 (66 %)	119 (100 %)

Table 10 Number an share of innovations by companies from developed countries by R&D location and disruptive potential

	Disruptive potential		
R&D location	Yes	No	Grand total
Developed world	4 (10 %)	3 (7 %)	7 (17 %)
India	15 (36 %)	20 (48 %)	35 (83 %)
Grand total	19 (45 %)	23 (55 %)	42 (100 %)

marketing-know-how that has already been applied by competitors within the same industry.

72 innovations require the innovator to apply either technological or marketing skills that have never been implemented within the same industry before and finally 23 (13 %) of all innovations within the sample classify as being radical in the sense that they require the innovator to apply both market-know-how and technology-know-how that hasn't been used within his industry before (see Fig. 13). Considering how previous studies have described radical innovation as rare, and, when successful, game-changing within their industry (e.g. Chandy & Tellis, 2000; Hill & Rothaermel, 2003), this number is to be considered quite substantial.

Figure 14 shows the distribution of the innovations' disruptive potential according to the criteria described in Sect. 2.4. While 116 (65 %) of the sample

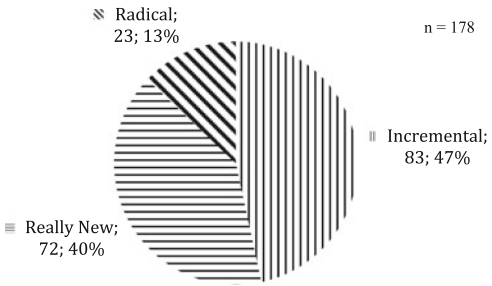

Fig. 13 Number of innovations in sample by their newness

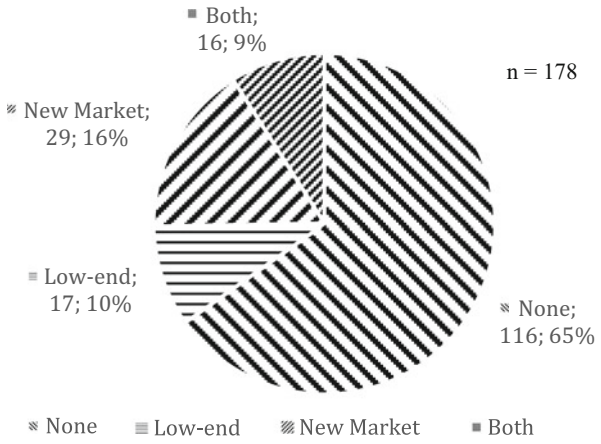

Fig. 14 Number of innovations in sample by their disruptive potential

carry no disruptive potential and can therefore be classified as 'sustaining' innovations, 62 (35 %) have the potential to be shaped into a disruptive innovation in the sense of Christensen (1997) and Christensen and Raynor (2003). Closer inspection shows that among the third of the sample having disruptive potential, the largest group of 29 innovations (16 %) has some potential for being shaped into a new-market disruption, extending a product or service into parts of the population excluded by previous offers, while a somewhat smaller group of 17 innovations (10 %) have potential to become low-end disruptions in markets where previous customers have been overserved by existing alternatives. 16 innovations combine both kinds of disruptive potential.

When combining both evaluations (degree of novelty and disruptive potential, as shown in Fig. 15), the overall picture is confirming initial expectations. All 23 innovations classified as radical also have potential to become disruptive innovations. Among the really new category only 34 (close to 50 %) of innovations have disruptive potential, while the rest (38) are of purely sustaining character. A large majority (78 of 83) of incremental innovations have no disruptive potential. However, the five remaining innovations have potential to be shaped into low-end disruptions. While this combination may seem unlikely, (Christensen & Raynor, 2003) describe how incremental und sustaining are not mutually enforcing

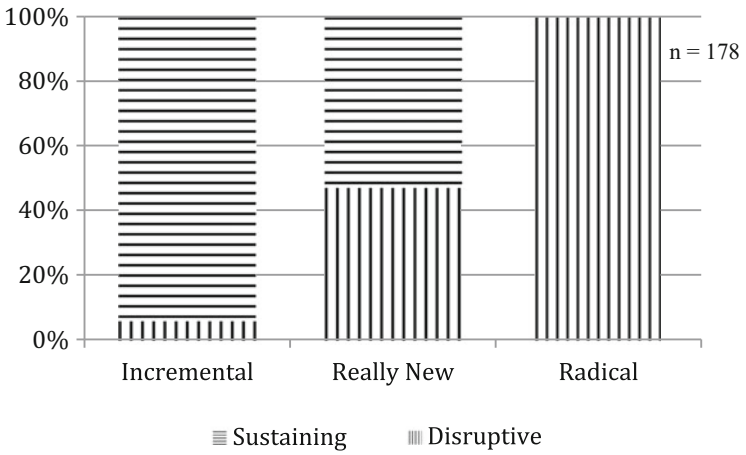

Fig. 15 Share and number of innovations by degree of novelty and disruptive potential

classifications. The cases included in this study encompass innovations that lower the price of the product/service to the consumer while utilizing established technology in functionally simplified solutions. Among them is for example an e-book reader using standardized, well established components and drastically simplified functionality in order to reduce its price to around 40 % of its largest competitors. While the product in question does not apply technology- or market-know-how that is in any way new to the industry, its value proposition may be shaped into a product serving established customers who are presently overserved by the functionality of existing e-book readers and willing to accept a less functional product at a significantly lower price.

The match between the degree of novelty and disruptive potential of the innovations within the sample suggests that, even though individual innovations might diverge as exceptions, both classifications describe the innovative potential of an innovation along similar lines. While both classifications certainly contribute to the understanding of an innovations potential, this result somewhat contradicts the presumption that 'traditional' classifications oriented along the degree of novelty fail to adequately classify an innovations character (Christensen & Raynor, 2003).

An additional result emerging from the present data-analysis is the direct correlation of the definitions for a market-discontinuity on a macro (industry) level and potential new-market disruptions. Whenever an innovation involves a market-discontinuity on a macro-level as described in Sect. 2.3.2 the innovator addresses a customer segment that by definition has never had access to the product or service being offered. Especially, but not exclusively, when the innovator's industry is already well established in other market-segments, this by itself fulfills a potential new-market disruption as described in Sect. 2.4 Vice-versa, any innovation fulfilling the criteria for a potential new-market disruption must by definition

involve a market-discontinuity on a macro-level—otherwise the new customer segment would have had access to the product or service before.

A large group of 143 (80 %) of all innovations within the sample are product innovations, followed by marketing (19, 11 %), process (13, 7 %) and organizational (3, 2 %) innovations (see Fig. 16). As publicly available news reports were used as the primary source for this sample, a connection between the choice of sources and the large share of product innovation in the sample is possible as a consequence of the high media attention focused on the launch of innovative products compared to company-internal changes inherent to organizational innovation. Across all types of innovations, the share of incremental, really new and radical innovations is comparable (Fig. 16). Due to the small sample-sizes in all but product innovations, these results would have to be validated using an additional data source, possibly more focused on firm-internal innovation.

Corresponding to the majorities of incremental and sustaining innovations, a large number within the sample (70, 47 %) encompasses additional product features in their innovative effect. This is in turn followed by innovations lowering product cost (57, 30 %) and innovations increasing availability (41, 23 %). When subdividing the sample into its sustaining and potentially disruptive subgroups (as shown in Fig. 17), the innovative effects split as predicted by literature (Christensen & Raynor, 2003). While more than half of all sustaining innovations involve additional product features and thereby put a focus on increased versatility, less than 10 % of innovations with disruptive potential involve such additional functionality. Instead, they are dominated by reduced cost and increased availability. There is no discernible difference in the share of localizations and innovations simplifying product use between the sustaining and disruptive subgroups.

Some studies (e.g. Hart & Christensen, 2002; Lee, Lin, Wong, and Calantone, 2011) have suggested that simplified usage is of primary importance in order to ensure swift adoption of new products within developing markets. While some of the innovations within the sample do include simplification, it is the rarest of the innovative effects recorded. Tiwari and Herstatt (2012b) describe innovations emerging from India as being characterized by *"their affordability, robustness and 'good enough' quality"*. The considerable share of potentially disruptive innovations and innovations introducing reduced costs seem to confirm the affordability and 'good enough' quality of the products and services within the study's sample. The results also suggest that robustness may just be a necessary precondition for enabling easier distribution and availability of innovations in rural environments where infrastructure and population are stretched thinly across vast regions.

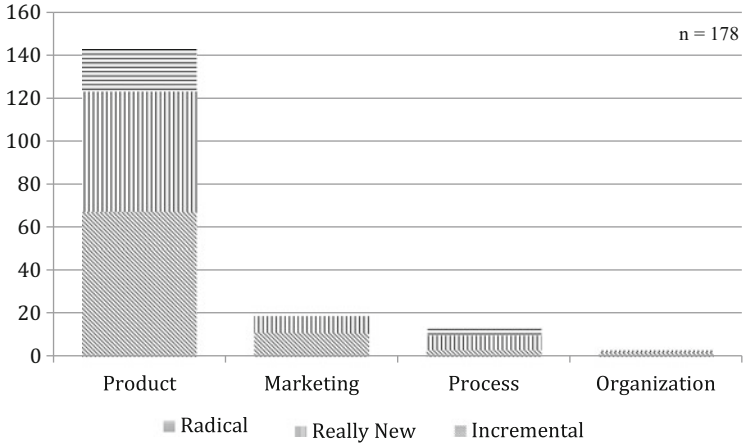

Fig. 16 Number of innovations in sample by their type and newness

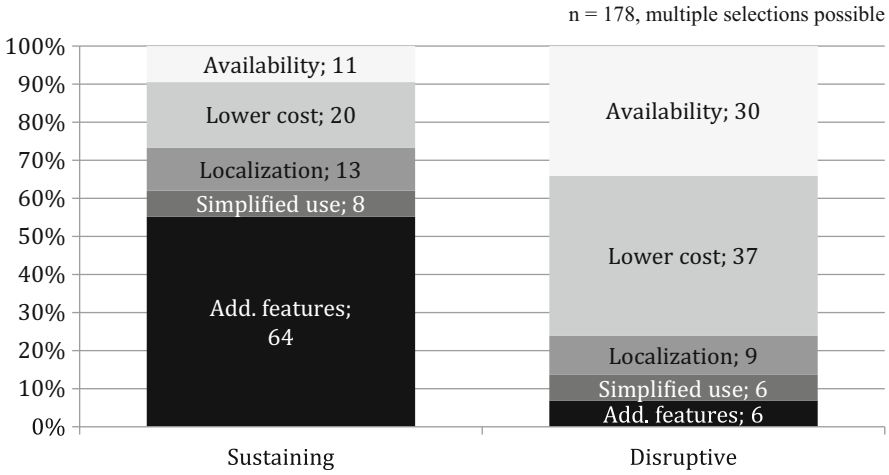

Fig. 17 Share of impacts of innovations by disruptive potential

4 Conclusions and Implications

This study built a database of 178 innovations by more than 140 individual innovators from a basis of 1200 news reports. The innovations were classified by a variety of criteria derived from current literature and an initial evaluation of the results has been conducted. The following sections discuss the methods and sources used for this study and its initial results. Possible practical implications as well as avenues for future research will be examined.

4.1 Discussion

The evaluations showed a considerable share of radical innovations and such with disruptive potential (both low-end and new-market) among the study sample. This finding very much agrees with past statements that India is in the process of establishing itself as a hub for disruptive innovation (Bellman, Misquitta, & Glader, 2009; Prahalad & Mashelkar, 2010) and the interconnectedness between disruptiveness and frugality (Hart & Christensen, 2002; Tiwari & Herstatt, 2012a).

The distribution of innovative effects among the evaluated innovations confirms the importance of reduced costs for potentially disruptive innovations (e.g. Christensen, 1997) and also highlights a large share of innovations increasing the availability of a product or service among those with disruptive potential. As numerous case studies have shown, the rural Indian environment poses significant challenges to traditional distribution networks and supply chains both in the product and service sectors (Gradl et al., 2010; Immelt et al., 2009; Wooldridge, 2010). As these challenges, among others comprised of widespread population, little infrastructure and low levels of literacy and education, and low amounts of daily per capita income (Prahalad & Hart, 2002), have seldom been part of the innovation process of products and services from the developed world, they create a number of difficulties for companies trying to transfer their innovations into the emerging market. Hence, innovations adapting traditional solutions from the developed world often encompass ways to simplify access and distribution. For similar reasons, data-infrastructure and telecommunications (that reduce the dependence on heavy infrastructure such as power grids, land lines etc.) are among the most strongly represented industries within the sample. While the tendency of India developing towards a hub for software and electronics has been recognized before (e.g. Ernst et al., 2009; Vardi, 2010), this finding further justifies this development towards an Indian leadership in widespread, cheap access channels (be they digital or not).

A considerably higher share of radical innovations by innovators from India compared to innovators from the developed world (similar numbers for innovations with disruptive potential) support the importance of 'social capital' and knowledge of local customs and environments as an important factor in the successful development of innovations tailored for an emerging market, as other studies have suggested on a case and theory basis (Subramaniam & Youndt, 2005; Tiwari & Herstatt, 2012a). The findings contribute to this a much higher share of radical and disruptive innovations for small and micro-innovators, giving credit to a) Christensen and Raynor's (2003) claim that such innovations thrive better within smaller organizational units and start-ups and b) supporting the connection between frugality and disruption, as small and especially micro-enterprises are expected to make more use of 'good enough'/frugal technologies and choosing unestablished solutions for their innovations (Hart & Christensen, 2002; Prahalad & Mashelkar, 2010). Combined, these findings also provide credit to emerging theories talking about India as a possible 'Lead Market' for frugal innovation (Tiwari & Herstatt, 2012a, 2012b).

Additionally, the strong increase in technology orientation for innovations by companies from developed countries suggests a rising availability as well as trust in local resources and know-how.

Beyond the results from the actual data evaluation, the process for categorizing innovations according to a consistent typology developed in Sect. 2 of this paper can easily be applied for other innovation studies and thereby contributes the literature on innovation studies and their comparison. The application of this process on the study's data sample yielded additional insights into the relation of different innovation classification schemes (such as disruption vs. novelty), further simplifying future studies.

4.2 Practical and Managerial Implications

The findings presented in this study have several implications for firms innovating in the context of emerging markets and especially India. When aiming for radical and/or disruptive innovations that may be transferrable to developed markets, India's natural conditions favor innovative distribution channels, high product and service availability, and low life-cycle cost. Hence these are areas best developed within the emerging market, using local knowledge. Additionally, the use of small organizational sizes for such innovations seems preferable.

As the amount of technology oriented innovation from India as well as for the Indian market (especially by innovators from developed countries) increases noticeably over the timeframe of inspection, traditional reservations against building technology hubs within emerging markets seem to shrink for established players, thereby further increasing the viability of localized R&D within emerging markets.

4.3 Implications for Further Research

The sources used for this study are all internet-based news reports. An influence of this choice on the resulting spectrum of innovations through uneven coverage of the innovative landscape and focused PR-campaigns of major firms cannot be ruled out. However, these effects may well be countermanded by focused grassroot-networks and innovation prizes, making up a significant portion of the sample.

The scope of this study allowed for the chosen 2-year timeframe. While this yielded a sufficiently large number of innovations to deduce clusters, timelines are still heavily influenced by spikes and outliers introduced through tournaments, prizes and in-depth media coverage of single events. Accordingly, regressional

analyses and statistical significance testing are among the analysis methods suggested for future research projects.

Building upon the results of this study as well as its above mentioned limitations, several extensions and more specific avenues for further research are suggested. For once, the timeframe and depth of analysis can be extended consistently by using the criteria described in this paper. By covering a greater timespan and increasing the number of innovations, the results, especially for timeline evaluations, can be improved and made less vulnerable to outliers and spikes in the data. Such an extension of the study would also permit the evaluation of policy changes on innovation activity—changes that would not be visible within the present timelines.

By extending not the number of cases in the sample but the evaluation criteria, additional influences on the success of innovations may be gained. Promising criteria for such extensions are the innovations' target population (rural/urban, rich/poor) and the requirement of social capital in order to implement any given innovation. These two criteria might deliver meaningful insight into the possibilities of foreign innovators to develop solutions for local markets with or without local involvement in the R&D process.

Finally, a comparison of the results with similar data from other emerging markets (e.g. China, Russia, South America) would yield a valuable distinction between factors typical for the individual market and results generally applicable to emerging economies and their innovation systems. Similar results could be achieved by gathering a comparable sample of innovations from developed countries in order to better contrast the different shares of innovation types against each other.

Extending the database in one or several of the above directions should also permit the use of more in-depth statistical analysis such as regressions and significance testing.

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References

Ablett, J., Baijal, A., Beinhocker, E., Bose, A., Farrell, D., Gersch, U., et al. (2007). *The 'bird of gold': The rise of India's consumer market*. San Francisco: McKinsey Global Institute.

Bellman, E., Misquitta, S., & Glader, P. (2009). Indian firms shift focus to the poor. *Wall Street Journal Online*.

Chakrabarty, R. (2010, November 21). *Bollywood channel Zing creates India's first channel innovation*, press release. Mumbai: Zee Networks.

Chandy, R. K., & Tellis, G. J. (2000). The incumbent's curse? Incumbency, size, and radical product innovation. *The Journal of Marketing, 64*, 1–17.

Christensen, C. (1997). *The innovator's dilemma*. New York: HarperCollins.

Christensen, C. M., & Raynor, M. E. (2003). *The innovator's solution: Creating and sustaining successful growth*. Boston: Harvard Business Press.

Ernst, H., Dubiel, A., & Fischer, M. (2009). *Industrielle Forschung Und Entwicklung in Emerging Markets: Motive, Erfolgsfaktoren, Best-Practice-Beispiele*. Wiesbaden: Gabler Verlag.

Eurostat. (2008). *NACE Rev. 2 – Statistical classification of economic activities in the European Community*. Luxembourg: Eurostat – Statistical Office of the European Communities.

Eurostat. (2011). *Key figures on European business*. Luxembourg: Eurostat – Statistical Office of the European Communities.

Garcia, R., & Calantone, R. (2001). A critical look at technological innovation typology and innovativeness terminology: A literature review. *Journal of Product Innovation Management, 19*, 110–132.

Gerybadze, A., & Merk, S. (2014). Offshore R&D and host-country patenting of multinational corporations in emerging countries. *International Journal of Technology Management, 64* (2–4), 148–179.

Gibbert, M., Hoegl, M., & Välikangas, L. (2007). In praise of resource constraints. *MIT Sloan Management Review, 48*(3), 15–17.

Gradl, C., Herrndorf, M., Knobloch, C., & Sengupta, R. (2010). *Learning to insure the poor – microinsurance report*. Munich: Allianz Group.

Hart, S. L., & Christensen, C. M. (2002). The great leap. *Sloan Management Review, 44*(1), 51–56.

Herstatt, C., Tiwari, R., Buse, S., & Ernst, D. (2008). *India's national innovation system: Key elements and corporate perspectives*. East-West Center Working Papers. Economic Series 96.

Hill, C. W. L., & Rothaermel, F. T. (2003). The performance of incumbent firms in the face of radical technological innovation. *Academy of Management Review, 28*(2), 257–274.

Immelt, J. R., Govindarajan, V., & Trimble, C. (2009). How GE is disrupting itself. *Harvard Business Review, October*, 56–65.

Knowledge@Wharton. (2005). *Human capital: Can India bridge the knowledge gaps needed for research?* Knowledge@Wharton.

Kumar, N., & Puranam, P. (2012). *India inside: The emerging innovation challenge to the West*. Boston: Harvard Business Review Press.

Lee, Y., Lin, B. W., Wong, Y. Y., & Calantone, R. J. (2011). Understanding and managing international product launch: A comparison between developed and emerging markets. *Journal of Product Innovation Management, 28*(s1), 104–120.

Mahajan, V., & Ramola, B. G. (1996). Financial services for the rural poor and women in India: Access and sustainability. *Journal of International Development, 8*(2), 211–224.

Nakata, C. (2012). Creating new products and services for and with the base of the pyramid. *Journal of Product Innovation Management, 29*(1), 3–5.

OECD, & Eurostat. (2005). *Oslo manual: Guidelines for collecting and interpreting innovation data*. Paris: Organisation for Economic Co-Operation and Development (in joint publication with Eurostat).

Prahalad, C. K., & Hart, S. L. (2002). The fortune at the bottom of the pyramid. *Strategy + Business, Spring* (26), 2–14.

Prahalad, C. K., & Mashelkar, R. A. (2010). Innovation's holy grail. *Harvard Business Review, July–August*, 132–141.

RBI. (2011). *Handbook of statistics on Indian economy*. Mumbai: Reserve Bank of India.

Schumpeter, J. A. (1934). *Theorie der wirtschaftlichen Entwicklung: Eine Untersuchung über Unternehmergewinn, Kapital, Kredit, Zins und den Konjukturzyklus*. Berlin: Duncker & Humblot.

Sehgal, V., Dehoff, K., & Panneer, G. (2010). The importance of frugal engineering. *Strategy + Business, Summer*(59), 1–5.

Subramaniam, M., & Youndt, M. A. (2005). The influence of intellectual capital on the types of innovative capabilities. *The Academy of Management Journal, 48*, 450–463.

Tiwari, R., & Herstatt, C. (2012a). *Frugal innovations for the 'unserved' customer: An assessment of India's attractiveness as a lead market for cost-effective products*. Hamburg University of Technology – Working Paper 69.

Tiwari, R., & Herstatt, C. (2012b). *India – a lead market for frugal innovations? Extending the lead market theory to emerging economies*. Hamburg University of Technology – Working Paper 67.

