PALGRAVE STUDIES IN THE HISTORY OF ECONOMIC THOUGHT

Science, Technology and Innovation in the History of Economic Thought

Edited by
Estrella Trincado Aznar · Fernando López Castellano

palgrave
macmillan

Palgrave Studies in the History of Economic Thought

Palgrave Studies in the History of Economic Thought publishes contributions by leading scholars, illuminating key events, theories and individuals that have had a lasting impact on the development of modern-day economics. The topics covered include the development of economies, institutions and theories.

The series aims to highlight the academic importance of the history of economic thought, linking it with wider discussions within economics and society more generally. It contains a broad range of titles that illustrate the breath of discussions — from influential economists and schools of thought, through to historical and modern social trends and challenges — within the discipline.

All books in the series undergo a single-blind peer review at both the proposal and manuscript submission stages.

For further information on the series and to submit a proposal for consideration, please contact Wyndham Hacket Pain (Economics Editor) wyndham.hacketpain@palgrave.com.

The series is dedicated to the memory of former editor and distinguished economist Geoff Harcourt.

Estrella Trincado Aznar
Fernando López Castellano
Editors

Science, Technology and Innovation in the History of Economic Thought

palgrave
macmillan

Editors
Estrella Trincado Aznar
Department of Applied Economics, Structure and History
Complutense University of Madrid
Madrid, Spain

Fernando López Castellano
Department of Applied Economics
University of Granada
Granada, Spain

ISSN 2662-6578 ISSN 2662-6586 (electronic)
Palgrave Studies in the History of Economic Thought
ISBN 978-3-031-40138-1 ISBN 978-3-031-40139-8 (eBook)
https://doi.org/10.1007/978-3-031-40139-8

This Palgrave Macmillan imprint is published by the registered company Springer Nature Switzerland AG.
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Paper in this product is recyclable.

Contents

Notes on Contributors

Ramiro E. Álvarez is Professor of Microeconomics and Argentine Economic Policy at the National University of Moreno (UNM, Argentina). He is also a post-doctoral fellow at the National Scientific and Technical Research Council (CONICET, Argentina). His research focuses on the Argentine political economy in the light of the Classical-Keynesian Approach and integrated with Latin-American Structuralism. His works cover the modern revival of the classical theory of value and distribution, also known as the Surplus Approach, the history of economic thoughts, the political economy of small-open economies, demand-led growth theories, and the Argentine political and economic history. His research has been published in the *Review of Political Economy* (*ROPE*) and the *Review of Keynesian Economics* (*ROKE*).

Javier Arribas Cámara currently works as a lecturer at the Universidad Complutense of Madrid. He holds a PhD in Economics from the Universidad Complutense. The PhD was funded by a doctoral research fellowship granted by the Madrid City Hall. He has been a visiting lecturer and visiting researcher in Quito (Ecuador) and Mar del Plata (Argentina). His research has been focused on public services, the ecological and digital transitions and their social and employment impact. He coordinated the book in Routledge titled *Institutional Change After the Great Recession: European Growth Models at the Crossroads*, and he also is the author of the book *Economía y sostenibilidad: El debate de la gestión en la historia del pensamiento económico*, with the collaboration of the public foundation ICO.

Thomas Baumert is Professor of Applied Economics at the Universidad Complutense of Madrid, where he obtained his PhD in Economics in 2006. He majored in Business Administration, Political Science and Sociology, with complementary studies at the universities of Oxford, Harvard, George Washington and the London School of Economics. He has been a visiting researcher at the Fraunhofer-ISI in Karlsruhe (Germany) and visiting professor at the Westfälische Wilhelms-Universität in Münster (Germany). His research has been funded by the European Union, the US Department of Homeland Security, the German Historical Institute (Washington), and the Spanish Ministry of Economy, Industry and Competitiveness. He is a permanent member of the scientific committee of the International Conference on Applied Economics (ICOAE) and a trustee of the Cultural Foundation "Salvador Tuset".