TRAI. (2011). *Highlights of telecom subscription data as on 31st December, 2011*. New Delhi: Telecom Regulatory Authority of India. Press Release.
UNCTAD. (2005). *Globalization of R&D and developing countries: Proceedings of the expert meeting*. New York: United Nations Conference on Trade and Development.
Utterback, J. M., & Abernathy, W. J. (1975). A dynamic model of process and product innovation. *The International Journal of Management Science, 3*(6), 639–656.
Vardi, M. Y. (2010). Globalization and offshoring of software revisited. *Communications of the ACM, 53*(5), 5.
Veach, E. (2010). Vecor recycles waste from coal plants into building materials. *The Wall Street Journal*.
Wooldridge, A. (2010). The world turned upside down – a special report on innovation in emerging markets. *The Economist*, London,

Part IV
Actual Practices of Frugal Innovations

India's Electronic Voting Machines: Social Construction of a Controversy Surrounding a Frugal Innovation

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1 Introduction

On Friday, the 16th of May 2014 the results of the General Election in India were declared. The outcome was a historic moment for the winning Bharatiya Janata Party (BJP) and the new elected Prime Minister Narendra Modi. It was described as "India's biggest election victory in 30 years" (Biswas, 2014). This was the first time that a party managed to get a simple majority, since the Congress party in 1984 won in the aftermath of the assassination of then Prime Minister Indira Gandhi. In the Indian electoral system there are 543 constituencies and consequently 543 seats in the Lower House ("Sansad") of the national parliament.

To hold democratic, free and fair elections in India is an amazing and a daunting task. In the 2014 elections, 66.4 % from total eligible electorate of 834,101,479 cast their vote (ECI, 2014a). The elections took place in multiples phases spread over several weeks. For making election procedures fast and efficient an electronic voting system has been employed. Electronic Voting Machines (EVMs) used in India are unique and quite different from EVMs employed in other nations like the USA.

Rather than large, expensive, complex and computer-like systems the Indian machine is praised for its simplicity, inexpensiveness, and efficiency. The Election Commission of India is very proud of this system and stated that the machines are perfect and tamperproof (Agarwala, Shahani, & Indiresan, 2006: 5–12). Those overly positive remarks caused skepticism amongst certain political parties, activists, academics and voting security specialists. It has been argued that the simplicity

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of EVM design would have negative implications when it comes to questions of transparency, verifiability and the overall security of the election practice.

Although the ECI generally claims that EVMs are tamperproof and perfect for the Indian elections, there have been occasions where EVMs have malfunctioned and had to be replaced. In 2014 elections, for example, there were a few occasions where EVMs malfunctioned in a way that regardless of the button pressed the vote would go always to the same party. The Times of India published an article titled *An EVM that 'votes' only for BJP stuns poll staff in Assam* (Kalita, 2014), which caused for discussion on social media platforms like 'Twitter' (Hashtag: #BJPRiggedEVM). Taking into account that there are over 1.7 million machines in use those isolated instances could seem negligible. Yet members of an Indian civil society initiative called VeTA (Citizens for Verifiability, Transparency & Accountability in Elections) raised suspicion that those kinds of "malfunctions" occur when people tried to tamper the EVM. This is not the first time that people raises doubt and claimed that it was possible to manipulate EVMs and change election outcomes. After the outcome of the 2009 General Election some political parties and concerned citizens had claimed that EVMs could have been tampered and caused a wrong election outcome.

In this paper we take a closer look at this particular controversy. Additionally, we want to provide the reader with information about the Indian electronic voting system more generally. This includes reasons to change from the earlier paper ballot system and design challenges for EVM in the Indian context. We are writing within the frame of a theoretical model called Social Construction of Technology (SCOT), developed by Wiebe Bijker and Trevor Pinch (1987). Along the lines of this model we argue that after the EVM has been adopted in India, different 'relevant social groups' interpreted the EVM in diverse ways. From the social constructivist perspective, we argue that there has been not just one but at least three different EVMs. With time the 'interpretative flexibility' diminished and 'relevant social groups' more or less agreed on one interpretation of the EVM. The EVM has 'stabilized' and the controversy has been closed basically. We show the SCOT model to be helpful for structuring the controversy in a fruitful manner. The research questions addressed here are: How did the ECI and EVM manufacturers react to allegations made by political parties, VeTA, and voting security researchers that EVMs are vulnerable to manipulation? How was the election practice affected?

2 Research Methodology

We will describe the development of the Indian EVM from its implementation to the current use of it. In this sense we are taking a historical and chronological approach. The development will be explained through the eyes of the relevant social groups, in alignment with the theoretical framework. Our research is based on document analysis of a variety of publicly available sources, including official

reports from ECI, articles and books about electronic voting in India and worldwide, economic studies and technical studies on EVMs. In addition, we conducted a number of interviews. We interviewed Hari Prasad in India via telephone to gain in depth knowledge about security concerns of EVMs. Moreover, we interviewed people who have actually used the EVM. This turned out to be difficult; hence we prepared a questionnaire to be filled out by them and sent back via email. This worked out and we received 24 for detailed information about the interviewees. However, we are not using the results in a statistic or generalizing manner. Rather we treat their replies as additional interviews and use their reports for a more detailed and richer description.

This paper is structured along following lines: After introduction in Sect. 1, we introduce the theoretical frame (SCOT) in Sect. 3. India's EVMs are described through the eyes of relevant social groups in Sect. 4. Section 4 further deals with the interpretive flexibility of the EVMs. In Sect. 5 we describe how the controversy was brought to a closure. The paper ends with conclusions in Sect. 6.

3 Theoretical Frame (SCOT)

> What is needed is an understanding of technology from inside, both as a body of knowledge and as a social system. Instead, technology is often treated as a 'black box' whose contents and behavior may be assumed to be common knowledge.
>
> (Layton, 1977: 198 cited after Pinch & Bijker, 1987: 21–22)

The theoretical model we are using is called the Social Construction of Technology (SCOT) developed by Wiebe Bijker and Trevor Pinch from 1983 and 1987. Basically this is a theoretical framework for explaining technological development as a social process. One of the objectives is to argue against the idea that the development of a technology is always logical and rational, following a pre-determined path. From social constructivist perspective one cannot explain why a technology 'works' in society in merely technical terms. It is not the machines but rather the people who decide over uses, meanings, and designs. More specifically relevant social groups (RSG) decide everything that has to do with a technology's development according to their needs, values etc. RSGs can be institutions and organizations, organized and unorganized groups of individuals; "key requirement is that all members of a certain social groups share the same set of meanings, attached to a specific artifact" (Pinch & Bijker, 1987: 30).

Now because there are several RSGs with difference in opinion it often occurs that in the development of a technology there is 'interpretative flexibility'. For example, it is not unusual that users of a technology find alternative ways of using a technology, different from the intended use by the manufacturer. Or it simply means that different RSGs do not agree over a technology's use in society. RSGs can have different views, standards, aims, problem definitions, problem-solving strategies, standards, risk perceptions and so forth. The authors use the term 'technological frame' to bring together all these aspects in one concept.

What usually happens is that over time interpretative flexibility diminishes. Whereas in the earlier stages of a technology's development there is a variety of interpretation attached to it, in later phases one dominant interpretation evolves. This is referred to as 'closure'. "Closure in technology involves the stabilization of an artifact and the 'disappearance' of problems. To close a technological 'controversy', one need not solve the problems in the common sense of the word" (Pinch & Bijker, 1987: 44). Most important in this context is whether the RSGs see the problems of a technology being solved.

4 The Indian EVM Through the Eyes of Relevant Social Groups

The most important and dominant RSGs seem to be the Election Commission of India (ECI), civil society initiative VeTA, a security research team, and economic researchers on EVMs. Political parties, Indian citizens, and EVM manufacturers appear less prominent in the way we describe the development of EVMs. We refer to political parties in rather general terms when some of them raised doubts about the integrity of EVMs. We interviewed a number of Indian citizens however not enough in order to make any general statements. And the EVM manufacturers interestingly stayed out of the debate around EVMs themselves and there is only very little information publicly available about their stance over EVMs. The more dominant RSGs shall be introduced in more detail now.

The ECI has the superintendence, direction and control over the entire process of conducting elections in India. It is a permanent and independent constitutional body (Rana, 2006: 4). This means the ECI, as an autonomous, constitutional body, has the final authority to decide anything that has to do with the EVM, like its operation, security features, and any other changes in the system. Whenever people have questions or concerns about anything related to EVMs they turn to the ECI. In December 2005 the ECI set a technical expert committee under the leadership of Prof. P.V. Indiresan, with Prof. D.T. Shahani and Prof. A.K. Agarwala from the Indian Institutes of Technology (IIT). They were made responsible for examining EVM and making recommendations of changes needed in the system to the ECI (Agarwala et al., 2006: 1).

VeTA, as per its own statement, "is an independent national level Citizens' Forum for promoting Verifiability, Transparency and Accountability in Indian Elections. The Forum is a civil society initiative involving some of the best known computer experts, political scientists, public activists, administrators, academicians, legal professionals etc." (VeTA, 2010). President of VeTA is GVL Narashima Rao, who has written a book titled *Democracy at Risk! Can we trust our electronic voting machines?* (2010), which provides detailed information about concerns regarding EVMs, instances of malfunctioning, suspicions of EVM tampering, suggestions for improvement and more. Hari Prasad is the Technical

Coordinator of VeTA and is managing director of NetIndia Private Limited, an IP Surveillance & Streaming Systems & Solutions company. He is a key technical person in the controversy about EVM security in India. V.V. Rao is the National Coordinator. He is an election watch specialist and is the main petitioners in the public interest litigation filed in the Supreme Court on EVMs (VeTA, 2010). Hari Prasad, as already mentioned, is one of the key technical persons, who identified vulnerabilities in the Indian electronic voting system. In collaboration with a team of researchers and computer science experts he conducted the first non-government security analysis of Indian EVMs. His team included Dr. J. Alex Halderman, professor of computer science at University of Michigan and Rop Gonggrijp, a technology activist who played a major role in banning electronic voting in the Netherlands.

4.1 Problems with Earlier Paper Ballot System and Corruption

> EVMs have changed the way elections are conducted in India. Earlier it used to be a lengthy and tiring exercise including complex procedures. Now the process has been simplified. *(Views expressed by one interviewee)*

India is the biggest democracy in the world and the management of elections is a huge task. In 2014 General Election the elections were done in nine phases from 7 April to 12 May 2014. For approximately 814.5 million eligible voters the ECI set up about 930,000 polling stations all over the country (ECI, 2014b). Before the implementation of an electronic voting system, India was using a paper-based ballot system. Casting and counting votes used to be done manually. In manual elections of the previous kind "a nationwide ballot could consume around 8000 tons of paper and 400,000 phials of indelible ink and require some 2.5 million strong boxes to store them under heavy security until votes were counted" (Kumar & Walia, 2011). Indelible ink is still used today, to mark a person's finger after voting. The counting of votes could take several days or weeks and the number of invalid votes was relatively high. For example, in 1999 there were 7,098,879 votes declared invalid, which went down to 101,625 in 2004. Overall the expenses for printing ballot papers, storage, transportation and hiring personnel for counting votes were becoming higher with every election and counting of votes took a lot of time and effort. Those were main incentives for the ECI to think about changing the system (Table 1).

Not only was the paper ballot system perceived as expensive and inefficient, it also had major security problems. One of the major problems is called "booth capturing". Often it happened that criminal groups, often on behalf of certain candidates or even political parties, captured a polling station and literally stuffed the ballot box with large numbers of votes for the favored candidate. Moreover, the stealing of votes used to be a common practice. One of our interviewees, who

Table 1 Impact of EVMs on the election process

General Elections (A)	1999 (B)	2004 (C)	2009 (D)
Total seats (E-voting)	543 (45)	543 (543)	543 (543)
Eligible electorate	619.55 million	671.49 million	716.99 million
Actual turnout	371.67 million	389.95 million	417.04 million
Polling stations	774,651	687,402	834,919
Number of EVMs used	–	1.075 million	1.368 million
Total invalid votes	7,098,879 (1.91 %)	101,625 (0.043 %)	198,705 (0.048 %)
Invalid EVM votes	–	67,121 (0.017 %)	77,342 (0.019 %)
Quantity of paper saved	–	8000 tons	10,000 tons

Based on Tiwari and Herstatt (2014: 69)

comes a small village in the state of Uttarakhand, said: "I remember very well that in the villages those ballot papers were misused by wrong peoples". He explained that it was not a completely uncommon practice in India that some other person unlawfully cast one's vote. And this happened not only in small villages but also when he moved to a bigger town called Mussoorie, he remembered, "once somebody else voted for me and my vote was misused". As we will explain later, the problem of booth capturing was addressed in the design of EVM and it is now technically much more difficult than in the paper ballot system. Hence in technical terms, cheating the system in this way became more difficult, however with the electronic system there are new potential threats for election fraud.

A general issue, which is still occurring nowadays, is that some Indian politicians tend to "buy" votes. This is especially the case with poor people and slum inhabitants, since they will most likely care more about what to eat than about national politics. "Quite a few Indian politicians may be accused of literally buying their votes from the electorate," explained another interviewee. Hari Prasad put it this way: "The thing is that the politicians in India are buying votes. They buy each vote at 500 to 1000 bucks; sometimes go to 5000 bucks. And money and liquor play a major role in Indian elections. Though there are lots of organizations which are trying to bring awareness among the public, but still the corruption goes". Overall the ECI and Indian citizens we interviewed agree that the election system, as it used to be, posed too many problems and had to be replaced by another system.

4.2 Implementation of EVMs

Because of "recurring expenditure on printing, storage, transportation and security of ballot papers," the ECI discussed electronic voting for the first time in 1977 (Saini, 2013: 68). In collaboration with ECI, Electronics Corporation of India Ltd. (ECIL) developed a prototype by 1979 (Tiwari & Herstatt, 2012). In 1983 they were

used for the first time in the Delhi Metropolitan Council Election. Then in the 1998 Assembly elections in Madhya Pradesh, Rajasthan and Delhi EVMs were used in 16 out of 543 constituencies. The ECI considered their use a success and hence decided to make use of EVMs on larger scale. "Being a peaceful State with a high literacy rate, Goa became EC's choice for experimenting with EVMs on this scale as a 'historic step'" (Rana, 2006: 13), and the ECI saw this as a crucial step in modernizing electoral management. On national scale EVMs were employed in the 2004 General Elections for the first time, and have been used since then in all General Elections and State Assemblies (Rana, 2006: 4). Due to requirements for EVMs in large numbers, another public sector company, "BEL (Bharat Electronics Limited), Bangalore, was involved in mass manufacturing" (Saini, 2013: 68).

The ECI has been proud of introducing this machine and described EVMs as "perfect", "infallible", "tamperproof", with "no need for technological improvement" (Halderman, 2011). But not everybody was so enthusiastic about the implementation. Several sources revealed initial "skepticism of the political parties as well as the intelligentsia" (Saini, 2013: 68). An Indian citizen we interview remembered that "people have been talking about it and there was a huge discussion of course also among intellectuals. Many people were saying it might be that people will manipulate with it and that was one concern. [...] I remember that young people were for that and traditional people were skeptical".

4.3 Voting on an EVM

Before voting, eligible voters have to enroll with the ECI and are issued with individual Voter ID cards. The voter has to carry and show that card at the time of voting to the presiding officer. If the identification is found valid, voting is permitted by the presiding officer of the booth. When the voter enters the Polling Booth and is in front of the machine, a green light flashes on the Control Unit, which indicates the machine is ready to receive a vote. After the voter cast his or her vote, a red light flashes and there is a loud beep sound (12 s long). The next vote can only be cast after the presiding officer resets the "Ballot" button. Once everybody cast their vote a seal consisting of string, paper and wax is opened and the presiding officer presses the black close button. From now on no more votes can be cast and the machine is ready for counting. Armed escorts are transporting the polled EVMs to "strong rooms with a double lock system and guarded 24×7 by armed police" (ECI, 2014b). Strong rooms are supposed to be watched round the clock and monitored by security cameras. On counting day, a second seal is opened and the personnel presses against the result button. On the display the EVM will show the total number of votes cast, the number of candidates and the number of votes for each candidate (Prasad et al., 2010: 3).

4.4 Design Challenges for ECI and Manufacturers

When the ECI delegated ECIL and BEL to design an electronic voting machine, a number of challenges specific to the Indian context, had to be considered. This includes the cost of those machines, power supply, natural hazards, (technological) illiteracy and booth capture.

Due to the huge amount of machines employed all over the country and due to a limited budget, the ECI, one RSG, wanted to keep costs as low as possible. In the eyes of the economic research team, another RSG, this goal was achieved successfully: compared to other nations such as the USA, Indian voting machines are much more inexpensive (Tiwari & Herstatt, 2014: 70). Each machine comes at a price of 8670 plus taxes from the manufacturer (ECIL, 2013), which translates to about 110–120 euros. The geography of India poses challenges, since many polling stations across the country are in remote areas without electricity supply. In past elections the polling officials have made amazing efforts to make voting possible in even the most remote villages in the Himalayan Mountains or the deserts of Rajasthan. Their means of transportation include boats, elephants, camels and ferries and sometimes the polling teams are trekking through many kilometers of jungle (Chandrashekhar, 2014; Rana, 2006: 1). Due to those obstacles Indian EVMs are entirely operating on battery power and are standalone machines, not connected to any network (Prasad et al., 2010: 3). Compared to the old paper ballot boxes, EVMs are lighter, which also makes transportation easier. So generally EVMs are a relief for the ECI.

Extreme temperatures—from the freezing Himalayan mountain to boiling heat in deserts—and other environmental hazards like dust and pollution, pose further challenges for EVM design and operation. In certain areas it may rain so hard that the roads to the polling centers are blocked and the only way is travelling on elephant back (Rana, 2006: 162). EVMs must withstand those extreme conditions and have the capacity to absorb external shocks. Often EVMs are stored for extended periods in facilities that lack climate control. The Expert Committee of the ECI wrote in one of their reports about dangers from "attack by vermin, rats, fungus" that might cause malfunction (Agarwala et al., 2006: 6). In the eyes of the government these kinds of challenges are successfully addressed in the EVM design: The government of India has stated they are robust enough "to withstand rough handling and variable climatic conditions" (GOI, 2009: 181).

The total adult literacy rate in India in 2008–2012 was about 62.8 % (UNICEF, 2014). Hence the machines need to be easy to use and not require written instructions. Political parties and candidates use graphical symbols in their campaigns, which are then found on the ballot unit (BU). "The Presiding Officer will have a card-board replica of the ballot unit with him" (GOI, 2009: 182), to demonstrate to the illiterate voters how to vote. An Indian citizen explained in an interview: "Illiterate people find it easier to press a button than putting stamp on a paper". Hence in technical terms electronic voting does not pose any problems for the

illiterate. Moreover, blind voters have also been taken into consideration and the machines are made braille-compatible.

On the other hand, there are still people in India who are unfamiliar with technology and there have been some reports of tribal people who "felt intimidated" by the machines (Rao, 2010: 44). The problem of booth capture as such cannot be prevented with the EVMs. "However, the machine cannot register more than 5 votes in a minute or 300 votes in an hour whereas a ballot box could be stuffed with any number of ballot papers" (GOI, 2009: 184).

Considering all the aspects addressing particular challenges in India, we can make some general statements. From a technical engineering perspective EVMs seem to be well adapted to the particular circumstances: The machines are described as light and robust and do not need electricity. They can be carried easier than earlier ballot boxes, they withstand extreme climate conditions and they work in remote villages without power supply. From an economic perspective EVMs are a good solution, because they are cheaper than the earlier paper based system and do use considerably less paper. Counting is much faster and efficient and there is no need to hire extra personnel, which saves money as well. From a social perspective, EVMs take into consideration specific needs so that everyone is theoretically able to vote. And from an environmental perspective it has been argued that because of the high savings on paper EVMs have less of an impact than the paper ballot system. All of these points were incentives for the ECI to be optimistic about the machines and use the frame 'the perfect EVM'.

4.5 Economic Research Team Framing the EVM as Frugal Innovation

Tiwari and Herstatt (2014: 71) have described the Indian EVM is a "frugal solution" that preserves democratic processes in India. It is a "technically robust and cost effective solution with creditable acceptance" not only in India but also in other developing nations in Asia and Africa (Tiwari & Herstatt, 2014: 71). For instance, Indian EVM were employed in Bhutan and the reaction from the Election Commission of Bhutan was: "The decision was made in view of the EVM's simplicity and ease of use, portability, being battery-powered as well as convenience, speed and reliability in counting" (EC Bhutan, 2011 cited after Tiwari & Herstatt, 2014: 70). They see the particular attraction of the machine in its "low-tech system, which does not need electricity or Internet networks and yet provides a 'good-enough' solution" (Tiwari & Herstatt, 2014: 71).

5 Interpretative Flexibility of the EVM

So far we have described two RSGs and their technological frames. The ECI uses the frame 'the perfect EVM' and the economic research team uses the frame 'low-price, good enough EVM'. Both RSGs do not problematize the EVM and basically see the EVM very well fit for the Indian context. Both for the ECI and economic researchers the simplicity of design plays an important role. Resource constraints, and a number of design challenges, resulted in a voting system that is considerably less complex than other EVMs employed elsewhere. Alex Halderman (Assistant professor of electrical engineering and computer science at the University of Michigan) in a personal interview explained about the US voting machines that they are "very complex, large, expensive, computer like systems [. . .] they run full-fledged operating systems and have regular software security problems". The simplicity of Indian EVMs shall be explained in more depth below. It has been argued that the simple design does also have negative aspects, especially when it comes to security issues. In this sense there was interpretative flexibility created around the EVM.

5.1 Alleged Vulnerability and Security Holes

The debate on the integrity of the EVMs started with the 2009 General Election, after an election outcome that was surprising for some political parties, election analysts and others. Some raised the suspicion that the dubious election outcome is connected to malfunction or manipulation of EVMs. The parliamentary chairperson of the BJP L.K. Advani raised doubts about the security of EVMs and demanded from the ECI to revert to ballot paper, unless EVMs are proven to be tamperproof (Jha, 2009). Other leaders of political parties like Ghulam Nabi Azad (Congress party) stated: "EVMs were manipulated during the poll which resulted in defeat of many Congress candidates" (IANS, 2009). Chandrababu Naidu (Telugu Desam Party) and Jayalalithaa (AIADMK) raised concerns as well and "the EVM debate had acquired urgency and national prominence" (Jha, 2009). What were reasons for making such statements? What is behind these allegations?

The civil society initiative, VeTA, looked into reported instances of EVM malfunctioning in depth and detected vulnerabilities in the electronic voting system. From their perspective "three essential elements have come to the fore as universally important for a voting system" (Rao, 2010: 189–190): It should be transparent, meaning, "voters should be able to 'observe' the voting and counting process without any specialized knowledge" (Rao, 2010: 189). Voters should be able to verify that their vote has been cast properly "through a proper examination of the physical record of ballots" (ebid.). In terms of accountability, problems or attempts at election fraud should be detectable instantly in order to introduce the necessary steps for remedy. VeTA finds that all of these criteria were met

appropriately with the earlier paper ballot system, yet the current electronic system does not meet any of them: voters have no way of knowing whether their vote is cast correctly or not. There is no physical proof for cross verifying the results from the EVM in case of doubt. If something goes wrong inside the machine or the machine has been manipulated there is no way of proving it (Rao, 2010: 190). Clearly VeTA has a different technological frame than ECI and the economic research team. They use the frame "vulnerable and risky EVM".

They expressed their concerns to the ECI in form of writ petitions. V.V. Rao, the national coordinator of VeTA, played a major role in the communication with the ECI. In response, the ECI organized a public challenge for all political parties, petitioners, activists and anyone else "to come and demonstrate the points made in their allegations" (ECI, 2009). Present at this demonstration were the technical expert group appointed by ECI and engineers representing the manufacturers ECIL and BEL. The ECI had organized 100 real EVMs from various states for this and promised them full access to the machine. The team of VeTA took up this challenge and came to demonstrate how to tamper with the EVM on 17th August 2009 (ECI, 2009).

What were the results of this presentation? According to the official ECI report "none of the persons, who were given the opportunity, could actually demonstrate any tamperability of the ECI-EVM, in any of the hundred machines put on display. They either failed or chose not to demonstrate. The Election Commission would like to underline that it always had a firm conviction and complete satisfaction that EVMs could not be tampered with" (ECI, 2009). However, the interpretation of VeTA of this meeting is quite different from this official report. According to their statements the team was halted after 10 min (Rao, 2010: 103). When they started to open up the machine and inspect the insides of it, representatives of ECIL claimed that they were doing reverse engineering. In the eyes of the manufacturers and the ECI reverse engineering could not be allowed and in fact violates the property rights of the manufacturers. The ECIL representatives threatened the team will legal actions in the Supreme Court. After this incident the ECI modified the public challenge and stated: "You may do only normal tampering" (Rao, 2010: 108).

5.2 EVM as a Black Box

This suggests that the security of EVM relies on the secrecy of what is inside the machine and how it works technically. Both ECI and manufacturers treat the machine like a black box, because everything that has to do with the insides, technical details, source code etc. is held secret and is not publicly disclosed. Prof P.V. Indiresan, chairman of the expert committee on EVMs stated publicly that: "In these government firms actually not more than 3–4 people know what the source code is. It is kept secret. These are fairly junior officials they are not very senior officials. From what we know of their character they will not disclose." In other words, not even the ECI knows about technical details of the EVM software and

they rely entirely upon the integrity of the manufacturers. In this respect the security of EVMs relies on trust.

Interestingly the manufacturers themselves seem to stay completely out of the debate. Hari Prasad explained to these authors that the only argument the manufacturers make over and over again is: "trust us the machines are secure. The chip manufactures Microchip, Japan and Renesas, US are reputed companies and they will not cheat us, we trust them". The kinds of responses that both ECI and manufacturers make towards concerned people are not technical. However, the kind of questions VeTA asked to them and the problems they identified were often technical in nature. So the kind of language that is used differs.

5.3 Opening up the Black Box

The discussions took a radical turn, when in February 2010 Hari Prasad was approached by an anonymous source who gave him full access to a real EVM. In collaboration with experts on voting security including Alex Halderman from the US and Rob Gonggrijp from the Netherlands, they conducted the first non-government security analysis (Prasad et al., 2010). This was the first time anyone outside of the government or manufacturers saw what is inside the machine. Their results were made open to the public, so that Indian citizens could form their own opinion. They conclude, "in spite of the machines' simplicity and minimal software trusted computing base, they are vulnerable to serious attacks that can alter election results and violate the secrecy of the ballot". To prove this claim they demonstrated two attacks "using custom hardware, which could be carried out by dishonest election insiders or other criminals with only brief physical access to the machines".

Neither the manufacturers ECIL and BEL nor the ECI have ever released detailed technical descriptions of the EVMs' inner workings. The authors describe the hardware of an EVM based on their own observations and tests: "The control unit contains the main circuit board. The centerpiece is the EVM's CPU, a Renesas H8/3644-series microcontroller driven by an 8.8672 MHz crystal oscillator" (Prasad et al., 2010: 4). The display board connects to the main circuit board via a 16-pin ribbon cable. The control unit connects to a ballot unit where the voter presses the button. The ballot unit board is described as a "simple device," because it has no CPU of its own. It uses two electronically programmable logic devices that interpret signals coming from the control unit. In their technical terms the EVMs use a "simple embedded system design". Most other electronic voting machines employed worldwide "rely on commodity operating systems and run election software containing tens or hundreds of thousands of lines of code, the EVM software is compact, consisting of only a few thousand instructions that run directly on the hardware" (Prasad et al., 2010: 5).

We will not go into more detail about the insides of EVMs. But there are some relevant conclusions to draw from their analysis: The authors are disclosing

technical details about EVMs that were intended to remain secret because of property rights. Descriptions of ECI and manufacturers of EVMs are limited to instructions on how to use and operate the machine.

Hence the kind of language they are using differs from the computer science language the critics employ. Another important point is concerning the simplicity of EVM design. In the economists' technological frame of 'low-price, good enough technology' simplicity is regarded a beneficial aspect of the EVM. In their terms the simplicity of EVMs is mainly explained due to the minimalistic design and the low price. In the 'perfect machine' frame of the ECI simplicity of EVM design is the necessary outcome, resulting from the challengers that had to be faced in the Indian context. The simple design is necessary mainly because of budget constraints, and to enable an easy voting experience for all citizens. In terms of the security researchers' simplicity refers to the technical insides of the machine. From their perspective EVMs are simple compared to other voting machines they have analyzed previously. Yet the simple design poses significant security problems and "makes attacks involving physical tampering far easier". We propose both the members of VeTA and the security researcher team use the technological frame of 'vulnerable and risky EVM'.

In their analysis the researchers identify three different classes of vulnerability: dishonest look-alikes, tampering with machine and insider attacks using secret software. Those are examples of possible ways to physically manipulate the machine and change election outcomes. In all cases criminals would need physical access to a certain percentage of all machines. They explain that EVMs are usually stored in large numbers; this highly concentrated way of storing increases the risk for attacks and makes tampering in large numbers theoretically possible.

How realistic are those two attack scenarios? One might argue that considering the large amount of EVMs (over 1.7 million) those attacks are simply not manageable. The security researchers argue that this might not even be necessary. "A small number of tightly contested seats often determine which party holds a majority in the parliament" and hence it would be enough to tamper with a 'small' fraction of EVMs (Prasad et al., 2010). Another obstacle to realize those attacks is posed by the seals. However, those seals are described as extremely weak, consisting of stickers, strings, melted wax and plain paper labels. Those are rather simple materials, which could be easily bought at the supermarket. This way of sealing has been taken over from the earlier ballot paper system. Ballot boxes used to be closed and sealed with wax in a similar fashion (Hauser & Singer, 2001: 306–307). It is a simple, low-tech solution and it is debatable, whether this system is secure enough.

Another major security flaw in their opinion is the fact that the Indian EVM does not produce any physical record of the votes cast, which is also a major concern raised by VeTA. However, there is a possibility of cross verification. In a public discussion Prof. P. V. Indiresan (chairman of technical expert committee) explains: It is possible to "check *every single vote* that has been done, who did it and to whom the person voted. [...] It is possible to cross check, who voted for what and when, because there is a real time clock in every machine". This means that it is possible to find out what individual citizens votes for and hence violates the secrecy of the

ballot. The security researchers propose to implement a paper trail (VVPAT) that would produce a small print out for every vote cast. This would allow for a different kind of cross verification. Moreover, voters could see with their own eyes whether their vote has been recorded correctly. All in all, they argue that EVM are treated as black boxes because everything that has to do with the technology's insides is kept secret. The machine itself is a black box, because the voter cannot verify with her own eyes whether her vote is cast correctly.

We have now pointed out that the EVM has interpretative flexibility and proposed a third way of framing the machine, which is fundamentally different from ECI's and economists' frame. I now look at how the 'vulnerable and risky EVM' frame was received by ECI and its expert committee. Finally, I will explain how the interpretative flexibility diminishes and the controversy is closed.

5.4 Response by ECI and Expert Committee

On 29 April 2010 Hari Prasad appeared on a Telugu TV channel. He made a demonstration of how to tamper with EVMs and publicly announced that he gained access to a real EVM, manufactured by ECIL, from a source whose identity he wants to protect (ECI, 2010b). After this he was charged with the theft of the voting machine and according to his own account: "they put me in jail for eight days". The official comment by the ECI was: "While the Commission has every respect for technologists and is always open to suggestions for improvement in the voting system, it cannot overlook any illegal act, especially the theft of a public property like the EVM given in its custody for conduct of elections" (ECI, 2010a). In this sense the ECI realized that the electronic voting system could be improved. Hari Prasad and his team aimed an improvement of the EVM security, but in order to do so they needed full access to a machine. This was not granted by the ECI, but they have found a different way and exposed a number of vulnerabilities.

The fact that Prasad gained access to a machine itself could be interpreted as an indication that it *is* possible to gain access to the machine. Either the security measures to protect EVMs were not strong enough or the anonymous source was an insider being concerned about EVM security as well. Although the ECI later claimed that they are open for suggestions their initial reaction was the arrest of Hari Prasad. Fellow researcher Alex Halderman's comment on this was: "This is like the pentagon paper situation here. This is a case where citizens are critical against those in power and those in power are retaliating against them for their criticism. We want you to work with us and we'd be very happy to work with you to make this system better. That's all of our goal, to have secure and fair elections in India" (Halderman, 2011, panel discussion).

Initially the ECI denied all allegations made by petitioners and the security researchers. However, this changed over time. On August 9, 2010, a workshop for electronic voting technology and trustworthy elections took place in Washington,

DC. In this workshop a panel discussion on the Indian EVM was scheduled. First panelist was P.V. Indiresan, who was the chairman of the technical expert committee, set up in 2005 by the ECI, to examine EVMs and give recommendations (Agarwala et al. 2006: 1). Prof. Indiresan used to be director of the Indian Institute of Technology—Madras (IIT). Second panelist was Narasimha Rao, president of VeTA. Third, Alok Shukla, working for the Election Commission of India. And forth J. Alex Halderman, professor of computer science at University of Michigan, specialized on voting security.

P.V. Indiresan argued that all allegations of possible attacks are theoretical in nature. In practice EVMs are tamperproof until somebody can bring evidence that past elections have been manipulated. Similarly, the ECI representative Alok Shukla, stayed with the technological frame of 'the perfect machine' and denied that any of the allegations of EVM malfunctioning or possibilities of tampering are practically possible. Both Shukla and Indiresan concluded that the allegedly possible ways to tamper with EVMs are very unlikely to happen. Contrary to the allegations made they both argued that the system of sealing the EVMs is highly secure and nobody has ever managed to tamper with the seals. At that point they did not see any reasons to change the system.

6 Closure of the EVM Controversy

Different relevant social groups had different perspectives on the alleged tamperability and security problems with EVMs. Moreover, the kinds of remedies that have been proposed by them also differ and it is worth looking at them. In the SCOT model closure of a technological controversy does not mean to 'solve' a problem in the common sense of that word, but rather look at whether relevant social groups *see* the problem as being solved.

When presidents and heads of political parties raised concerns about EVM security towards the ECI in April 2010, they considered it might be necessary to revert to the paper ballot system (Jayalalitha et al., 2010). They argued, "many democracies like Germany, Ireland and Holland and the United States of America have either banned use of EVMs or imposed stringent safeguards for their use" (Jayalalitha et al., 2010). Also VeTA argued that reverting to paper ballot could be a solution to the problem. From their perspective the paper ballot system is the most transparent and verifiable way of voting and this is the reason why other countries are using paper ballot. The ECI responded that Indian EVMs are not comparable to any other EVM employed elsewhere, because they are standalone machines, which cannot be networked and do not have an operating system (ECI, 2010b). They did not consider reverting to the old paper based system as a viable option.

At the beginning of the controversy the ECI generally refuted that there were any security flaws in the system and stayed with the frame of 'the perfect EVM'. They also argued that there are much more advantages in the electronic system compared to the paper system (concerning invalid votes, paper saving, booth capture,

efficiency of counting etc.). In terms of security the general assumption made by the ECI is that the risk of EVM being manipulated is very low. At a later stage of the controversy the ECI acknowledged that the alleged security flaws and ways to cheat the system were at least possible in theory. However, in practice elections in India have never been manipulated and hence there are no reasons to adopt any changes. After continuous discussions with concerned people and activist groups the ECI "finally realized that the problem is real". In the 2014 General Elections for the first time a paper trail (VVPAT) has been added to the EVMs. Although this paper trail is only introduced on an experimental level, this has been a relief for most of the people concerned.

We argue that the interpretative flexibility of EVMs has diminished to the extent that almost everyone agrees on the EVM in its current use. Hari Prasad said that he and his team are still fighting and Rob Gonggrijp: "in my opinion, India is trying to do as little as possible in terms of actual change, merely experimenting with paper trail here and there" (Gonggrijp, personal email). However, we sense that the general opinion about the current EVM is positive. All of the 25 Indian citizens interviewed within this research have been overly positive about EVMs and generally regarded the security much higher compared to the old ballot paper system. And although there have been instances of EVM malfunctioning in the current elections, those instances are so marginal that they can almost be neglected. Hari Prasad is optimistic that the EVM with paper-trail will succeed, although the federal government did not allocate the necessary funds yet to implement the VVPAT on large scale.

7 Conclusion

We explained the social construction of the Indian EVM. The concepts of relevant social groups, interpretative flexibility, technological frame, and closure turned out to be useful in structuring and analyzing the case study. Interpretative flexibility occurred when political parties, VeTA and others opposed ECI's technological frame of 'the perfect EVM', by claiming that EVMs are vulnerable and pose a risk for Indian democracy. The Security research team led by Hari Prasad and VeTA used the frame 'vulnerable and risky EVM'. In many respects the electronic voting system has advantages over the paper ballot system. Yet in terms of transparency and verifiability, VeTA and the security research team claim that the paper ballot system had advantages. More radically it has been argued by them that paperless electronic voting will never be secure. Initially the ECI denied all their claims and arguments and was reluctant to make any changes. However, in the 2014 elections a paper trail was added to the system on experimental basis. This decision was decisive for closure to occur in the controversy. Yet the controversy has not only been closed in technical terms. Many of the allegations that were made about EVM malfunctions and manipulation possibilities were simply answered by neglecting them. VeTA and the security research team have made a number of technical claims

in terms of security flaws. Generally, the way the ECI and manufacturers responded was not with technical language.

Rather everything that has to do with the inside of the technology was concealed and kept secret. Keeping technical details like the source code secret (known by only three or four people), was interpreted differently among RSGs. ECI, its technical expert committee and manufacturers believed the secrecy of technical details was necessary to prevent reverse engineering and to conserve property rights. In their eyes this was a good base for a trustworthy security system. However, VeTA and the security researchers argued that this is a major security flaw. Looking at the present situation of electronic voting in India we think it is fair to say that the EVM has stabilized and the controversy has been closed, although there are still some isolated individuals who fight on for their voice to be heard.

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References

Agarwala, A. K., Shahani, D. T., & Indiresan, P. V. (2006). *Report of the expert committee for evaluation of the upgraded electronic voting machine (EVM)*. New Delhi: Election Commission of India.

Biswas, S. (2014). India's BJP scored a historic win. *BBC*. Retrieved June 5, 2014, from http://www.bbc.com/news/world-asia-india-27435647

Chandrashekhar, V. (2014). India's election: Five questions on the world's largest democracy. *The Christian Science Monitor*. Retrieved May 29, 2014, from http://www.csmonitor.com/World/Asia-South-Central/2014/0407/India-s-election-Five-questions-on-the-world-s-largest-democracy-video

ECI. (2009). *Electronic voting machines – regarding*. (PN/ECI/41/2009). New Delhi. Retrieved June 3, 2014, from http://eci.nic.in/eci_main1/current/pn080809.pdf

ECI. (2010a). *A background note on investigation against Mr. Hari Prasad and others in the case of the missing EVM in Maharashtra*. Retrieved June 4, 2014, from http://eci.nic.in/eci_main/recent/NOTE_HARIPRASAD.pdf

ECI. (2010b). Letter No. 51/8/16/9/2010-EMS. Retrieved May 17, 2014, from http://www.indianevm.com/evm-resources.php

ECI. (2014a). *Voter turnout highlights of Lok Sabha election 2014*. Retrieved June 19, 2014, from http://eci.nic.in/eci_main1/SVEEP/VoterTurnoutHighlightsLokSabha2014.pdf

ECI. (2014b). *General elections – 2014: Schedule of elections*. New Delhi: Election Commission of India.

ECIL. (2012–2013). *46th Annual Report 2012–13*. Hyderabad: Electronics Corporation of India Limited.

GOI. (2009). *General elections 2009: Reference handbook*. New Delhi: Press Information Bureau. Retrieved March 23, 2014, from http://www.pibaizawl.nic.in/pr/archive/e2009/rhandbook_english.pdf

Halderman, A. (2011). *Security problems in India's electronic voting system (CRCS Lunch Seminar)* [Lecture]. Boston: CRCS. Retrieved March 15, 2014, from https://www.youtube.com/watch?v=mCg3KUtkypo

Hauser, W., & Singer, W. (2001). The democratic rite: Celebration and participation in the Indian elections. In N. G. Jayal (Ed.), *Democracy in India* (pp. 289–310). New Delhi: Oxford University Press.

IANS. (2009). Voting machines 'manipulated' in Orissa polls, claims Azad. *Thaindian News*. Retrieved May 1, 2014, from http://www.thaindian.com/newsportal/politics/voting-machines-manipulated-in-orissa-polls-claims-azad_100206516.html

Jayalalitha, J., Biswas, D., Prasad, B. S. B., et al. (2010). *All-party meeting to discuss Electronic Voting Machines (EVMs) – Potential for manipulations – Reg*. Retrieved May 29, 2014, from http://www.indianevm.com/evm-resources.php

Jha, S. K. (2009). Advani has doubts about EVM, wants ballot papers back. *The Indian Express*. Retrieved March 28, 2014, from http://archive.indianexpress.com/news/advani-has-doubts-about-evm-wants-ballot-papers-back/485248/

Kalita, P. (2014). An EVM that 'votes' only for BJP stuns poll staff in Assam. *The Times of India*. Retrieved May 25, 2014, from http://timesofindia.indiatimes.com/news/An-EVM-that-votes-only-for-BJP-stuns-poll-staff-in-Assam/articleshow/33153152.cms?

Kumar, S., & Walia, E. (2011). Analysis of Electronic Voting System in Various Countries. *International Journal on Computer Science and Engineering, 3*(5), 1825–1830.

Pinch, T. J., & Bijker, W. E. (1987). The social construction of facts and artifacts: Or how the sociology of science and the sociology of technology might benefit each other. In W. E. Bijker, T. P. Hughes, & T. J. Pinch (Eds.), *The social construction of technological systems: New directions in the sociology and history of technology* (pp. 17–50). Cambridge, MA: The MIT Press.

Prasad, H., Halderman, A., Gonggrijp, R., Wolchock, S., Wustrow, E., et al. (2010). *Security analysis of India's electronic voting machines*. Retrieved March 12, 2014, from http://indiaevm.org/evm_tr2010-jul29.pdf

Rana, M. S. (2006). *India votes: Lok Sabha and Vidhan Sabha elections 2001–2005*. New Delhi: Sarup & Sons.

Rao, G. V. L. N. (2010). *Democracy at Risk! Can we trust our electronic voting machines?* New Delhi: VeTA. Retrieved March 28, 2014, from http://www.indianevm.com/book_democracy_at_risk_2010.pdf

Saini, M. (2013). Electronic voting machine: New attack vector. *VIVEK: Issues and Options,* (2). Retrieved May 4, 2014, from http://de.scribd.com/doc/124478041/Vivek-Issues-n-Options-February-2013

Tiwari, R., & Herstatt, C. (2012). Frugal innovation: A global network's perspective. *Die Unternehmung, 66*(3), 245–274.

Tiwari, R., & Herstatt, C. (2014). *Aiming big with small cars. Emergence of a lead market in India*. Cham: Springer.

UNICEF. (2014). *UNICEF India statistics*. Retrieved May 12, 2014, from http://www.unicef.org/infobycountry/india_statistics.html

VeTA. (2010). *About VeTA*. Retrieved May 22, 2014, from http://www.indianevm.com/about-

Renewable Energy in India: Policies, Trends and Foreign Direct Investments in Research and Development

Aditya Prasad Bhagwat and Rajnish Tiwari

1 Introduction

India has the second largest population in the world with a median age of around 27.3 years (Ministry of Health & Family Welfare, 2006). It is the second largest among emerging markets and developing economies and globally ranks third in terms of Gross Domestic Product (GDP) based on Purchasing-Power-Parity (PPP) valuation (International Monetary Fund, 2015). These demographic and economic development indicators point towards a rapidly developing economy powered by the working age youth.