Juan Francisco Galán holds a bachelor's degree in Physics at the Complutense University of Madrid and in Economics at UNED (Spain). He has more than 20 years of professional experience working in companies of the Innovation sector, such as Cagemini, Fujitsu, IBM, Indra or Oracle, and performing business development tasks, project management and training. Besides, he is an associate professor at the European University of Madrid, where he teaches the subject "Technology and Innovation" in the Master in Business Administration. He works as a teacher for the Community of Madrid, teaching Mathematics in secondary education. He is carrying out studies and research on Innovation in collaboration with the Department of Applied Economics, Structure and History of the Complutense University of Madrid.

Elena Gallego Abaroa holds PhD in Economics and is Associate Professor of History of Economic Thought at the Complutense University of Madrid. Her research has been focused on two areas: labour market and women and economics, both from a historical perspective. Among her publications, there are *Mujeres Economistas* (2005), *Mujeres y Economía* (2007), *Universidad y Mercado de Trabajo* (2008), *Breve Historia del Mercado de Trabajo* (2009) and *Economía en Perspectiva de Género* (2020).

Antonio García Sánchez is Lecturer in Applied Economics at the Department of Economics and Economic History (University of Seville, Spain). He is also director of the Master's Program in Economic Consultancy and Applied Analysis. He holds a PhD degree in Economics from the University of Huelva. He is a member of the research groups

"Economic Analysis and Political Economy" (University of Seville) and "Economics and Politics of Innovation and Technical Change" (Complutense Institute of International Studies). His main research interests are in the economics and policy of innovation (theory and microeconometrics); cooperation for innovation, internationalization and regional distribution of innovation activities and the relationships between culture, creativity and innovation.

Baruc Jiménez Contreras holds a degree in Economics from the National Autonomous University of Mexico (UNAM), a Master's in Economics from the Institute of Economic Research of the UNAM, a Master's in Philosophy, Science and Values at the University of the Basque Country (Spain) and a PdD in Economics from the Complutense University of Madrid. He received a pre-doctoral scholarship from the Complutense University of Madrid and has been teaching assistant of the Complutense University and of the Institute for Social Research of the UNAM. Scholar of the National Council of Science and Technology (Mexico), he was awarded an honorific mention at the Mtro. Jesus Silva Herzog prize for "Notes on ethics and morality in Marx" (2016) organized by the Economic Commission for Latin America and the Caribbean and the Institute for Economic Research of the UNAM.

Fernando López Castellano holds PhD in Economics and Business and is a professor at the University of Granada. He teaches History of Economic Thought in the Degree in Economics and Development Cooperation, Public Management and NGDOs at master's level. He has participated in various development cooperation projects in Peru, Ecuador and other countries. He is currently a member of the Regional Development Institute of the University of Granada and Principal Investigator of the SEJ 476 Research Group "Economic History, Institutions and Development". His main lines of research focus on the History of Economic Thought, Political Economy, Institutions and Development Economics. He has published *Neoliberalism and Unequal Development, Alternatives and Transitions in Europe, Latin America and Sub-Saharan Africa*, with Roser Manzanera and Carmen Lizárraga, (2022) and several articles in *Brazilian Journal of Political Economy*, *Real World economics*, or *Review of Radical Political Economics*.

Alfredo Macías Vázquez is an economist and anthropologist. Professor at the University of Leon (Spain), he is currently studying the impact of

the scientific-technical revolution on capitalist development, with a theoretical approach based on the theory of value. In 2017, he published *The Collapse of Technological Capitalism* (in Spanish). He has obtained the "José Luis Sampedro" Economics Prize (2011), awarded by the World Economic Society.

Ignacio Martínez Fernández is Assistant Lecturer in Economic History at the Department of Economics and Economic History (University of Seville, Spain), PhD candidate in Economics in the University of Seville, MSc in Austrian Economics (King Juan Carlos University, Spain) and Graduate in Economics (University of Seville). He is a member of the research group "Economic Analysis and Political Economy" (University of Seville). His main research interests are history of economic thought, macroeconomic analysis and competition policy.