Energy is a critical enabler of growth and in the case of advanced economies secure access to modern sources of energy has contributed in their development and prosperous growth (OECD/IEA, 2015a). India is still unable to provide secure energy access to all of its population. According to a statistic from 2012, only 78.7 % of the population had access to electricity (The World Bank, 2015). Furthermore, those with access to electricity face problems such as electricity shortage and peak power deficit (CEA, 2015a). Besides providing energy access and energy security to meet the commercial demand and sustain economic growth, affordability of energy to all of its population is important in case of India. India, in the year 2010, had the largest share (32.9 %) in the global total of 1.2 billion extremely poor people, who were living on less than $1.25 a day (United Nations, 2014). The energy challenge therefore, is not only limited to generation of additional and/or cheaper power by the power producers but also involves ensuring the supply of that power at very less per unit costs to the current as well as prospective consumers spread across a large range of income. These amounts must also include the costs that are necessary to build the additional infrastructure capable of delivering the

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power to the remote and/or rural regions which are mostly inhabited by people with lower income. RE technology which is able to provide off grid power and decentralized system solutions such as solar street lighting systems can therefore be one of the appropriate solutions especially in case grid connectivity is not physically viable or is not cost effective.

India is the fourth largest energy consumer, the third largest electricity producer in terms of gross output and also the third largest Carbon Dioxide (CO_2) gas emitter in the world (BP, 2015a). The world is heading towards dangerous climate change owing to rapid increase in the Green House Gas (GHG), particularly CO_2, emissions (WMO, 2015). This makes India's stand on climate change crucial to mitigate the risk. India's economical, demographical and environmental position on today's global stage compels one, therefore, to consider the extent of international collaboration between India and the World, if one has to look at the future of energy in the world.

It has become imperative to look at India's domestic RE endeavors and international RE collaborations, if one has to understand the future of RE innovation and RE related business in the world. For instance, in an interview published by the US based National Bureau of Asian Research (NBR), Manish Bapna of the World Resources Institute (WRI) states "India is a key country in the efforts of the international community to shift to a sustainable, low-carbon path that will confront climate change, improve human health, and foster prosperity for all" (Luthra, 2014: 1). As stated earlier, RE can provide off grid and decentralized solutions for increasing the accessibility and affordability. RE power projects can also be connected with the grid thereby reducing the overall deficit and achieving energy security. Pursuing the goals of energy security, energy access and mitigation of climate change while taking care of the affordability points logically towards RE solutions with localization approach in R&D and manufacturing for catering to the Indian market. A report by the 'International Science Panel on Renewable Energies (ISPRE)' states, "Coherent R&D programs for renewable energies are key elements in designing political strategies, not only for renewable energies but also for carbon mitigation" (ISPRE, 2009: ii). The report argues that strong efforts nationally and internationally are necessary to establish RE R&D in almost every part of the world (ibid). This favors the theme of globalization of RE R&D. The report also mentions that "R&D has a particular role to play in helping to adapt technology to local needs and build capacity through the fostering of skills and local enterprise" (ISPRE, 2009: vii).

2 Energy Situation in India

It has already been mentioned that India is the fourth largest energy consumer in the world. The current situation of energy in India particularly the Power generation and the contribution of RE has to be understood in the beginning. In 2014, India's total primary energy consumption was 4.9 % of the world total (BP, 2015a). The

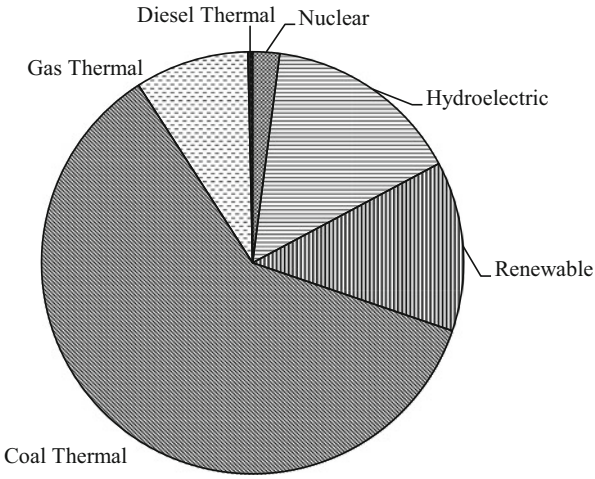

Fig. 1 All India installed capacity of power stations in GW. Source: Own illustration based on CEA (2015b)

share of renewables consumed in India is just 2.18 %. The energy production increased 4 %, the highest growth rate in 5 years, while consumption increased 7.1 % (all time high) over the previous year (BP, 2015b). It is important to note here that India is still highly dependent on the fossil fuels for its energy demands. In 2014, India's increase in both production and consumption of coal was highest in the world (ibid). India was the fifth largest coal producer in 2014 and the third largest coal market in the world (ibid). The dependency on coal and gas for energy is emphasized by Fig. 1 which shows the mode wise breakup of installed electricity generation capacity (Utilities) released by Central Electricity Authority (CEA) in India. The total installed capacity for utilities stands at 280.328 Giga-Watt (GW) as on 31.10.2015 (CEA, 2015b).

The share of RE based electricity in electricity mix is also an important indicator of the present situation. This stands at around 6 % of the total electricity generated in India and the government intends to increase it to 15 % in the next 10–12 years (PIB, 2015a). Total gross electricity generation (Utilities) in India in 2014–2015 was 1105.446 billion units[1] out of which 5.59 % i.e. 61.780 billion units electricity was generated from RE (CEA, 2015a). These figures give a static picture of the share of RE in consumption, installed capacity and energy mix. It is essential to look at the growth rates and other dynamic indicators. According to the country specific insights published in the 'BP statistical review of World Energy, 2015', RE consumption grew 11.5 %, the fastest among all fuel types over the previous year, in 2014 in India. Renewables in power in India, according to BP, have grown more than six times over the last 10 years (BP, 2015b). These growth rates show that although there is a huge dependency on coal, cleaner sources of energy are being

[1] 1 unit = 1 kW-h, 1 billion unit = 1 TW-h

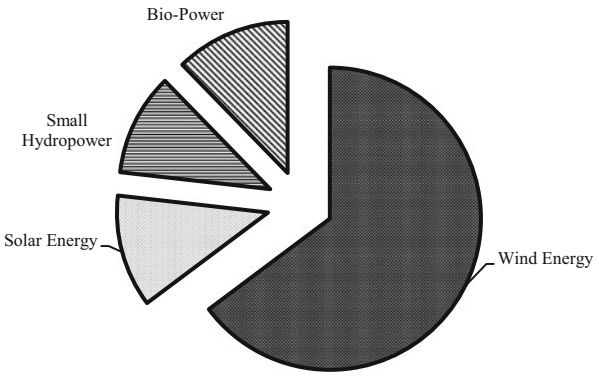

Fig. 2 Mode wise breakup of installed RE capacity in GW. Source: Own illustration based on CEA (2015b)

increasingly adopted in India. Currently there is an installed renewable power generation capacity (grid interactive) of 38.8216 GW[2] in India according to Ministry of New and Renewable Energy (MNRE), Government of India (GoI) (MNRE, 2015a). At this stage it becomes necessary, to look into certain relevant aspects of this capacity. Figure 2 shows the mode-wise breakup of the total capacity as on 31.10.2015 in GW.

It is interesting to note that out of the total RE capacity, almost 95 % of the capacity belongs to private sector and around 5 % to the state governments, with no generation capacity directly under central government (CEA, 2015b). Large involvement of private sector is indicative of the business opportunities present. Wind Energy dominates the Indian RE market. To get an idea of the size of the Wind sector in India, it is essential to note that India is the fifth largest Wind Energy producer in the world after China, the US, Germany and Spain in terms of installed capacity (MNRE, 2015b). India is also an important Wind Turbine and Equipment manufacturing hub with annual production capacity reaching 9500 MW in 2014 (MNRE, 2015b). Solar energy, although much behind Wind energy in terms of installed capacity, is receiving increased attention both domestically and internationally due to the ambitious targets set by the government, largely untapped estimated potential, a national level solar mission and other development initiatives taken by the government. The potential power generation capacity has been estimated and the targets for the installed capacities till 2022 have been determined by the government (PIB, 2015b). These targets are placed alongside the installed capacities in Fig. 3 in GW. The sector-wise estimated potential capacities are mentioned above the corresponding graphs of the sector in boxes.

The significant thing here is the particularly ambitious target for solar energy considering the current standing of solar based capacity. Also, the estimated potential of solar energy based capacity is quite large in comparison to that in

[2]Hydropower plant with capacity under or equal to 25 MW is considered in RE Power and is termed as Small Hydro Power. Hydropower plants with more than 25 MW are considered in conventional power and not included in RE Power in India.

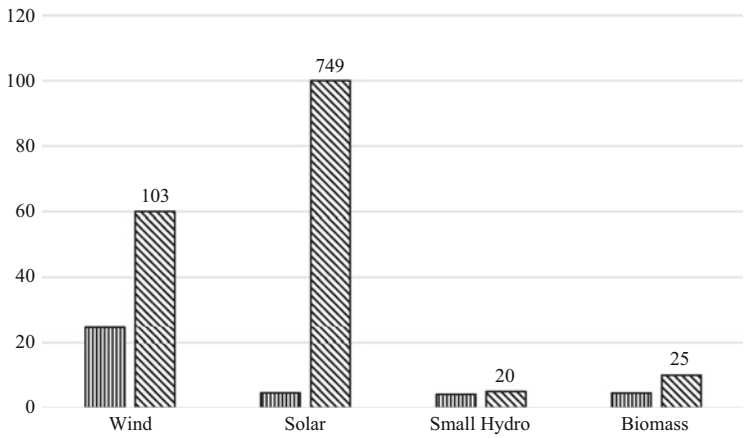

Fig. 3 Current (Oct 2015) installed RE capacity vs. target till 2022 estimated potential in GW. Source: Own illustration based on official data (PIB, 2015b)

other subsectors. Looking at this figure, it is obvious that Wind and Solar energy sectors have importance in the Indian RE market. These targets are important indicators for understanding the focus of the government as well as the future of RE business in India. From an outsider's perspective these can be viewed as internal targets. One may argue that there exists a need to consider the targets, which are committed by India on an international platform, with a certain obligation to achieve them in set time. These can also serve as another indicator for future of RE business in India as well as of India's efforts in mitigation of climate change.

India has formally committed in its 'Intended Nationally Determined Contribution' (INDC) to 'United Nations Framework—Convention on Climate Change' (UNFCCC) that emission intensity of its GDP is to be reduced by 33–35 % by 2030 from 2005 level and around 40 % of the cumulative installed power capacity is to be achieved from non-fossil fuel based energy resources (GoI, 2015). In the same submission, it is stated that India intends to "build capacities, create domestic framework and international architecture for quick diffusion of cutting edge climate technology in India and for joint collaborative R&D for such future technologies" (ibid). This commitment is highly relevant as it is indicative of the attention given to encourage diffusion of climate technologies and collaborative R&D by the highest level of government.

Paris based International Energy Agency (IEA), in its World Energy Outlook special report titled 'Energy and Climate Change' has projected (OECD/IEA, 2015b) that in India:

1. Wind energy based installed capacity is projected to be 80 GW by 2025 and to 109 GW by 2030 at Compound Average Annual Growth Rate (CAAGR) of 10.4 % whereas solar energy based capacity is expected to increase to 101 GW by 2025 and to 139 GW by 2030 at CAAGR of around 28 %, the fastest among other energy sources.

2. Wind energy based gross electricity power generation is expected to increase to 149 billion units by 2025 and to 210 billion units by 2030 at a CAAGR of 11.6 % whereas for solar energy, it is projected to increase to 161 billion units by 2025 and 224 billion units by 2030 at a CAAGR of more than 30 %, the fastest among other energy resources.

These projections paint an optimistic picture for the growth of RE based power in India, particularly in case of solar energy. This fortifies the argument that RE sector as a whole and in particular solar energy sector, has a lot of untapped growth potential in India.

3 Relevant Renewable Energy Policies, Initiatives and Statistics

Ability of a sector to attract foreign investment depends upon several factors such as financial policies of the government and banking institutions, economic situation, legal framework, market barriers and business opportunities etc. Thus, it becomes necessary to look at the policy measures and initiatives etc. which create an environment for collaboration. Market attractiveness is complex to analyze and difficult to quantify. However, there are indicators published by different agencies that help point in the right direction for investment and opportunities.

Professional services organization Ernst & Young (EY) which publishes Renewable Energy Country Attractiveness Index (RECAI) quarterly, has ranked India third on its index after the US and China (EY, 2015a). According to RECAI, the countries have been ranked 'on the attractiveness of their renewable energy investment and deployment opportunities, based on a number of macro, energy market and technology-specific indicators' (EY, 2015a). The report recognizes that, in India, there are a significant number of challenges in the way of achieving set targets but also states that there is a "relentless" rollout of policy measures, continuous flow of big projects, deals and funding commitments made by major domestic and international investors (EY, 2015a: 21). In March 2015 RECAI, it is stated that there is a "significant policy, project and investment activity both at national and state level" (EY, 2015b: 15).

Up to 100 % Foreign Direct Investment (FDI) in the RE sector is allowed under the automatic route in India (PIB, 2015b). According to the Department of Industrial Policy& Promotion (DIPP) of the Ministry of Commerce & Industry, GoI, the cumulative FDI equity inflow in the Non-Conventional Energy sector from April 2000 to September 2015 has been US$3926.89 million which is 1.48 % of the total cumulative FDI equity inflows over this period (DIPP, 2015b). This is definitely a small fraction. For the sake of a more appropriate comparison, the cumulative FDI equity inflow in the power sector[3] is US$9967.22 million in the same period, which

[3]The amounts for both of the sectors i.e. Non-Conventional Energy sector and Power sector are mutually exclusive.

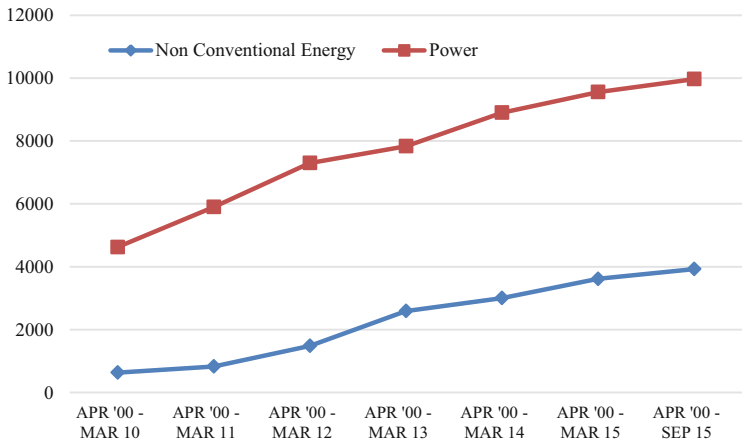

Fig. 4 Cumulative FDI equity inflow in million US$. Source: Own illustration based on DIPP (2015b)

is 3.76 % of the total FDI which is just 2.5 times that in the Non-Conventional Energy sector. Figure 4 shows the comparison of these FDI inflows over the years.

The above figure shows that by September 2015, the cumulative FDI equity inflow in non-conventional energy sector has increased to almost six times its level in March 2010, whereas in power sector it has increased to a bit more than twice its level in March 2010. This shows the increasing FDI in favor of clean energy compared to conventional power. According to the same statistics, the FDI received in the last 12 months i.e. September 2014 to September 2015 was US$544.97 million which is 13.87 % of the cumulative FDI in this sector till date. This seems to be indicative of the increasing interest shown by foreign investors in this sector as well as the effectiveness of the FDI policy. However, from a neutral perspective it is also worth noting that the difference between cumulative FDIs of both the sectors (from April 2000–March 2010 to April 2000–September 2015) has increased from approx. US$4 billion in the first year to approx. US$6 billion over the shown period. This highlights a widened gap over this period between the cumulative FDIs in both the sectors.

Figure 5 builds up on the same data set for cumulative FDI in both Power and Non-Conventional Energy sector and illustrates the yearly FDI equity inflow over the same period.

When the yearly inflow of FDI equity in both the sectors is seen over these years the picture becomes clearer and one can see that there have been ups and downs but the average annual FDI inflow over this period in the Non-conventional energy has remained at around US$600 million and during the first 5 months of financial year 2015–2016 it had already achieved more than US$300 million figure. When compared with the Power sector this average is less and observing this trend over the coming years will provide with more definitive conclusions for researchers and enthusiasts.

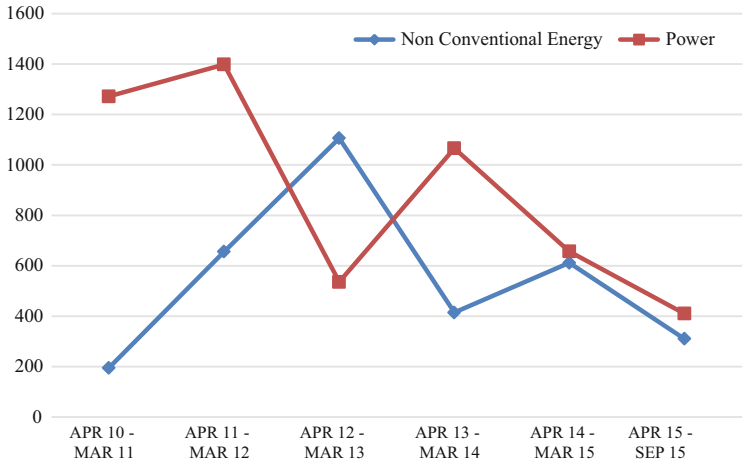

Fig. 5 Yearly FDI equity inflow in million US$. Source: Own illustration based on DIPP (DIPP, 2015b)

Reserve Bank of India (RBI) has recently included the RE sector in the 'priority sector lending' category (RBI, 2015). This is done in order to provide finance to small and medium enterprises in a manner that facilitates their investment in different areas of this sector. It would help these enterprises raise the necessary capital for investing in solar power, biomass power etc. (Upadhyay, 2015a).

The central government offers fiscal, financial and promotional benefits in the RE sector to boost investment, entrepreneurship and growth. This helps the spread of different types of REs even if the grid parity is not reached for that particular method or source. Easy and flexible method of repayment of borrowed funds is important for involving more investors in India. Ensuring this, increases the activity in the sector and make RE cost competitive, thereby fostering business. Some important benefits and schemes are mentioned here which have had positive impact.

Accelerated Depreciation (AD) is a type of fiscal incentive provided for Wind, Solar (PIB, 2015c) and Biomass Power sector in India (MNRE, 2015c). AD provides tax benefits to renewable energy projects by depreciating the capital assets by 80 % in the first year and thereby reducing taxable income in the initial years of the project. Large companies e.g. Public Sector Undertakings, small investors and captive power producers have increasingly participated in the wind sector due to this incentive (PIB, 2014). AD has been recognized as the main driving force behind the development of Wind sector in India so much so that when the incentive was withdrawn from April 2012 to July 2014, a sharp drop in the annual capacity addition (ibid) and a sharp decline in investments in the wind sector was observed (Singh, 2014).

Generation Based Incentive (GBI) is an another important incentive offered for Wind and Solar sectors which is intended to incentivize actual generation of power instead of incentivizing just capacity building projects like that in the case of AD (The Economic Times, 2012). This was also intended to broaden investor base by

attracting large Independent Power Producers (IPP) who were not able to avail the AD benefits (PIB, 2009). The positive effects of these two schemes in boosting wind sector growth and investment in India have been widely reported in several articles and it is also estimated that these schemes in their current form will continue to benefit and bring investment in this sector in the near future (Prithiani, 2014).

Apart from these two schemes, a number of support schemes and benefits such as tax holidays, capital subsidies, concessional duties for critical components, excise duty exemptions, viability gap funding and preferential tariff etc. are offered by Central and state governments which directly or indirectly encourage investment for RE in India (DIPP, 2015a). For instance, a recent decision to exempt parts and components of Wind Operated Electric Generators from excise duty (The Economic Times, 2015a) is expected to benefit Wind turbine and equipment manufacturers in India, many of which are subsidiaries of foreign companies (Mittal, 2015). This is an example of the policies influencing the international collaboration in a positive manner. Indian Renewable Energy Development Agency (IREDA) is a financial institution set up by the government exclusively for financing the RE sector. It promotes, develops and extends financial assistance for renewable energy and energy efficiency or conservation projects. Foreign loans and line of credit have been a major component of financial resources of IREDA.

The ambitious RE capacity targets by 2022 according to an estimate would entail an investment of total US$160 billion with US$120 billion in the capital investment and US$40 billion as equity in the next 7 years till 2022 (Energy Next, 2015). The solar energy target (100 GW) alone calls for around US$100 billion (Upadhyay, 2015b). RE sector in India saw an investment of around US$7.4 billion in 2014, a 14 % increase over the previous year (Ren21, 2015). Foreign investment could play a major role in terms of achieving the required increase in investments. Thus, it makes sense that the GoI has been making efforts to arrange these finances by attracting investment.

'RE-Invest', which aims to bring together global investors exclusively for the RE sector, is a joint initiative taken by the GoI, MNRE, IREDA and several other agencies since 2015. This event is the first of its kind organized by the government where the domestic market potential is showcased, government policy and strategies are highlighted and business to business interactions are arranged etc. in order to make a case for investing in RE in India. This event is also associated with a larger initiative of 'Make in India' for attracting foreign investment and collaboration to boost domestic manufacturing.

According to a report published by 'Institute for Energy Economics and Financial Analysis' (IEEFA), 8 months after the first RE Invest in 2015, well over US $100 billion firm commitments have been signed including those with many of the leading global RE firms and utilities (IEEFA, 2015). The report also argues that this influx of investment announcements in the sector shows that the initial skepticism expressed by global financial markets regarding big targets and promises of Indian RE sector growth can be done away with. "India is executing one of the most radical energy sector transformations ever undertaken, and this year has shown that the

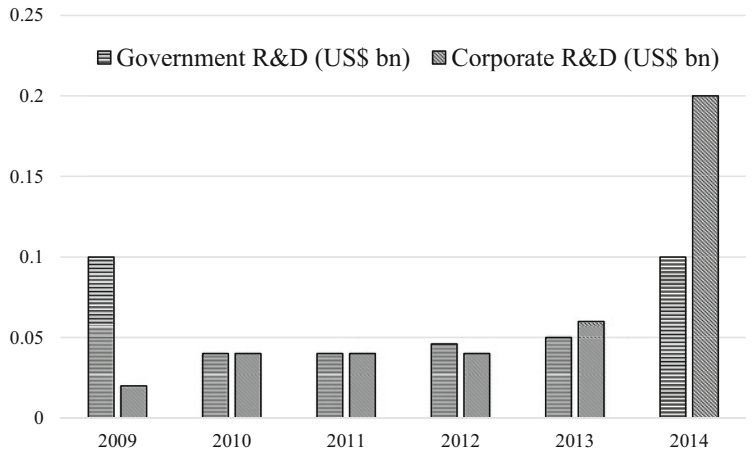

Fig. 6 Trend in RE R&D in India in billion US$. Source: Own illustration based on Frankfurt School-UNEP Centre/BNEF (2015)

flow of finance is matching the ambition", said Tim Buckley, the author of this report (IEEFA, 2015: 1).

Owing to the primary focus of the companies, domestic or international, on power generation, capacity addition, FDI and manufacturing, in this rapidly expanding sector, it is difficult to pin-point the impact of the above mentioned policies and initiatives on the 'collaborative R&D' in RE in India. However, it is logically arguable that such large commitments to building power projects, manufacturing and investments would certainly boost RE R&D collaboration as well.

Figure 6 is based on the data from the 'Global Trends in Renewable Energy Investment' reports published annually (from 2009 to 2015). This figure shows the trend of RE R&D investment in India from the last 6 years. It is clearly visible that these have increased over the last few years with a notable increase in 2014, particularly in the Corporate R&D. It is however, noteworthy that the share of RE R&D (US$0.3 billion) in total RE investments (US$7.4 billion mentioned previously) for the year 2014 is just 4.05 %.

Figure 7 shows the trend in total new RE investment in India based on the 2015 annual report. This is adjusted for re-invested equity. The investment figures also include estimates for undisclosed deals. This helps in understanding the past and future financial situation in the Indian RE sector to some extent. As earlier mentioned, the fall of investments in 2012 and 2013 was attributed to the withdrawal of incentives.

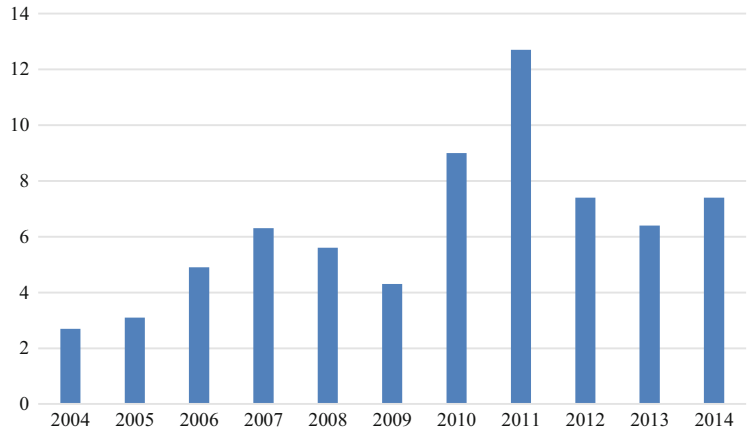

Fig. 7 Total RE investment trend in India in billion US$. Source: Based on Frankfurt School-UNEP Centre/BNEF (2015, p. 15)

4 Wind and Solar Energy Sector

It is important to mention that there are autonomous R&D institutions exclusively set up for the RE sub sectors by the government e.g. National Institute of Wind Energy (NIWE) and National Institute of Solar Energy (NISE) etc. These institutes carry out their activities in different areas and in different capacities in addition to the R&D carried out by private or public companies. It is essential to begin the discussion on RE collaboration by further looking at the estimated potential for installed capacities in some detail. This is because the promise of untapped potential in terms of generation capacity is one of the important reasons behind the international attention that the Indian RE sector has received.

Wind Atlas for India was prepared in 2010 for 50-m hub height with actual measurements and indicative values for 80-m hub height were used for estimation of the potential that yields the sum of 49,130 GW at 50 m and 102,788 GW at 80 m (NIWE, 2015a). Recently potential has also been estimated at 100-m hub height with more advanced modelling and data collection techniques that yields a sum of 302 GW (NIWE, 2015b). Riso National Laboratory, Denmark has been majorly involved in the Wind Resource assessment and preparation of Wind Atlas in collaboration with NIWE (ibid).

According to MNRE, India receives 4–7 kW-h of solar radiation per square meter per day (MNRE, 2015d), with clear sunny weather in most parts of India for 250–300 days, which translates to equivalent energy potential of around 6 billion GW-h per year (MNRE, 2015e). The previously mentioned figure of 749 GW solar potential has been determined by NISE (NISE, 2014). NIWE has been involved in carrying out Solar Radiation Resource Assessment and has launched 'Indian Solar Radiation Atlas' in June 2015 in collaboration with Deutsche Gesellschaft für

Internationale Zusammenarbeit (GIZ) Gesellschaft mit beschränkter Haftung (GmbH) and a German consulting company 'Suntrace GmbH' providing technical assistance in the preparation (NIWE, 2015c). The Atlas is prepared under the 'SolMap' Project which is a part of Indo-German Energy Programme with financial support from German Federal Ministry for the Environment (ibid).

The history of international collaboration in the Wind sector dates back to the 1980s in India. The first grid connected wind turbine that was demonstrated in India in 1984 was an imported Dutch turbine according to a joint report published by International Renewable Energy Agency (IRENA) and Global Wind Energy Council (GWEC) (IRENA & GWEC, 2013).

One of the significant collaboration in the initial stage of development of Wind sector, according to the above mentioned report, was between the GoI and the Danish Agency DANIDA. In 1987–1988, DANIDA granted funds worth 180 million Danish Krone (US$58.99 million) for the supply of wind turbines, erection, commissioning and monitoring of wind farm projects (ibid). These were the first demonstrations of large scale grid connected wind farms in India. Owing to this, real data on the techno-economic feasibility of wind energy generation in India could be obtained.

In 1999, the R&D Unit in NIWE (C-WET) was established with the support from DANIDA which provided generic information and knowledge to innovate wind turbine components and sub-systems suited for India's specific conditions (ibid). The Wind Turbine Testing Station at NIWE was established in the same year for standardization, testing and certification of Wind Turbines, with the financial support from DANIDA and technical assistance from Riso National Laboratory, Denmark (MNRE, 2015b).

A number of licensing agreements with German and Danish companies among many others gave early momentum to domestic wind energy manufacturing sector (IRENA & GWEC, 2013). According to the report, over 24 companies had formed collaborations with foreign companies from Austria, the USA, Denmark, Germany, The Netherlands, Sweden and Belgium. Notable case among these is the one of Suzlon, an Indian company which began by entering into an agreement with Sudwind Energiesysteme GmbH to share technical know-how, later on set up wholly owned subsidiaries in Germany and The Netherlands and is one of the top Wind Energy companies in the world. Some of the other collaborations were RRB-Vestas and NEPC-Micon (ibid).

Wind Energy program benefited from the World Bank's Renewable Resources Development Project (US$195 million) during 1993–1999, which supported commercial RE development. The project also provided technical assistance from Global Environment Facility (GEF) (ibid).

According to the list of manufacturers published by NIWE, there are a total of 19 wind turbine and equipment manufacturers, who manufacture 53 models of turbines ranging from 250 kW to 3 MW (NIWE, 2015d). 12 out of 19 have either foreign collaboration (licensed production/Joint Ventures) or are wholly owned subsidiaries of foreign companies. Only 13 out of total 53 models are made without any foreign collaboration. India is a well-established manufacturing hub for wind

turbines with global manufacturers like Gamesa, GE, Vestas and Suzlon etc. having production facilities and at the same time are engaged in exports as well. "A number of global firms with subsidiaries here source over 80 % turbine content from local sources" according to an article published (Renewables International, 2015). In the 'Small wind turbine' sector a total of nine manufacturers of small wind turbines are empanelled by MNRE/NIWE out of which four have collaboration with foreign companies (NIWE, 2015e).

Apart from manufacturing collaborations, R&D collaboration is also an active element in the current times. For instance, MNRE/NIWE has collaborated recently with Spain's renewable energy modelling specialist, 'Vortex Factoria de Calculs, S. L., Spain' for developing first-of-its kind project to improve Wind power forecasting and scheduling in Tamil Nadu, India. This helps predict power generation and to better manage fluctuations and downtime (Vortex, 2015). This shows that future focus will be not just on adding capacity but also on employing techniques and developing better models for prediction of wind regimes.

As mentioned earlier in this section, there are 19 Manufacturers of Wind Turbine/Equipment in India and some of these are subsidiaries of global major companies like Gamesa, GE etc. In addition to manufacturing in India, these companies have been involved in wind farm development and R&D as well. Following are some representative example cases which help understand the different ways in which collaborative R&D and manufacturing activities in the Indian Wind Energy sector function.

Example Case 1 'Gamesa', the leading wind turbine manufacturer in India (Business Standard, 2015) has one of its eight R&D center in India since 2011 which participate in the leading international, national and regional wind energy projects (Gamesa, 2015). Gamesa, India is a subsidiary of Gamesa, Spain (NIWE, 2015d). According to the company's annual report the company invested 109 million euros in R&D in 2014 globally, made 26 % (the highest of all countries) of its sale (in %MW) in India and developed a custom made variant of one of its turbine models in order to suit local market characteristics and maximize performance at low-wind sites (Gamesa, 2014). This showcases the attention paid by large companies in the RE sector in terms of R&D towards localization in order to maximize business.

Example Case 2 'Global Wind Power Limited' is a Joint Venture between Reliance Anil Dhirubhai Ambani Group and China's Ming Yang Wind Power Group (Global Wind Power, 2015a). The foreign collaboration partner to the company is registered with NIWE as 'Guangdong Ming Yang Wind Power Industry Group Co. Ltd, China'. The company has four technology partners namely Norwin, Lagerway, Führlander and Ming Yang as per their website with different technical license agreements (Global Wind Power, 2015b).

Example Case 3 'Suzlon' brings in to light another side of international collaboration. Unlike other large leading wind energy companies in India which are either subsidiaries or Joint ventures of foreign companies or produce under license or

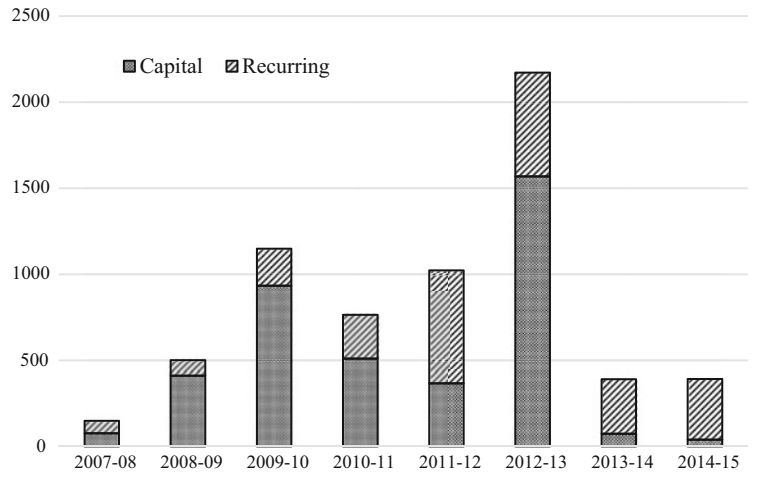

Fig. 8 Suzlon R&D expenditure trend INR (millions). Source: Own illustration based on resp. Annual Reports (Suzlon, 2015c)

depend for technology from foreign companies, Suzlon is an Indian company which has a global presence in terms of number of R&D centers, production facilities and markets all across the globe (Suzlon, 2015a). As mentioned earlier, Suzlon started in India with a technical knowledge transfer from a German company but today the picture is different and it has its R&D Headquarters in Hamburg, Germany with cross border development teams in Germany, The Netherlands, Denmark and India working together (Suzlon, 2015b). Figure 8 shows the trend of R&D expenditure in INR (millions) by Suzlon over last couple of years.

Example Case 4 Another interesting example of an Indian Wind company that has ownership of foreign R&D and production facilities is 'Kenersys'. In 2007, 'Kalyani Group' from India bought a German design and engineering firm that used to offer expertise in Wind energy sector and renamed it to 'Kenersys' (The Economic Times, 2007). Today it has headquarters as well as global technology center in Germany in addition to a production facility (Kenersys Kalyani, 2015).

A number of other foreign Wind energy companies such as Vestas and GE also have R&D centers in India. This proves a robust wind energy R&D capability in the Indian wind energy private sector. There are also seven manufacturers that manufacture without any collaboration and have indigenously developed their own R&D capabilities for manufacturing Wind turbine for e.g. M/s Siva Wind turbine India Private Limited (Siva Wind, 2015).

With a strong background of collaboration in the past and present and much of the estimated Wind resource potential still untapped, the future seems promising. In addition, GoI has recently approved (Sep 2015) the 'National Offshore Wind Energy Policy' (PIB, 2015d). This policy opens up the possibility of allocation of offshore wind energy blocks, setting up projects and R&D activities up to a seaward

distance of 200 nautical miles which is termed as the 'Exclusive Economic Zone' from the base line according to the press release by MNRE. The press release also mentions that this policy is aimed at providing a 'level playing field for investors/beneficiaries, domestic and international'. This statement itself is profound and indicative of willingness of the policymakers to invite collaboration and investment. The wind seems to blow favorably since before the policy for offshore wind was even approved. For instance, GWEC is spearheading a project named 'Facilitating Offshore Wind in India' or 'Fowind' along with other Indian consortium partners and DNV-GL, Norway (Fowind, 2015). This project has received 4 million euros from the European Union and has multiple and diverse R&D goals according to the website of the project (ibid). Another example is that of China's Sany group which has announced US$3 billion investments in RE in India. It has also expressed interest in the offshore wind energy sector and plans to establish efficient technologies for the same (The Economic Times, 2015b). Based on the report by a ratings and research firm, Indian Wind sector can attract an investment worth a potential INR 1000 billion (Sengupta, 2015). This shows a promise for the future.

The most recent and high impact effort towards seeking international collaboration in Solar Energy was made by the GoI in the Paris Climate Conference in November end 2015. India along with France has launched an 'International Solar Alliance' of 120 countries for large scale expansion of solar energy use in the tropical regions and other parts of the world (UNFCCC, 2015). The declaration of the launch mentions many things among which the intention to work together for 'development of appropriate benchmarks, facilitating resource assessments, supporting research and development and demonstration facilities, with a view to encouraging innovative and affordable applications of solar technologies' is one that of relevance to this topic. It is the statement that shows the emphasis on Solar R&D collaboration by topmost level of government.

In 2010, India launched a National Solar Mission titled 'Jawaharlal Nehru National Solar Mission' (JNNSM). This mission is the umbrella under which all other efforts of the government in the solar sector are planned. The initial Solar capacity target of 20 GW by 2022 has now been increased to 100 GW by 2022 (PIB, 2015e) with 40 GW for Rooftop and 60 GW for grid connected Solar Power. The government has integrated all endeavors such as policy innovation, getting the finance, acquiring the technological acumen, achieving grid parity for solar, rural electrification and developing the manufacturing capabilities etc. under this mission. Thus, this mission is the biggest driver for solar sector in India and hence important from the point of view of collaboration.

There primarily two types of technologies to harness solar power, Solar Photo Voltaic (Solar PV) and Concentrating Solar Technology (CST). According to MNRE annual report of 2014–2015, there are two internationally funded projects that India is running for CST under JNNSM (MNRE, 2015b): The objectives of these projects are multiple and include promoting commercialization of CSTs, developing knowledge documents, test standards and test protocols, and removing barriers in promoting these technologies, develop business models for solar based heating/cooling and tri-generation projects through different CST technologies for

industries and for commercial purposes. Thus innovation that is centered around local needs is in focus.

Manufacturing companies have also partnered with international companies and institutions for technology. Indian company 'Tata Power Solar' has collaborated with different companies such as US based 'Transphorm Inc.' in order to use their patented technology for manufacturing efficient solar inverters (Transphorm Inc., 2014), and with 'DuPont' which provides material for the Solar Home Lighting Systems manufactured by 'Tata Power Solar' (DuPont, 2014). 'Moser Baer Solar', another Indian manufacturer, has several collaborations with international players for R&D. According to its website, SINTEF and UMOE Solar from Norway and OM&T from The Netherlands are its collaborative research partners (Moser Baer Solar Limited, 2015).

4.1 Solar Energy for Rural/Remote Areas: Low Cost Solutions and Localization

As mentioned in the introduction Energy access and affordability are one of the major goals for India's development. The task of taking electricity to rural areas or remote areas is thus very important. If one thinks of RE, the challenges such as infrastructure, cost and adaptability to local environment appear. Several companies in the solar energy sector are collaborating to target these issues and offer solutions. For instance, 'Moser Baer' and 'DuPont' have joined hands and developed PV units that can supply reliable solar power to 'Ladakh' region of Indian Himalayas (DuPont, 2013). This region experiences harsh weather and is remote due to high altitudes and limited connectivity by road. These units as per the website are low cost due to higher efficiency (reduced number of panels for the same amount of power generated) and durable against the harsh climate (DuPont, 2015).

Another example is that of 'SELCO (Solar Electric Light Company) Solar Private Limited', an Indian manufacturer that has a number of international partnerships for technology (e.g. D-Lab, Massachusetts Institute of Technology) and in the form of funding or investments (SELCO Solar, 2015). As a recent example, its partner 'SELCO Foundation' was awarded a grant worth US$200,000 by the United States Agency for International Aid (USAID) to help establish 'innovation labs' aimed at developing and testing sustainable energy solutions (The Economic Times, 2014). SELCO sees customers in the rural sector as its target and engages in providing customized products, services and affordable finance to customers such as small businesses and households in order to increase the diffusion of solar energy. SELCO offers products such as Solar Lighting, Solar Thermal Heaters, Solar Inverters, customized products such as DC Sewing machine and Solar micro grid etc. and financial services such as helping underserved households obtain necessary credit for purchasing solar equipment. SELCO has gone beyond the

role of manufacturer in order to become a social enterprise working towards rural electrification and development of rural communities. Thus, this is a classic example of international collaboration which has reached grassroots in India through innovative business processes and localized products.

4.2 Near Future of Solar Energy Sector: Collaboration

Looking at the future, recently there have been a number of announcements of collaboration and foreign investment. For example, India and Germany have signed an MoU on Indo-German Solar Energy Partnership based on concessional loans in the range of 1 billion euros over the next 5 years and stating that collaboration will be intensified on 'next generation solar technology' (The Federal Government of Germany, 2015). According to the press release, the implementation of the Green Energy Corridors Partnership with an overall German commitment of 1.15 billion euros in the last 2 years is progressing well.

In the private sector also there are a number of recent announcements. A three-way Joint Venture 'SBG Cleantech' worth US$20 billion of 'SoftBank', Japan, Taiwan-based 'Foxconn', and Indian 'Bharti Enterprises' is announced to set up solar power projects (SoftBank, 2015). 'SunEdison', USA intends to invest US$15 billion by 2022 (Marketwatch, 2015). It will put US$2 billion into a Joint Venture with 'Adani Group' to manufacture PV modules. China's Trina Solar has plans to invest US$500 million in a plant to make panels with 'Welspun Energy' (See News Renewables, 2015).

4.3 Academic Research Collaboration

In addition to R&D and manufacturing collaborations in both the sectors, number of examples of academic collaboration between universities and research institutions can also be seen.

The 'Solar Energy Research Institute for India and the United States' is co-led by the Indian Institute of Science Bangalore, India, and the National Renewable Energy Laboratory, Golden, Colorado, USA. It also has number of university, research and industry partners from both countries. The consortium comes under a larger Indo-US joint R&D center namely 'Joint Clean Energy Research and Development Centre'. The center is designed to promote clean energy innovation by teams of scientists and engineers from India and the United States. It supports multi-institutional network projects using a public-private partnership model of funding (Seriius, 2015).

To summarize, a lot of activity with regards to international collaboration can be observed in the field of R&D, manufacturing and academics in the two sectors

discussed. This gives a broader picture of knowledge exchange as well as business that has crossed borders.

4.4 Export and Import

The export and import of equipment, devices and other products is a lower level of business engagement with the world as compared to other collaborations such as setting up subsidiaries and research labs etc. Nevertheless, it is an interesting aspect to look into in terms of gaining information about the trends in international trade in a particular sector. Analysis of exports and imports in any sector requires larger data sets and analysis of several influencing parameters such as actual mechanism of export-imports, regulations and policies etc. which may or may not be sector specific. Thus it requires a separate study.

5 Analysis of the Study and Its Findings

A case study research technique of qualitative and exploratory nature is employed here to understand the topic as no quantitative data collection methods or analysis is done. The emphasis of this study remains on the exploration of different aspects concerning the main topic rather than formulating a complete theory or arriving at concrete conclusions from the findings. Thus, further research into the individual details of the topic, into similar areas in other contemporary sectors, in other developing countries and with the use of other research strategies has to be conducted. This apparent limitation is also an advantage of this work as this approach provides flexibility in exploration of the topic.