Luis Palma Martos is a Graduate (1981) and obtained his PhD (1989) in Economics and Business Administration from the University of Seville. He has articulated his career on four fronts: teaching, research, management and transfer of knowledge. He has been advisor for 30 doctoral dissertations and has been a researcher or visiting lecturer in more than 20 universities over the world. He is the president of the Academic Committee of the PhD Program in Economics, Business and Social Sciences of the University of Seville. He has been a vice dean of International affairs at the Faculty of Economics and Business Administration in the Universidad de Seville (1993–2003) and director of the Department of Economics and Economic History of the University of Seville (2008–2012). Since July 2015, he is acting as a member of the Consejo de la Competencia de Andalucía (Agencia de la Competencia y la Regulación Económica de Andalucía, ACREA).

Jose A. Pérez-Montiel is Professor of Economics at the University of the Balearic Islands. He is also research director at the Angelo King Institute for Economic and Business Studies. His research focuses on the Historical Political Economy of growth, with special interest in the Classical-Keynesian tradition. His works also cover topics in applied economic analysis and policy, history of economic thought, and ecological economics. His research has been published in *Applied Economic Analysis*, *Metroeconomica*, *Journal of Post Keynesian Economics*, *Review of Political Economy*, *Review of Keynesian Economics*, *Bulletin of Economic Research*, and *Economic analysis & Policy*, among others.

Pablo José Martínez Rojo is a senior consultant in Science & Innovation Link Office (SILO). He has a Master's in Economics and Innovation Management at the Complutense University of Madrid and a degree in Business Administration (UNED) and a Bachelor's in Management in the Universidad Veracruzana, Xalapa-Enríquez, Mexico. He works in project management (design, preparation and execution of strategy and innovation projects), digital transformation, optimization of services and processes, and reorganization and change management in the public administration and private companies. He is a manager of R+D+i financing processes (FEDER, Next Generation EU, EDUSI, CDTI) and makes market studies and consultation for ICT sectors (Smart cities, blockchain, big data, cloud; Aeronautical; Health; Civil Engineering).

Manuel Santos Redondo holds PhD in Economics and is a professor at the Complutense University of Madrid. He is a specialist in innovation and entrepreneurship in the history of economic thought, in cultural industries and in arts, literature and economics. He has published *Economics, Entrepreneurship and Utopia: The Economics of Jeremy Bentham and Robert Owen* (2017, with Estrella Trincado Aznar), *Economía de las industrias culturales en español* (Ariel, 2011, with Manuel Montás), *Economía y Literatura* (Ecobook, 2006, coordination with Luis Perdices) and *Los economistas y la empresa. Empresa y empresario en la historia del pensamiento* económico (Alianza, 1997).

Estrella Trincado Aznar obtained PhD in Economics and holds a degree both in Economics and in Philosophy. She is a professor at the Complutense University of Madrid (Spain). Elected member of the Executive Committee of the *European Society for the History of Economic Thought* (ESHET), she received the ESHET History of Economic Analysis Award 2005 and the ESHET Young Scholar of the Year Prize 2011. She has been Visiting Scholar of the Department of Economics at Harvard University and visiting staff at the Université Lumière Lyon 2 (Minerva). She has published several high-impact articles and books such as *Ideas in the History of Economic Development: The Case of Peripheral Countries* (2019, with Lazzarini and Melnik); *The Birth of Economic Rhetoric. Communication, Arts and Economic Stimulus in David Hume and Adam Smith* (Palgrave Macmillan, 2019) and *Economics, Entrepreneurship and Utopia: The Economics of Jeremy Bentham and Robert Owen* (2017, with Santos).