5.1 Limitations of the Study

Owing to above mentioned exploratory nature and positioning of this study, the criteria for interpreting the findings of this study are subjective. For instance, the significance of the large power capacity building commitments given by companies in 'RE-Invest' in predicting the increase in the future investments is open to questions, as there can be multiple and consistently changing policy influences. Since this sector is young and developing, many of the activities are in their early stages of plan. Policies are continuously being structured or restructured according to changing realities. Thus any analysis criteria can only be applied in the limited context of the phenomenon being observed without generalizing.

There are many questions such as 'How much has the collaborative RE R&D helped for the purpose of rural electrification and which R&D methods are required

to make the technology more affordable?' which require additional data collection, surveys, expert opinions from industry and policy makers etc. to answer. Only after doing this any recommendations can be made to improve the situation further. This illustrates that although many areas have been explored around the central theme of the study, further research is necessary for understanding the totality of the situation.

5.2 *Analysis of the Findings*

The study has shown that India has been a market for RE products especially those related to Wind energy since over a decade. An interesting concept of 'lead markets' and 'lag markets' can be of use here to analyze the findings. There has been quite a lot of research about what a lead market is and what characteristics it has which drive the innovation, with one of the most appreciated one conducted by Beise (2004). Lead market is the country where an innovation is first widely accepted and adopted followed by diffusion into other countries (ibid). Similarly lag market is where the innovation design is adopted after its acceptance in the lead market. The typical attributes that researchers have associated with lead markets are 'largest, most sophisticated and most competitive' (Bartlett & Ghoshal, 1990) with examples of lead market commonly cited as USA for the internet, Japan for Robotics and LCD monitors (European Commission, 2006) etc. It has also been argued that despite the prevalent thought that lead markets are typically sophisticated, have technological prowess and are located in developed countries, evidence is emerging due to changing ground realities that some emerging countries such as India can be considered as lead markets (Tiwari & Herstatt, 2011). Thus, it is justifiable to examine the findings of this study considering India as a lead market for RE.

R. Tiwari and C. Herstatt in their working paper referred above, propose that lead markets will increasingly emerge in "countries that offer volume driven growth, favorable policy framework and entrepreneurial spirit" (Tiwari & Herstatt, 2011: 13). They also argue that with changing ground realities for global innovation, a sizable and growing market, a demand that drives low cost and frugal innovations to be produced by companies, openness to foreign collaboration and supporting institutional infrastructure together confer a potential lead market status to India in different sectors.

Coming to the RE sector, this study has shown in previous sections that:

1. India has a need for low cost renewable energy and products, especially for rural and remote areas
2. India has taken up ambitious RE targets for 2022, the RE sector has promising future projections and the country has made international commitments to reduce emission intensity and adopt non-fossil based energy

3. India has a well-developed Wind energy sector both in terms of R&D and Manufacturing with a lot of activity in terms of research collaborations and also there are examples of custom made Wind turbine model being developed for India
4. Large investments have been promised by foreign companies for solar manufacturing.
5. New policies are being rolled out such as 'National Offshore Wind Energy Policy' that has signaled the opening up of a new sub-sector and
6. Support mechanisms such as inclusion of RE in 'priority sector lending' category that are aimed at increasing entrepreneurial spirit etc. are being introduced.

It was mentioned that many global leading RE companies already have R&D centers that are operational and at the same time new R&D centers along with manufacturing enterprises are being proposed by foreign companies. This can also be an emerging evidence of India qualifying as a Lead market for RE innovations owing to its local needs and market size. There are many other initiatives being taken to engage investors, forge academic collaborations and provide fiscal and monetary benefits to power producers. Hence, it can be seen that low cost-innovative products and localized business models that deliver power projects according to local needs in India can be taken to other 'lag' markets such as other developing countries, thereby conferring a tag of 'lead market' for RE to India. As stated earlier there can be numerous more theories which can be applied to this work to look at different aspects of international collaboration, RE R&D or other such sectors in India. However, this lies outside the limited scope in which this exploratory study is conducted.

5.3 Future Research Scope

As has been mentioned in the previous sections, this study has started by exploring different aspects of RE sector in India while always maintaining central theme of collaborative R&D and manufacturing. Thus, it has brought to light different possible research questions such as the study of policy influence, study of administrative framework, study of roles played by private sector and study of academic collaboration etc. in relation to the topic of foreign collaboration. It has also highlighted the importance of market needs such as need for attention to per unit costs, to localization and customization as well as need for innovations aiding in rural diffusion of RE technologies and remote area electrification. Thus, this work can be treated as a base for augmenting the understanding of foreign collaboration in RE in India.

To better use this study in practice, future research has to be in the direction of recognizing the patterns of favorable policies and functional business model examples like that of SELCO which can be used to make decisions and design products and services by companies, governments and other such stakeholders involved in

diffusion of RE technology and products in India. These patterns can be recognized on the basis of specifically designed surveys, further case studies of similar nature looking into different developing countries, expert opinions and most importantly quantitative research based on data collected for such purpose. Grounded theory as first proposed by Glaser and Strauss (1967) is an excellent tool which deals with qualitative research data and works in a reverse manner developing labels for different categories of data and studying the interaction between different variables. The detail sequence of steps illustrated in this technique, when applied, lead to emergence of a theory based on these data and qualitative facts. Thus, the theory is 'Grounded' into the dataset. In the context of studying foreign collaboration in RE R&D, this strategy could work really well as mostly qualitative data is available and the number of influencing variables cannot be determined from the beginning. Hence, there is an immense scope for future research into this area on which practical business applications can be conceived.

6 Conclusion

Rapid and large scale adoption of RE has become an urgent necessity for India to power its fast growing economy, mitigate the burden of consistent energy shortage, provide basic access to electricity in underserved regions, curb increasing GHG emissions and reduce its current dependency on fossil fuel based sources of energy of which imports constitute a major share. The targets set by India to achieve all of this hold a certain promise. The commitments made on international forums regarding RE inclusion are also in line with the domestic targets. There is a continuous activity in terms of new policy rollout such as Offshore Wind policy in order to achieve the targets. However, the policy actions have to be dynamic, bold and have to address concerns on multiple fronts such as finance, regulation etc. This is illustrated by past examples of poor policy decisions which have harmed the RE sector growth directly e.g. the AD and GBI policy withdrawals in the Wind sector.

The current energy supply situation gives a picture of an economy which is dependent on coal, facing energy shortages and power deficits with large population lacking basic access to electricity leave alone the electricity for commercial activities. The RE sector in its present form is relatively small compared to conventional power but has been assessed to have an immense potential for meeting capacity and generation demands in the near future. The growth projections for Solar and Wind sectors are particularly remarkable.

The initiatives and policy measures taken have been designed to back the ambitious targets. The manufacturing industry, particularly Wind, has responded positively and there are signs of increasing manufacturing activity that can be seen from the announcements and Green Energy commitments given by companies. The research institutions, government or private have jumped in to maximize the

efficiency of technologies and adopt better means of assessing the resources via collaborating internationally for technology transfer and funding.

India has received international support in the RE sector since quite a long time and many positive developments particularly in the Wind sector in the past few decades would have been impossible without it. This study shows that such collaborations have been increasing in the recent past with the attractiveness of RE sector increasing continuously which is corroborated by agencies such as EY. The level of R&D activity is certainly increasing and also good extent of localization is being done before formulating product development and market strategies as can be seen in the example of custom made turbines by 'Gamesa'. Financial influx also holds promise with investors using different means of investing in India e.g. Joint ventures and FDI etc.

In the solar sector, as shown by the remarkable case of SELCO, manufacturing enterprise has grown beyond the traditional lines of R&D, Design, Production and Sales into the territory of social enterprise where custom made products are being offered along with the facilities of financial packages in partnership with banks that enable rural customers and many a times customers who don't have grid access to purchase equipment and access electricity at affordable rates. Coupled with such offering are the services that cater to the needs from installation till after-sales. This case is most inspiring and also relevant to this research topic as SELCO has a number of international partnerships.

Overall it can be said that due to the concerted effort of government agencies and banking and R&D institutions, the RE sector in India is poised to embark on the path of exponential growth majorly aided in many ways (technology and finance etc.) by foreign companies. In chapter "Consumer Innovation in the *Poor* Versus *Rich* World: Some Differences and Similarities" it is also concluded that India can be considered a lead market by companies that can take the successful innovation to other markets. However, concrete results and more research is the only sure way to confidently determine the success of collaboration and that has to be seen objectively in the near future. RE in India shows a natural propensity towards absorbing the techno-commercial knowledge coming its way.

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References

Bartlett, C. A., & Ghoshal, S. (1990). Managing innovation in the transnational corporation. In C. A. Bartlett, Y. L. Doz, & G. Hedlund (Eds.), *Managing the global firm* (pp. 215–255). London: Routledge.

Beise, M. (2004). Lead markets: Country-specific drivers of the global diffusion of innovations. *Research Policy, 33*(6–7), 997–1018.

BP. (2015a). *Statistical review of world energy 2015: Workbook*. Retrieved November 17, 2015, from http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

BP. (2015b). *India | Country and Regional insights | Statistical Review | Energy Economics | BP Global*. Retrieved November 17, 2015, from http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/country-and-regional-insights/india.html

Business Standard. (2015). *Gamesa tops wind energy installations in India*. Retrieved December 20, 2015, from http://www.business-standard.com/article/companies/gamesa-tops-wind-energy-installations-in-india-115031001160_1.html

CEA. (2015a). *Growth of electricity sector in India from 1947–2015*. Retrieved November 18, 2015, from http://www.cea.nic.in/reports/others/planning/pdm/growth_2015.pdf

CEA. (2015b). *All India installed capacity October 2015*. Retrieved December 2, 2015, from http://www.cea.nic.in/monthlyinstalledcapacity.html

DIPP. (2015a). *Renewable energy – make in India*. Retrieved December 9, 2015, from http://www.makeinindia.com/sector/renewable-energy

DIPP. (2015b). *FDI statistics – The Department of Industrial Policy & Promotion*. Retrieved December 9, 2015, from http://dipp.nic.in/English/Publications/FDI_Statistics/FDI_Statistics.aspx

DuPont. (2013). *Providing reliable solar power in India*. Retrieved December 20, 2015, from http://www.dupont.com/corporate-functions/our-approach/global-challenges/energy/articles/solar-power-in-india.html

DuPont. (2014). *DuPont photovoltaic solutions addresses India's energy challenges*. Retrieved December 20, 2015, from http://www.dupont.co.in/corporate-functions/media/press-releases/dupont-photovoltaic-solutions-addresses-energy-challenges.html

DuPont. (2015). *Advanced photovoltaic materials to enable electrification of remote corners of Ladakh, India*. Retrieved December 20, 2015, from http://www.dupont.com/products-and-services/solar-photovoltaic-materials/case-studies/cs-ladakh-india.html

Energy Next. (2015). *RE-INVEST: A road to India's RE glory!* Retrieved December 18, 2015, from http://www.energynext.in/re-invest-a-road-to-indias-re-glory/

European Commission. (2006). *Economic reforms and competitiveness: Key messages from the European Competitiveness Report 2006*. Brussels: Commission for European Communities.

EY. (2015a). *Renewable energy country attractiveness index*. Retrieved December 20, 2015, from http://www.ey.com/GL/en/Industries/Power---Utilities/Renewable-Energy-Country-Attractiveness-Index

EY. (2015b). *Renewable energy country attractiveness index*. Retrieved December 20, 2015, from http://www.ey.com/GL/en/Industries/Power---Utilities/Renewable-Energy-Country-Attractiveness-Index---Archive

Fowind. (2015). *Fowind | Home| About the project*. Retrieved December 20, 2015, from http://fowind.in/

Frankfurt School-UNEP Centre/BNEF. (2015). *Global trends in renewable energy investment reports*. Retrieved December 18, 2015, from http://fs-unep-centre.org/publications/global-trends-reports

Gamesa. (2014). *Annual report*. Retrieved September 10, 2015, from http://www.gamesacorp.com/en/investors-and-shareholders/financial-information/annual-report/

Gamesa. (2015). *Gamesa | Products-and-services | Wind turbines | R&D*. Retrieved December 20, 2015, from http://www.gamesacorp.com/en/products-and-services/wind-turbines/rd/

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research* (8th ed.). Piscataway, NJ: Aldine Transaction.

Global Wind Power. (2015a). *About us | Profile*. Retrieved December 20, 2015, from http://www.gwpl.co.in/about-us/profile.php

Global Wind Power. (2015b). *About US | Technology partners*. Retrieved December 20, 2015, from http://www.gwpl.co.in/about-us/technology_partner.php

GoI. (2015). *INDC submissions*. Retrieved December 31, 2015, from http://www4.unfccc.int/submissions/INDC/Published%20Documents/India/1/INDIA%20INDC%20TO%20UNFCCC.pdf
IEEFA. (2015). *India's electricity-sector transformation: Global capacity building*. Retrieved December 18, 2015, from http://ieefa.org/us100-billion-in-new-renewable-investments-in-2015-power-indias-energy-transition-2/
International Monetary Fund. (2015). *World economic outlook: Adjusting to lower commodity prices*. Retrieved December 17, 2015, from http://www.imf.org/external/pubs/ft/weo/2015/02/
IRENA, & GWEC. (2013). *30 years of policies for wind energy: Lessons from 12 wind energy markets: India*. Retrieved December 18, 2015, from http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=281
ISPRE. (2009). *Research and development on renewable energies: A global report on photovoltaic and wind energy*. Retrieved January 26, 2016, from http://www.icsu.org/publications/reports-and-reviews/ispre-photovoltaic-wind
Kenersys Kalyani. (2015). *KENERSYS – an ideal partner for growth*. Retrieved December 20, 2015, from http://www.kenersys.com/KENERSYS-Profile.23.0.html?&L=1%27%22%22
Luthra, S. (2014). *India's shift to a sustainable energy future*. Retrieved December 2, 2015, from http://www.nbr.org/research/activity.aspx?id=409
Marketwatch. (2015). *SunEdison to invest $15 billion in India by 2022*. Retrieved December 21, 2015, from http://www.marketwatch.com/story/sunedison-to-invest-15-billion-in-india-by-2022-2015-06-07
Ministry of Health & Family Welfare. (2006). *Population projections for India and states 2001–2026*. Retrieved December 21, 2016, from https://nrhm-mis.nic.in/Pages/HMIS-PeriodicReport.aspx
Mittal, S. (2015). *India announces tax incentives for wind turbine equipment*. Retrieved December 17, 2015, from http://cleantechnica.com/2015/10/26/india-announces-tax-incentives-wind-turbine-equipment/
MNRE. (2015a). *Physical progress (achievements)*. Retrieved December 4, 2015, from http://mnre.gov.in/mission-and-vision-2/achievements/
MNRE. (2015b). *Annual report 2014–15*. Retrieved October 20, 2015, from http://mnre.gov.in/file-manager/annual-report/2014-2015/EN/Chapter%201/chapter_1.htm
MNRE. (2015c). *Biomass power/Cogen – MNRE*. Retrieved December 17, 2015, from http://mnre.gov.in/schemes/grid-connected/biomass-powercogen/
MNRE. (2015d). *Programmes and technology | Grid connected power| Solar*. Retrieved December 20, 2015, from http://mnre.gov.in/schemes/grid-connected/solar/
MNRE. (2015e). *Public information | Solar RPO*. Retrieved December 20, 2015, from http://mnre.gov.in/information/solar-rpo/
Moser Baer Solar Limited. (2015). *About us | R&D*. Retrieved December 20, 2015, from http://www.moserbaersolar.com/about-rnd.asp?links=ab6
NISE. (2014). *State wise estimated solar power potential*. Retrieved December 20, 2015, from http://mnre.gov.in/file-manager/UserFiles/Statewise-Solar-Potential-NISE.pdf
NIWE. (2015a). *Estimation of installable wind power potential at 80 m level in India*. Retrieved December 19, 2015, from http://niwe.res.in/department_wra_est.php
NIWE. (2015b). *Wind power potential at 100m agl*. Retrieved December 19, 2015, from http://niwe.res.in/department_wra_100m%20agl.php
NIWE. (2015c). *Solar radiation resource assessment*. Retrieved December 20, 2015, from http://niwe.res.in/assets/Docu/srra_solar_radiation_brochure.pdf
NIWE. (2015d). *Revised list of models and manufacturers of wind turbines*. Retrieved December 19, 2015, from http://niwe.res.in/rlmm.php
NIWE. (2015e). *NIWE| Downloads | Small wind turbine*. Retrieved December 20, 2015, from http://niwe.res.in/downloads.php
OECD/IEA. (2015a). *Modern energy for all: why it matters – world energy outlook*. Retrieved November 17, 2015, from http://www.worldenergyoutlook.org/resources/energydevelopment/modernenergyforallwhyitmatters/

OECD/IEA. (2015b). *Energy and climate change – world energy outlook special report*. Retrieved November 5, 2015, from https://www.iea.org/publications/freepublications/publication/weo-2015-special-report-energy-climate-change.html
PIB. (2009). *Winds of change: MNRE incentives for independent power producers | PIB english features*. Retrieved December 17, 2015, from http://pib.nic.in/newsite/efeatures.aspx
PIB. (2014). *Shri Piyush Goyal holds discussion with stakeholders in wind sector*. Retrieved December 16, 2015, from http://pib.nic.in/newsite/PrintRelease.aspx?relid=106001
PIB. (2015a). *PM inaugurates re-invest 2015; Says India is graduating from megawatts to gigawatts and renewable energy production*. Retrieved December 4, 2015, from http://pib.nic.in/newsite/PrintRelease.aspx?relid=115472
PIB. (2015b). *Renewable energy manufacturing sector*. Retrieved September 2, 2015, from http://pib.nic.in/newsite/PrintRelease.aspx?relid=117383
PIB. (2015c). *Year end review – MNRE*. Retrieved December 16, 2015, from http://pib.nic.in/newsite/pmreleases.aspx?mincode=28
PIB. (2015d). *Approval of national offshore wind energy policy*. Retrieved December 20, 2015, from http://pib.nic.in/newsite/PrintRelease.aspx?relid=126754
PIB. (2015e). *Revision of cumulative targets under National Solar Mission from 20,000 MW by 2021-22 to 1,00,000 MW*. Retrieved December 20, 2015, from http://pib.nic.in/newsite/PrintRelease.aspx?relid=122566
Prithiani, R. (2014). Fresh surge of wind power. *The Hindu*. Retrieved December 17, 2015, from http://www.thehindu.com/business/Industry/fresh-surge-of-wind-power/article6533470.ece
RBI. (2015). *Priority sector lending-targets and classification – RBI notification*. Retrieved December 10, 2015, from https://rbi.org.in/Scripts/NotificationUser.aspx?Id=9688&Mode=0
Ren21. (2015). *Renewables 2015 global status report - key findings*. Retrieved November 2, 2015, from http://www.ren21.net/status-of-renewables/global-status-report/
Renewables International. (2015). *Wind projects and economy in India*. Retrieved December 19, 2015, from http://www.renewablesinternational.net/wind-projects-and-economy-in-india/150/435/84942/
See News Renewables. (2015). *Trina Solar to make in India PV panels for US, EU – report*. Retrieved December 21, 2015, from http://renewables.seenews.com/news/trina-solar-to-make-in-india-pv-panels-for-us-eu-report-480943#
SELCO Solar. (2015). *Partners*. Retrieved December 20, 2015, from http://www.selco-india.com/
Sengupta, D. (2015). *Wind power can attract Rs 1 lakh crore investments by 2020: CRISIL*. Retrieved December 20, 2015, from http://articles.economictimes.indiatimes.com/2015-07-09/news/64243968_1_crisil-wind-power-project-lakh-crore
Seriius. (2015). *Home page*. Retrieved December 21, 2015, from http://www.seriius.org/
Singh, S. P. (2014). *Wind power industry body asks govt to re-introduce fiscal incentives | Business Standard News*. Retrieved December 16, 2015, from http://www.business-standard.com/article/companies/wind-power-industry-body-asks-govt-to-re-introduce-fiscal-incentives-113072000530_1.html
Siva Wind. (2015). *Research and development*. Retrieved December 20, 2015, from http://www.sivawind.com/researchanddevelopment.html
SoftBank. (2015). *SoftBank, Bharti and Foxconn to form joint venture*. Retrieved December 21, 2015, from http://www.softbank.jp/en/corp/news/press/sb/2015/20150622_01/
Suzlon. (2015a). *Suzlon at a glance*. Retrieved December 20, 2015, from http://www.suzlon.com/about_suzlon/l3.aspx?l1=1&l2=1&l3=8
Suzlon. (2015b). *Suzlon research and development*. Retrieved December 20, 2015, from http://www.suzlon.com/about_suzlon/l4.aspx?l1=1&l2=2&l3=15&l4=12
Suzlon. (2015c). *Financial, annual reports | Suzlon*. Retrieved December 20, 2015, from http://www.suzlon.com/investors/annual_result.aspx?l1=6&l2=23&l3=42
The Economic Times. (2007). *Kalyani group buys German energy co*. Retrieved December 20, 2015, from http://articles.economictimes.indiatimes.com/2007-09-04/news/27687102_1_kalyani-group-wind-energy-amit-kalyani

The Economic Times. (2012). *Wind power needs a tax incentive on the power produced*. Retrieved December 17, 2015, from http://articles.economictimes.indiatimes.com/2012-05-09/news/31641790_1_wind-power-generation-capacity-renewables

The Economic Times. (2014). *USAID to provide $2.7 million for clean energy to India*. Retrieved December 20, 2015, from http://articles.economictimes.indiatimes.com/2014-03-04/news/47894600_1_clean-energy-usaid-sustainable-energy-solutions

The Economic Times. (2015a). *Parts, components of wind turbines exempted from excise duty*. Retrieved December 17, 2015, from http://economictimes.indiatimes.com/news/economy/policy/parts-components-of-wind-turbines-exempted-from-excise-duty/articleshow/49467590.cms

The Economic Times. (2015b). *Make in India: China's Sany Group to invest $3 billion in India on renewable energy projects*. Retrieved December 20, 2015, from http://economictimes.indiatimes.com/industry/energy/power/make-in-india-chinas-sany-group-to-invest-3-billion-in-india-on-renewable-energy-projects/articleshow/49388244.cms

The Federal Government of Germany. (2015). *Indo-German joint statement on climate change and energy technology cooperation*. Retrieved December 21, 2015, from http://www.bundesregierung.de/Content/EN/Pressemitteilungen/BPA/2015/2015-10-05-erklaerung-klima-und-energie-indien_en.html

The World Bank. (2015). *World development indicators: Electricity production, sources and access*. Retrieved November 18, 2015, from http://wdi.worldbank.org/table/3.7

Tiwari, R., & Herstatt, C. (2011). *Lead market factors for global innovation: Emerging evidence from India*. Institute for Technology and Innovation Management, Hamburg University of Technology (TUHH), Working Paper No. 61, pp. 1–18.

Transphorm Inc. (2014). *Transphorm partners with Tata power solar to introduce India's Most efficient solar inverter*. Retrieved December 20, 2015, from http://www.transphormusa.com/news/transphorm-partners-tata-power-solar-introduce-india%E2%80%99s-most-efficient-solar-inverter

UNFCCC. (2015). *India and France launch international solar energy alliance at COP21*. Retrieved December 20, 2015, from http://newsroom.unfccc.int/clean-energy/international-solar-energy-alliance-launched-at-cop21/

United Nations. (2014). *The millennium development goals report*. Retrieved December 1, 2015, from http://www.un.org/millenniumgoals/reports.shtml

Upadhyay, A. (2015a). *Reserve Bank of India notifies renewable energy under priority sector lending | Clean technica*. Retrieved December 10, 2015, from http://cleantechnica.com/2015/04/28/reserve-bank-india-notifies-renewable-energy-priority-sector-lending/

Upadhyay, A. (2015b). *India officially ramps up solar power target to 100 GW by 2022 | Clean technica*. Retrieved December 18, 2015, from http://cleantechnica.com/2015/06/22/india-officially-ramps-solar-power-target-100-gw-2022/

Vortex. (2015). *Vortex FORECAST helps India's wind industry to forecast wind farms*. Retrieved October 18, 2015, from http://www.vortexfdc.com/vortex-forecast-india/

WMO. (2015). *Greenhouse gas concentrations hit yet another record*. Retrieved November 17, 2015, from http://www.wmo.int/media/content/greenhouse-gas-concentrations-hit-yet-another-record

Commercial Vehicle Industry in India: An Investigation of the Innovation and Business Trends (2000–2015)

Rajnish Tiwari and Bhimsen Dattatraya Phadnis

1 Introduction

India's automobile industry contributes about 7 % to the country's gross domestic product (GDP), as per a report by India Brand Equity Foundation (IBEF, 2016). The cumulated gross turnover of all members of the Society of Indian Automobile Manufacturers (SIAM) in India stood at Rs. 3593.5 billion (around US$58.7 billion) in fiscal year (FY) 2014–2015, out of which the contribution of four-wheeled vehicles was about 71 % (SIAM, 2016d). Around 20.4 million two-wheelers, three-wheelers, passenger vehicles and commercial vehicles (CVs) were produced in India in FY 2015–2016 (SIAM, 2016a).

According to the International Organization of Motor Vehicle Manufacturers (OICA) India was the seventh largest producer of CVs in the world in 2015, after the United States, China, Mexico, Japan, Canada and Thailand, in that order (OICA, 2016). CVs are those vehicles which are used for commercial transportation of passengers and/or goods. They are classified based on gross vehicle weight (GVW) as shown in Table 1 (based on: ICRA, 2015).

India has made a long journey from being almost a non-entity in the global automotive industry prior to the launch of economic reforms in 1991 (Krueger, 2010; Wolf, 2010) to becoming a lead market for small cars (Tiwari & Herstatt, 2014). It is the passenger car industry that has mostly received scholarly attention due to its higher visibility and probably due to larger-scale involvement of global players. Developments in the CV industry, which remains dominated by domestic players such as Tata Motors, Mahindra & Mahindra, and Ashok Leyland, have by and large remained "invisible" outside the world of subject-matter experts. As a result, little is known of the in-depth business and innovation profile of the world's

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Table 1 Classification of CVs

CV segment	GVW (in metric ton)
LCV (light commercial vehicle)	Less than 7.5
MCV (medium commercial vehicle)	7.5–16.2
HCV (heavy commercial vehicle)	More than 16.2

seventh largest CV industry. Not many know that India's Tata Motors has been home to two of the most successful disruptive, frugal innovations in the CV industry; namely the Tata 407 prior to economic liberalization (Maira, 2015) and the Tata Ace in 2005 (Palepu & Srinivasan, 2008). The Tata Ace, a small commercial vehicle (SCV) from the stable of Tata Motors "was launched in May 2005 as India's first mini-truck with a sub-one tonne payload" (TML, 2010). It proved to be a resounding commercial success (TML, 2012b, 2013b), which was not only able to create a completely new space in the domestic CV industry (Palepu & Srinivasan, 2008; TML, 2015a), but also has fared quite well in the export market (Tiwari & Herstatt, 2012). Export of products from the Tata Ace family, according to company information, crossed the mark of 100,000 units in 2015, "with a foot print spanning 28 countries across South Asia, Africa and the ASEAN regions" (TML, 2015a).

A primary aim of this study, therefore, is to analyze the business profile of Indian CV industry and the types of innovations introduced by different companies in the years from 2000 to 2015. Companies, which are members of SIAM, have been selected for the purpose of the study as that helps us cover all manufacturers known to produce automobiles domestically. The investigated set of companies comprises of Tata Motors Ltd., Ashok Leyland Ltd., Mahindra and Mahindra Ltd., Force Motors Ltd., Eicher Motors Ltd., SML Isuzu Ltd., Piaggio group, Daimler India Commercial Vehicle (DICV), Scania Commercial Vehicle India (SCVI) and Asian Motors Works (AMW). The profile study is based on analysis of product portfolios, financial data, research and development (R&D) expenditure on in-house R&D, royalty fees and license fees for technical know-how, innovative products/features and processes, open innovation in innovative products, launch of products and product selling points. Data for profile study is collected from annual reports, press releases, official websites and other publically available sources. We make use of "thick description" (Barzelay, 1993) for this qualitative study, which has been conceptualized as containing small vignettes ("nested cases") within a larger single case (Dyer & Wilkins, 1991; Eckstein, 1975; Gibbert, Ruigrok, & Wicki, 2008).

The paper is structured as follows: After this brief introduction, we familiarize the reader with India's CV industry covering macro-economic trends and developments in Sect. 2. This section contains key profile information for top-3 players that jointly control about more than three-quarters of the CV industry. In Sect. 3 we provide some examples of innovations that we were able to observe based on publically available information. The section exemplifies the innovative solutions along the typology of innovation in accordance with the Oslo Manual (OECD &

Eurostat, 2005). Section 4 contains the aggregated analysis at industry level. The paper concludes with Sect. 5.

2 Indian Commercial Vehicle Industry

2.1 Industry Developments

Indian automobile industry has come a long way after India became independent. Growth of the post-Independence Indian automobile industry is generally thought to have occurred in four phases (see, e.g., D'Costa, 1995; Kathuria, 1987; Narayanan, 1998, 2004; Tiwari, Herstatt, & Ranawat, 2011). The first phase (1947–1965) saw policies which protected domestic companies from foreign competition. In the second phase (1966–1979), policies were designed to overcome economic problems of India. These policies aided particular automobile segments such as Two-wheelers and tractors. In the third phase (1980–1990) certain relaxations were provided to encourage technological acquisitions and foster joint ventures. This increased competition in the industry. In the ongoing fourth phase (since 1991) the automobile industry was opened up successively for foreign direct investments (FDI) and has been fully liberalized in the course of time. In 2006, the government introduced an "Automotive Mission Plan" to strengthen the industry and to make India a global player in this field (GOI, 2006). Today there are about 10 main players in the CV industry, who are spread throughout India. Figure 1 shows clusters of CV manufacturers in India.

The improvement in the road infrastructure has also played a part in the development of the CV industry. While India, after Independence, had a road network of less than 400,000 km in FY 1950–1951, the network size had increased to 2.3 million km by FY 1990–1991 by the time economic liberalization program was launched. The network more than doubled to 5.2 million km by FY 2012–2013 (SIAM, 2016e). The length of the national highways alone has increased from 33,650 km in FY 1990–1991 (SIAM, 2016e) to more than 100,000 km according to the latest official figures by the Ministry of Road Transport and Highways (GOI, 2016). This has enabled faster transportation of vehicles and has increased the number of possible trips per vehicle for (business) customers reducing the total cost of ownership (TCO), especially relevant for small businesses and self-employed service providers. Not surprisingly, therefore, in a press release to mark the tenth anniversary of the Tata Ace, the manufacturer claimed that "the Ace family has helped uplift many lives and has been a strong contributor to the growth of many entrepreneurs and small scale businesses in India" (TML, 2015a). The increase in the road network has, thus, facilitated CV manufacturers to assist their customers in increasing their own sales and revenue (Roy, 2014).

As a result of liberalization the competition in the CV industry has intensified. This has also increased involvement of companies in innovation activities

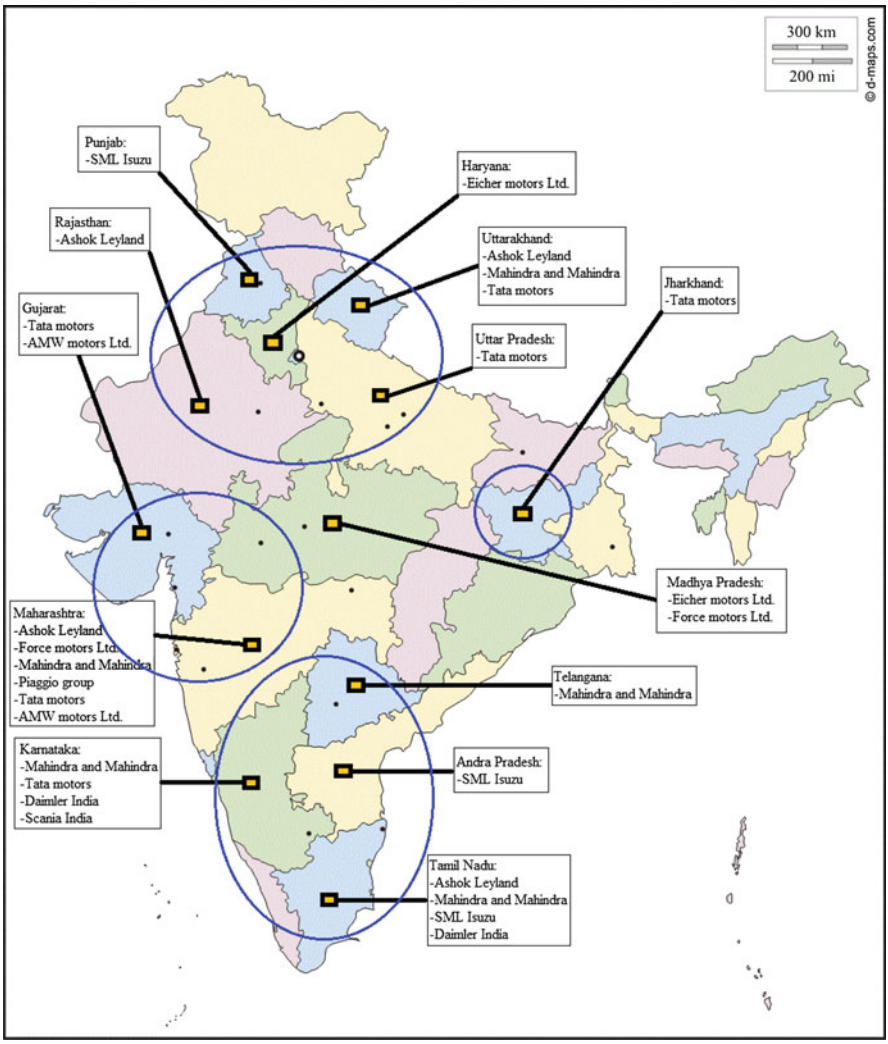

Fig. 1 Cluster of companies in India (Source: Self construction based on data collected from different companies chosen for this study)

(Narayanan, 2001, 2004). Thus, efforts in in-house R&D activities and technological agreements increased as well (Ranawat & Tiwari, 2009). In FY 2014–2015, the automobile industry in India spent close to US$1 billion on R&D up from US$860 million in the previous year (SIAM, 2016d). Companies have apparently also realized the importance of open innovation in creating "frugal solutions" that are based on enabling affordable excellence. This has resulted in significant efforts to involve innovation from different sources into their products (Khanna, Lal, & Manocaran, 2005; Palepu & Srinivasan, 2008; Wielgat, 2002). These, partly

pioneering, activities have enabled companies to successfully launch products that are technologically advanced, have high fuel efficiency and are available at affordable price.

With these developments, companies have been able to offer different products fulfilling specific customer needs. This has not only helped companies to expand their product portfolios but also increased the number of units sold and the revenues generated. In addition, technological agreements, joint ventures, acquisitions and mergers have assisted companies to enter into new markets. Consequently, revenue from exports has significantly increased. These agreements have also resulted in change of organizational practice and business environment.

Apart from providing unique product features, different strategies like celebrity endorsement, race championships and road shows have been put in practice to market products. Even if this is not something completely new to the world, many of such practices have been at the very least new to the concerned firm, fulfilling the definitional criteria for innovations (Garcia & Calantone, 2002; OECD & Eurostat, 2005). Emphasis on process innovation has also helped companies to manufacture high-quality products at low cost. Thus, it is a reasonable inference that different innovations in products, processes, organization structure and marketing have helped CV industry to develop.

Table 2 shows number of units sold by Indian CV industry from 2000 to 2015. It can be observed from the table that the relative fluctuation in the volume of domestic sales is higher compared to that of exports. Products like the Tata Ace and the Ashok Leyland Dost have significantly contributed to sales increase of industry. Products based on the Ace-platform crossed sales landmark of 1.5 million in 2015, 10 years after the launch (TML, 2015a). In a press release the company said that "Today, one in every five commercial vehicle sold in India, is from the Tata Ace Family" (TML, 2015a).

Ashok Leyland's Dost sold the 100,000th unit 4 years after launch in 2015 (Rishi Kumar, 2015). A top company representative said that the truck was being exported to around one-dozen countries and that "several features of Dost, including higher mileage and reliability and low total cost of ownership have helped achieve" commercial success (Rishi Kumar, 2015). Generally speaking, Bangladesh, Sri Lanka, Kenya, Nepal and South Africa belong to the top-5 destinations for Indian CVs meant for transport of goods (SIAM, 2016e).

About 80 % of M&HCV market segment is held jointly by Tata Motors and Ashok Leyland, whilst close to 88 % of LCV market segment is shared by Tata Motors and Mahindra & Mahindra (Autobei, 2015). Other important companies like Eicher Motors Ltd., Force Motors Ltd., AMW Motors Ltd. and SML Isuzu Ltd. offer products for specific applications. Market shares of leading players in India's CV industry based on their sales in the domestic and export markets in FY 2014–2015 are shown in Fig. 2. As can be seen, the top-3 players dominate the CV industry almost completely with a market share of about 85 %.

Table 2 Sales figures of Indian CV industry[a]

Fiscal year	Units sold	Domestic	Export	Percentage change (units sold)
2000–2001	150,452	N.A.	N.A.	N.A.
2001–2002	143,676	N.A.	N.A.	−(5)
2002–2003	202,937	190,682	12,255	41
2003–2004	277,546	260,114	17,432	37
2004–2005	348,378	318,438	29,940	26
2005–2006	391,641	351,041	40,600	12
2006–2007	517,648	467,882	49,766	32
2007–2008	549,488	490,494	58,994	6
2008–2009	426,747	384,122	42,625	−(22)
2009–2010	576,404	531,395	45,009	35
2010–2011	760,735	684,905	74,043	31
2011–2012	929,136	809,499	92,258	20
2012–2013	832,649	793,211	80,027	−(3)
2013–2014	699,035	632,851	77,050	−(19)
2014–2015	698,298	614,948	86,939	−(1)
2015–2016	782,814	685,704	101,689	(12)

[a]Source: Data for FY 2000–2001 to 2008–2009 was retrieved from Annual reports of Tata Motors Ltd., for 2009–2010 to 2014–2015 was retrieved from the website of SIAM (e.g., 2016a, 2016b, 2016c)

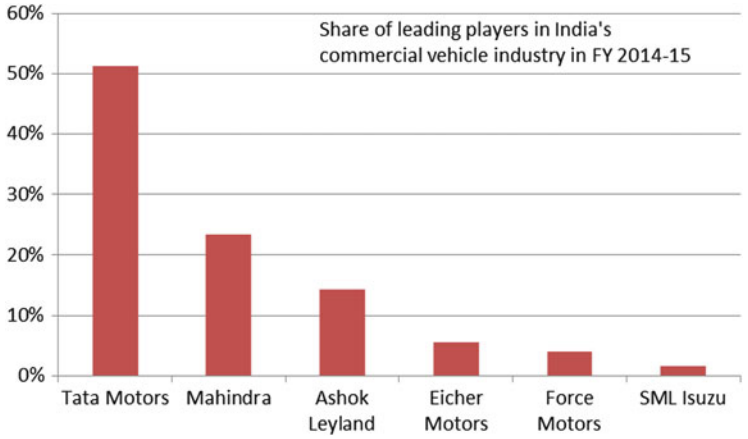

Fig. 2 Share of leading players in India's CV industry

2.2 Select Company Profiles

In this section we describe profiles of top-3 companies from India's CV industry. Data are based—unless specified otherwise—on the annual reports of the respective companies. Aggregated data for all companies in the sample are provided in Sect. 5.

Tata Motors Ltd. was established in 1945 as Tata Engineering and Locomotive Co. Ltd. The company produces full range of four-wheeled vehicles. Between 2000 and 2015 Tata Motors launched 23 vehicles in the CV segment. Among these, 17 vehicles are currently offered to customers in more than 204 variants; prices vary depending on the model between 4200 euros and 104,000 euros. It sold more than 377,000 units of CVs in FY 2014–2015 compared to 82,000 units in FY 2000–2001. Cumulative revenues of Tata Motors in FY 2014–2015 from its automotive business in India (including exports) stood at 5.1 billion euros, which was about 2.5 times higher in comparison to FY 2000–2001. The share of exports stood at 15 % in 2014–2015. The company has the largest market share in India. Export destinations are mostly located in other emerging markets like Bangladesh, Sri Lanka, Nepal, South Africa and Indonesia. Saudi Arabia, UAE and Qatar are also major export destinations of the company. It has grown in global market through various acquisitions and joint ventures. For instance, Tata Motors acquired Daewoo Commercial Vehicles Company in South Korea which has a significant local market share in the truck market segment. The company also acquired Hispano Carrocera in Spain, which is a reputed bus and coach manufacturer. Moreover the company has joint venture with Thonburi Automotive in Thailand which is known for expertise in pickup-trucks. The company has R&D centers in India, UK, Italy, Spain and South Korea. These centers are responsible for developing vehicles suitable for different climatic conditions and customers. In FY 2014–2015, it spent more than 6 % of its turnover on R&D. In absolute terms, the expenditure on R&D and royalties stood at about 360 million euros. Many of its innovative solutions (e.g. Ace, Xenon) have become known for enabling fuel efficient, affordable mobility.

Mahindra & Mahindra can also look back at a firm history that goes back to 1945. In FY 2014–2015 it sold 172,566 units of CVs (export share: 15 %), apart from passenger vehicles and two-wheelers; and generated cumulative revenues worth 5.2 billion euros. In FY 2000–2001 its revenues had stood at 1.1 billion euros. It is a global firm with a strong presence in Europe including in Germany. In FY 2014–2015 the company spent close to 200 million euros on R&D, which was about 3.65 % of its total turnover. Between 2000 and 2015 the company has launched 15 models, which are currently offered in more than 70 variants, which are sold for prices varying between approx. 2700 euros and 50,000 euros. Products like Maxximo (Pickup trucks) and Navistar trucks have helped the company to increase exports. With various products, the company has been exporting vehicles to South Africa, UAE, Uruguay and Malaysia. Apart from this, it also exports vehicles to Europe, South America and Australia. Mahindra's Annual Report for 2015 states that it has well established markets in Italy, Chile and Bangladesh. Pickup trucks of Mahindra & Mahindra are also reported to have considerable market share in Sri Lanka, Peru and Tunisia.

Ashok Leyland has a history, which can be traced back to 1948. It has a strong presence in M&HCV segment. In FY 2014–2015, Ashok Leyland sold 104,902 CVs and generated 1.9 billion euros in revenues. The company revenue in FY 2000–2001 had stood at 485 million euros, which means the company could

increase its revenues fourfolds within 15 years. Since 2000, Ashok Leyland has introduced 23 series of vehicles in the markets. Currently it offers 15 models in more than 90 variants for a price that ranges between 6500 euros and 53,000 euros. The net sales increased from 32,475 units in FY 2000–2001 to 104,902 units in FY 2014–2015. The company places emphasis on innovation and has a design and development center with close to 1000 engineers in Chennai (India). The company spent 1.36 % of the total turnover on R&D activities in FY 2014–2015. In absolute terms the company spent about 29 million euros on R&D, royalties and license fees for technical knowhow. It reportedly was "the first to introduce three-axled trucks, full-air brakes and a host of innovations like the rear-engine and articulated buses in India, the country's first CNG bus and the first Hybrid Electric Vehicle" (Gopalakrishnan, 2008). In 2006, Ashok Leyland formed a joint venture with Avia which is based in Prague (Czech Republic). AALM (Avia Ashok Leyland Motors) offers D series trucks in Czech Republic, Spain, Slovakia, Ireland, UK and Hungary. Furthermore, Ashok Leyland has entered into a joint venture with Ras Al Khaimah which has a bus assembly unit in UAE. With the help of this unit Ashok Leyland has secured footprints in Middle East. In addition, the Hinduja group, owner of Ashok Leyland, has a support division in Germany namely Albonair GmbH and this division has small scale sales office at Shanghai (China). Apart from this, Ashok Leyland has exported vehicles to several emerging markets like Sri Lanka, Africa and Russia.