José María Vindel holds a degree both in Physics and in Industrial Engineering, and a PhD in Physics. He has worked as Lecturer in Statistics at the Complutense University of Madrid and as Statistics Technician in the National Statistical Institute (INE). In addition, he has worked as a meteorologist in the Spanish Meteorological Agency (AEMET) and as a researcher in the Research Centre for the Energetic, Environmental and Technological Sciences (CIEMAT). Currently, he is a head of service of statistics in the Ministry of Labour and Social Economics (MITES). His research interests are econophysics, solar energy and environmental issues. He has published several articles in high-impact journals such as *Renewable and Sustainable Energy Reviews*, *Journal of Cleaner Production*, *Atmospheric Research or Renewable Energy*, amongst others.

List of Figures

CHAPTER 1

Introduction

Estrella Trincado Aznar and Fernando López Castellano

In this volume, a link between Science, technology, and innovation in the history of economic thought is established. There is barely any study linking these three important issues within the history of economic thought. Literature has usually studied them in an unconnected way. However, all of them consist of a societal knowledge with a need for vocation, inventiveness, and a desire for change. All of them are systems of knowledge about the physical world—matter and business type—which try to explain how matter and life works and how we may change it.

Landes and Duchesne questioned the explanation of the "Great Divergence" between Europe and Asia by arguing that Europe initiated from the twelfth century onwards a cumulative process of innovation and invention that generated a unique form of development. McCloskey has

E. Trincado Aznar (✉)
Department of Applied Economics, Structure and History, Complutense University of Madrid, Madrid, Spain
e-mail: etrincad@ucm.es

F. López Castellano
Department of Applied Economics, University of Granada, Granada, Spain
e-mail: flopezc@ugr.es

E. Trincado Aznar, F. López Castellano (eds.), *Science, Technology and Innovation in the History of Economic Thought*, Palgrave Studies in the History of Economic Thought,
https://doi.org/10.1007/978-3-031-40139-8_1

recently insisted that the creation of new ideas in human minds, "innovationism", has been ignored by economists. Precisely therein lies, in her view, the success of the Netherlands and Britain: liberalization at the level of ideas favoured a culture of a certain freedom of expression and a rather energetic entrepreneurial economy. Besides, economists have debated on who is to be praised or blamed for promoting innovation and change, they argue if this change is positive or deleterious to welfare or social cohesion, and they give advices on the type of legislation needed to promote or hamper innovation and science. Science is one of the most important channels of knowledge and it seems to be for the benefit of society, creating technology, new knowledge, improving education, and increasing the quality of our lives. However, knowledge economy is a complex non-linear process of technological innovation. Besides, some countries go towards the service economy where knowledge seems to be not a product of scientific research, but a creative activity. This requires reconsideration of the role of scientific research and technological innovation in both service and industrial sectors.

Science must respond to societal needs and global challenges and in the last analysis, it is a not intended cause of new troubles. The history of economics can contribute to the debate about the place that science and technology must have on our present understanding of progress. At present, the relationship between technological change and institutional development constitutes one of the main axes of debate and urgent research topics. We face climate change, hate discourse in social networks, technological unemployment, and there is a debate on the impact artificial intelligence or green technology have on human life and life on the planet. This volume contributes to enlarging the conversation and pointing to relevant controversies on these issues in the past and the present. It both brings new elements found in past thinkers and illuminates present debates with past ideas.

Most of the contributions of history of economic thought to economics of innovation deal with the importance of the French Economist School, based on the concept of the entrepreneur as defined by Cantillon. For sure, the Irish economist Richard Cantillon, in *Essay on the Nature of Trade in General* published in French in 1755, identified the nature of the entrepreneur. He defined this concept as the agent who buys the means of production at certain prices and combines them in an orderly manner to obtain a new product which he will sell at an uncertain price. So, he was a forerunner of the notion of innovation, which he bases on the production

or distribution for the search for a monetary profit. In this line of thought, other scholars stress the neglect in classical economics of Jean Baptiste Say's theory of the entrepreneur, which may be related to the Austrian economics view of innovation. All these debates are not emphasized in this volume, precisely because science and technology pretend to avoid, not assume, uncertainty and, so, they try to provide an intellectual grasp to link the present to the future. Besides, the scholarship on innovation based on the French Economist School has constructed the paradigm of a favourable view of innovation, based on individual action which goes along with progress. This book tries to go beyond this linear perspective and gives new food for thought on the relationship between science, technology, and innovation in the history of economics.