3 Select Examples of Innovations from India's CV Industry

In this section we provide select examples of innovations from India's commercial vehicle industry. The examples are organized along the dimension of "innovation type" in accordance with the Oslo Manual (OECD & Eurostat, 2005).

3.1 Product Innovations

Tata Motors has developed several innovative products. Products like Tata Ace has created new market segment in CV industry (Palepu & Srinivasan, 2008; Pradhan, 2015). Tata Ace operates on a two cylinder Common Rail Diesel Engine (CRDe) which reduces noise and vibration levels (Palepu & Srinivasan, 2008). In addition, the design ensures that electronic system is avoided. Apart from this, a rotary fuel injection pump was developed for Tata Ace which met the emission standards. This system reduces overall complexity of system and enables easy maintenance. It also has also resulted in significant cost reductions (Palepu & Srinivasan, 2008).

Force Motors developed vehicles using carbon fibers (FML, 2015). This has reduced the weight of vehicles, which in turn increases the fuel efficiency. Furthermore, an innovative arrangement was designed for hot and cold air option, mainly

used in the Traveller and the Gurkha (FML, 2013). Instead of providing different openings for air conditioning, air was directed from dashboard. These new materials and techniques have reportedly improved product performance. In 2015, Force Motors launched a new, "fully indigenous" model of its flagship carrier, the Trax, which is a CV for passenger transport aimed at rural buyers and with its robust features seeks to provide "connectivity from large cities to poorly connected villages and talukas" (Singh, 2015). To increase its appeal to its target customer groups, it has been fitted with a "wide extended foot-board on the sides" to ensure "comfortable entry and exit for sari clad women, children and the elderly" and is sold with a claimed "unmatched" warranty of 3 years/300,000 km and seven free services (Singh, 2015).

3.2 Process Innovations

Tata Motors have developed a new coating process for increasing corrosion resistance (TML, 2007). This coating process utilizes "T-coat" mainly used for large components. This coating helps to reduce powdering and cuts cost of manufacturing. In addition, the blast furnaces are modified to decrease slag volume which in turn reduces viscosity of slag and increases productivity of blast furnaces.

Mahindra & Mahindra focuses on process innovations in order to conserve energy and reduce manufacturing costs. It reportedly utilizes renewable energy sources such as solar in manufacturing process (Mahindra, 2013, 2015). An innovative, wet-on-wet painting process used by Mahindra & Mahindra, which is a three stage filtration process which reduces, reuses and recycles waste from paint process. In addition, the performance of paint guns and paint circulation pumps are optimized which have increased process efficiency. Apart from this, Mahindra and Mahindra is using a new four layered semiconductor rectifier known as thyristor for heating furnaces. This semiconductor reduces consumption of energy. These new processes decrease manufacturing cost and increase efficiency of production process.

3.3 Organizational Innovations

Xenon was developed by **Tata Motors** in joint venture with Thonburi Automotive Assembly Plant, Thailand (TML, 2008). Buses like Tata Divo and Xerus were developed by Hispano Carrocera S.A. (HC), Spain which was acquired by Tata Motors (TML, 2012a). Tata motors have played different role in developing these products. In addition, the company developed new technology for mass production of buses by forming joint venture with Marcopolo, Brazil (TML, 2007). Thus the company has modified organizational practices to increase innovation activities.

Various types of agreements (like joint ventures, acquisitions) have assisted **Eicher Motors Ltd.** in developing new products. For example in joint venture with Polaris industries (USA), Eicher Motors Ltd. is involved in design, development, manufacture and marketing (EML, 2015).

3.4 Marketing Innovations

Tata Motors address innovative features of a vehicle during launch of a product. These features create interest in customers and in turn help the company to connect with customers. For instance, during the launch of Prima trucks, the company addressed it as a "World truck". This assisted the company to inform customers that various truck components were developed in different parts of the world (TML, 2013a). Furthermore, the company started Truck racing championship in 2014 which was the first of its kind in India (TML, 2015b). These new promotion techniques assisted Tata Motors to differentiate themselves from competitors and grab attention of potential customers.

Mahindra & Mahindra has taken "pioneering initiatives" regarding warranty of vehicles. The company claims to be the first to offer a 5 year transferrable warranty to customers. The company also presented some vehicles to the members of Indian cricket team. For example, the first Bolero Stringer was presented to Indian batsman Gautam Gambhir and Bolero special edition was handed over to another Indian batsman Robin Uthappa. Thus the company utilizes new pricing and promotion methods to address customers. While these measures may not sound radically innovative, they do qualify as innovations and document innovation efforts if they are new to the firm (cf. OECD & Eurostat, 2005).

4 Aggregated Analysis at Industry Level

After analyzing business and innovation profile of different companies, profile of Indian CV industry is assessed. It was evident from the study that various innovation activities have assisted companies to develop new products and variants. In addition, the companies have also increased their footprint at global level. As a result, profile of CV industry depends on strategy and tactics of these firms (Fig. 3).

It can be observed from the above figure that there was a steady growth from 2000 to 2007. After a decline during 2008, the industry picked up the pace and grew rapidly till 2011, since then the sales have been somewhat erratic, though on a higher level.

Table 3 shows the number of product launches as well as those innovations that we could observe based on publically available reports and documents.

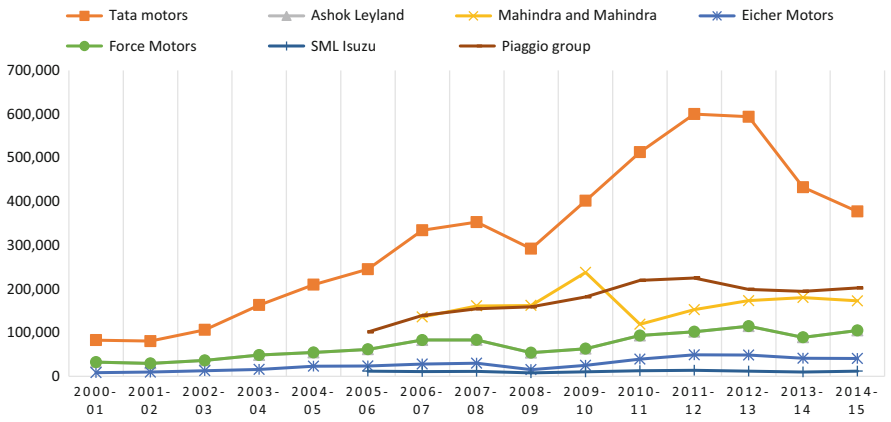

Fig. 3 Number of units sold by Indian CV industry and different companies (Self-construction based on data collected for CV industry and from respective annual reports of companies)

In this study, it was observed that most of the companies invest in in-house R&D activities. These activities have enabled the companies to offer more than 170 vehicles in the market today. Figure 4 depicts Types of innovations observed in India's CV industry from 2000 to 2015. It can be seen from that product innovation was the most dominant form of innovations, followed by process innovations. All companies engaged in product innovations in the period of analysis. A closer look at these innovations showed that they often aimed at improving fuel efficiency, providing alternate fuel options, increasing torque and power delivered by engines, developing new steering mechanisms (reduces fatigue of driver) and improving safety features.

Seven out of ten companies also engaged in process innovations. These innovations focused on using renewable energy sources, increasing efficiency in paint shops and heating systems (blast furnaces) which help reduce manufacturing costs.

Companies have also emphasized on Open innovations. These innovations have led to different types of agreements such as joint ventures, acquisitions, mergers, technical collaborations etc. In order to fulfill different roles in these agreements, the companies have made Organizational innovations. Organization innovation activities aim at developing new product components or process improvement to offer better solutions to customers. They have enabled the companies to enter new markets and increase revenue. These activities have also helped companies to improve existing products and provide different variants. As a result companies rely on product improvements which are due to Incremental innovations for their growth. Some of the companies adopt different marketing tactics to attract customers. These different Market innovation activities include celebrity endorsement, attractive warranty offers, road shows and truck racing championships.

Figure 5 shows the relative share of the different types of innovations in all observed innovations for FY 2004–2005 to FY 2014–2015. One interesting thing to note is that the innovation portfolio has, apparently, become more balanced or

Table 3 Innovation activity in Indian CV industry based on publically available (non-exhaustive) data[a]

	Product Portfolio			Innovations introduced				
Company	Discontinued products	Current products	Total	Product innovation	Process innovation	Organization innovation	Market innovation	Total
Ashok Leyland Ltd.	8	15	23	6	2	1	2	11
Tata Motors Ltd.	6	17	23	7	4	3	3	17
Mahindra & Mahindra Ltd.	0	16	16	6	3	2	3	14
Force Motors Ltd.	0	16	16	4	2	3	3	12
Eicher Motors Ltd.	4	27	31	5	1	2	3	11
Piaggio group	5	5	10	3	4	N.A.	N.A.	7
SML Isuzu Ltd.	1	16	17	4	5	2	N.A.	11
Daimler India	0	17	17	3	N.A.	1	N.A.	4
Scania India	0	8	8	5	N.A.	3	N.A.	8
AMW Motors Ltd.	3	7	10	2	N.A.	N.A.	3	5
Total	27	144	171	45	21	17	17	100

[a]Data summarized based on analysis of companies selected for this study

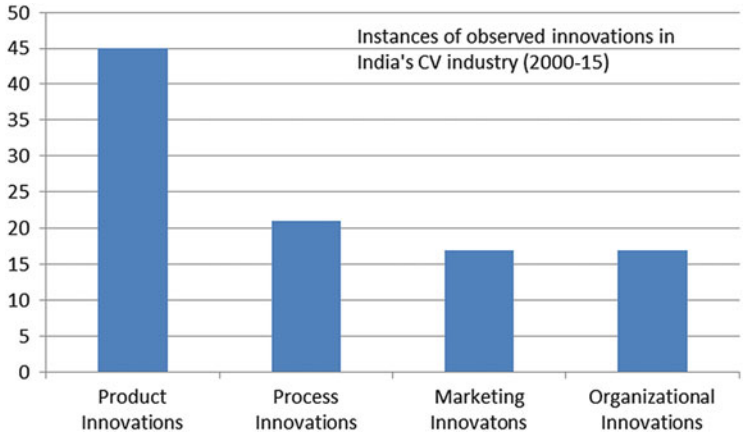

Fig. 4 Types of innovations observed in India's CV industry from 2000 to 2015

broad-based. While companies earlier engaged primarily in product innovations, of late, we can observe instances of all types of innovations. This, probably, can be interpreted as a sign of growing sophistication of the industry.

5 Conclusion

This study sought to investigate the innovation and business profile of Indian CV industry. It was observed that the industry has grown tremendously since the turn of the new millennium. Intensified innovation and R&D activities have, apparently, played a crucial role in strengthening the CV industry. These activities have resulted in new product components which provide unique value to customers. In addition, the companies have invested heavily on in-house R&D activities compared to expenditure on royalties and technical know-how.

R&D activities have led to various types of innovations. Many of the observed product innovations aimed at continuous improvement of product performance. These incremental innovation activities have assisted companies to increase their market share, revenue, profit and create new market segments. The focus has been, apparently, less on radical innovations, which also does not need to be an objective unto itself.

Apart from this, companies were found to be actively utilizing open innovation as an important source to develop new solutions. Companies have even changed their business practices (implemented organizational innovation) to integrate open innovation activities. These have also helped companies to increase number of units exported. Asian and African markets have a major share of these exports as customer needs are probably similar. This confirms the lead market character of affordability-driven, frugal solutions being created in India.

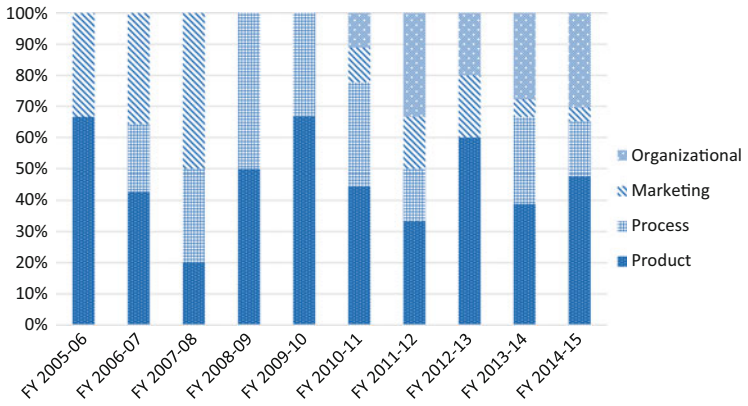

Fig. 5 Share of the different types of innovations in all observed instances

With the help of intensified innovation activities, Indian CV industry has increased its footprint across the globe. Furthermore, these have also assisted companies to offer unique value and meet specific customer needs. The industry is shifting towards improving fuel efficiency, providing alternate fuel options and reducing cost of manufacturing. This approach encourages total cost of ownership strategy to increase sales and revenue of companies.

A note of caution must be added before concluding the study. The findings must be treated as preliminary, as they are based on observance of publically available (secondary) data. In a next step, we intend to gather first-hand primary data through expert interviews with various stakeholders to further ascertain the validity of these results. Nevertheless, there is reason to believe that the findings point in the right direction and that India's commercial vehicle industry, just as its cousin—the passenger car industry, is driven by frugal solutions and possesses a strong lead market potential in regional markets and beyond.

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References

Autobei. (2015, December 2). *Indian commercial vehicle mega trend analysis*. Retrieved January 7, 2016, from http://www.acganalysis.com/indian-commercial-vehicle-mega-trend-analysis/

Barzelay, M. (1993). The single case study as intellectually ambitious inquiry. *Journal of Public Administration Research and Theory, 3*(3), 305–318.

D'Costa, A. P. (1995). The restructuring of the Indian automobile industry: Indian state and Japanese capital. *World Development, 23*(3), 485–502.

Dyer, W. G., & Wilkins, A. L. (1991). Better stories, not better constructs, to generate theory: A rejoinder to Eisenhardt. *Academy of Management Journal, 16*(3), 613–619.

Eckstein, H. (1975). Case study and theory in political science. In F. I. Greenstein & N. W. Polsby (Eds.), *Strategies of inquiry* (Vol. 7, pp. 79–137). London: Addison-Wesley.
EML. (2015). *2014 Annual report*. New Delhi: Eicher Motors Ltd.
FML. (2013). *Annual report 2012–13*. Pune: Force Motors Ltd.
FML. (2015). *Annual report 2014–15*. Pune: Force Motors Ltd.
Garcia, R., & Calantone, R. (2002). A critical look at technological innovation typology and innovativeness terminology: A literature review. *Journal of Product Innovation Management, 19*, 110–132.
Gibbert, M., Ruigrok, W., & Wicki, B. (2008). What passes as a rigorous case study? *Strategic Management Journal, 29*(13), 1465–1474.
GOI. (2006). *Automotive mission plan 2006–2016*. New Delhi: Department of Heavy Industry, Ministry of Heavy Industries and Public Enterprises, Government of India.
GOI. (2016). *National Highways Details*. Retrieved July 16, 2016, from http://morth.nic.in/index2.asp?slid=32&sublinkid=12&lang=1
Gopalakrishnan, K. (2008, August 2). *Ashok Leyland R&D Centre thrust on global technology*. Retrieved November 21, 2015, from http://www.motorindiaonline.in/commercial-vehicles/ashok-leyland-rd-centre-thrust-on-global-technology/
IBEF. (2016). *Automobile industry in India*. New Delhi: India Brand Equity Foundation.
ICRA. (2015). *Indian automobile and auto component industry report*. New Delhi: Information and Credit Rating Agency.
Kathuria, S. (1987). Commercial vehicles industry in India: A case history, 1928–1987. *Economic and Political Weekly, 22*(42/43), 1809–1823.
Khanna, T., Lal, R., & Manocaran, M. (2005). *Mahindra & Mahindra: Creating Scorpio, Case 9-705-478*. Boston: Harvard Business School.
Krueger, A. O. (2010). India's trade with the world: Retrospect and prospect. In S. Acharya & R. Mohan (Eds.), *India's economy: performances and challenges – essays in honour of Montek Singh Ahluwalia* (pp. 399–429). New Delhi: Oxford University Press.
Mahindra. (2013). *Sustainability review 2012–13*. Mumbai: Mahindra & Mahindra Ltd.
Mahindra. (2015). *Annual report 2015*. Mumbai: Mahindra & Mahindra Ltd.
Maira, A. (2015). *An upstart in the government: Journeys of change and learning*. New Delhi: Rupa Publications.
Narayanan, K. (1998). Technology acquisition, de-regulation and competitiveness: A study of Indian automobile industry. *Research Policy, 27*(2), 215–228.
Narayanan, K. (2001). *Liberalisation and the differential conduct and performance of firms: A study of the Indian automobile sector*. Institute of Economic Research, Hitotsubashi University, Tokyo and United Nations University Institute of Advanced Studies.
Narayanan, K. (2004). Technology acquisition and growth of firms: Indian automobile sector under changing policy regimes. *Economic and Political Weekly, 39*(5), 461–470.
OECD, & Eurostat. (2005). *Oslo manual: Guidelines for collecting and interpreting innovation data*. Paris: Organisation for Economic Co-Operation and Development (in joint publication with Eurostat).
OICA. (2016). *2015 Production statistics*. Paris: International Organization of Motor Vehicle Manufacturers (Organisation Internationale des Constructeurs d'Automobiles).
Palepu, K. G., & Srinivasan, V. (2008). *Tata Motors: The Tata Ace, Case 9-108-011*. Boston: Harvard Business School.
Pradhan. (2015, December 31). *How Tata Ace opened a new market segment*. Retrieved July 17, 2016, from https://trucks.cardekho.com/en/news/detail/how-tata-aceopened-a-new-market-segment-519.html
Ranawat, M., & Tiwari, R. (2009). *Influence of government policies on industry development: The case of India's automotive industry*. Working paper No. 57. Institute of Technology and Innovation Management, Hamburg University of Technology, Hamburg.
Rishi Kumar, V. (2015, July 21). *Ashok Leyland celebrates sales of 1,00,000 Dost LCVs*. Retrieved January 13, 2016, from http://www.thehindubusinessline.com/companies/ashok-leyland-celebrates-sales-of-100000-dost-lcvs/article7447795.ece

Roy, N. S. (2014, September 18). *Cost of ownership and new gen commercial vehicles to shape success*. Retrieved January 13, 2016, from http://www.rushlane.com/bharatbenz-success-value-truck-segment-12130952.html

SIAM. (2016a). *Automobile domestic sales trends*. Retrieved July 15, 2016, from http://www.siamindia.com/statistics.aspx?mpgid=8&pgidtrail=14

SIAM. (2016b). *Automobile exports trends*. Retrieved July 15, 2016, from http://www.siamindia.com/statistics.aspx?mpgid=8&pgidtrail=15

SIAM. (2016c). *Automobile production trends*. Retrieved July 15, 2016, from http://www.siamindia.com/statistics.aspx?mpgid=8&pgidtrail=13

SIAM. (2016d). *Profile: Automobile industry in India 2014–15*. New Delhi: Society of Indian Automobile Manufacturers.

SIAM. (2016e). *Statistical profile of automobile industry in India 2014-2015*. New Delhi: Society of Indian Automobile Manufacturers.

Singh, C. P. (2015, September 19). *Force Motors introduces air conditioned trax deluxe range*. Retrieved July 19, 2016, from http://newznew.com/force-motors-introduces-air-conditioned-trax-deluxe-range/

Tiwari, R., & Herstatt, C. (2012). Assessing India's lead market potential for cost-effective innovations. *Journal of Indian Business Research, 4*(2), 97–115.

Tiwari, R., & Herstatt, C. (2014). *Aiming big with small cars: Emergence of a lead market in India*. Heidelberg: Springer.

Tiwari, R., Herstatt, C., & Ranawat, M. (2011). Benevolent benefactor or insensitive regulator? Tracing the role of government policies in the development of India's automobile industry. *Policy Studies, 58*.

TML. (2007). *Sixty-second annual report 2006–07*. Mumbai: Tata Motors Ltd.

TML. (2008). *Sixty-third annual report 2007–08*. Mumbai: Tata Motors Ltd.

TML. (2010, April 13). *Tata Ace becomes India's first 1-lakh brand in goods commercial vehicles*. Press release.

TML. (2012a). *67th Annual report 2011–2012*. Mumbai: Tata Motors Ltd.

TML. (2012b, November 8). *Tata Ace races through the one-million mark in just 2,680 days*. Retrieved April 7, 2014, from http://ace.tatamotors.com/media-room/press-release.aspx

TML. (2013a). *68th Annual report 2012–13*. Mumbai: Tata Motors Ltd.

TML. (2013b). *The Ace story*. Retrieved October 12, 2013, from http://ace.tatamotors.com/aboutus.php

TML. (2015a, July 17). *India's No. 1 mini-truck – Tata ACE completes a decade of trust one in every five commercial vehicle, sold in India, is from the Tata ACE Family*. Press release.

TML. (2015b, January 20). *Tata Motors announces T1 PRIMA TRUCK RACING CHAMPIONSHIP 2015 – Season 2*. Retrieved July 17, 2016, from http://www.tatamotors.com/press/tata-motors-announces-t1-prima-truck-racing-championship-2015-season-2/

Wielgat, A. (2002). Manufacturing the Mahindra way. *Automotive Industries, 182*(10), 34–40.

Wolf, M. (2010). India in the world. In S. Acharya & R. Mohan (Eds.), *India's economy: Performances and challenges – essays in honour of Montek Singh Ahluwalia* (pp. 369–398). New Delhi: Oxford University Press.