Actually Joseph Schumpeter, considered the "father of entrepreneurship", in the *Theory of Economic Development*, which first appeared in 1911, stressed that capitalism is a dynamic process of wealth creation and change, driven by innovation, not routine. He established that the destructiveness of capitalism is inseparable from its creativity. However, Schumpeter was not an absolute non-interventionist, such as members of the Austrian School of Economics, and his theory of entrepreneurship significantly differs from that of Israel Kirzner, an Austrian economist who abundantly deals with the topic of innovation. This is particularly apparent in Schumpeter's argument that entrepreneurial activity is characteristic of both market and non-market economies. Within the model of Schumpeterian competition, Nelson and Winter add a treatment of a "cumulative technology", in which the expected outcome of innovation is a function of the firm's current level of productivity.

The relationship between innovation, changes in market structure, and the broader evolution of an industry has been studied starting from different histories, specific cases and empirical evidence of given sectors or firms, characterized by routines and capabilities. Firms find patents effective only in a limited set of innovations and in a small number of industrial sectors. In this sense, Marshall's analysis of economic development includes the organizing roles of firms and industries, the connection of the representative firm to population, and the nature of firms as accumulations of knowledge and capital. He studies this especially in relation to scientific management and the reduction of the unit costs of production either internal to a firm or external and residing in an industry or market. Internal organization reflects the risky efforts of firms, and especially managers, and so organization is a distinct type of productive factor. All this

mainstream view of innovation is contested by heterodox views of decision-making and path dependency, such as Marxian Economics, Feminist Economics, Institutional Economics, and Keynesian Economics. In this case, their focus is on the demand side of the economy, including the role of power relations in determining economic relationships and a study of economic systems.

However, in this volume the stress is made on the supply side of innovation and economic ideas led by science and technological advances. In particular, in the first two parts of the volume (Chaps. 2–9), the book is organized chronologically. Thus, it shows how the concepts of technological change, invention, and innovation have changed over time and it brings new elements of past thinkers to the forefront. Part I deals with classical theories, and Part II with neoclassical theories and their alternatives. In the third Part (Chaps. 10–13), the volume is organized by topics. It retraces debates in the history of economics on technological change, development, energy, or labour markets that could illuminate present debates or that could contextualize those debates in a longer history of ideas.

Chapter 2, "Some Misconceptions Regarding Innovation (and How Reading Classical Authors Might Help Overcome Them)", initiates with a search of Thomas Baumert for the genetics of the word "innovation", stressesing what we can learn from "the giants on top of whose shoulders we are standing". The economics of innovation has deserved, throughout the last decades, a preferential attention both by academics and by policymakers, derived from the broad consensus about the crucial role that innovation plays as a driver of economic growth, especially in the most advanced economies. As a result, we find that most economic leaders—be it on the national, regional, or municipal scale—bet on their speeches on innovation; that most companies define themselves as innovative and that a significant number of advertisements use this term as catchword to promote their products throughout a great variety of sectors. Then, Baumert goes into three "points of debate". The first one refers to the etymology of the word innovation and the fact that, originally, it was used with a negative connotation (in the sense of a subversive change). A second point deals with the question of whether the well-established concept of innovation system makes sense. There is no doubt that the innovation system approach is a fruitful one, but innovation is systematic to a lesser degree than so far is assumed and it actually is a much more spontaneous, unpredictable and, hence, non-systematical phenomenon. This would actually

fit—with some nuances—Schumpeter's view on innovation. And third—closely related to the previous—Baumert deals with a question much neglected, namely, who does really innovate in companies?

In Chap. 3, "Invention, Institutional Change and Economic Development: From Scottish Enlightenment to the IPE", we trace the emergence of the concept of innovation into the Scottish Enlightenment. In the eighteenth century, a Darwinian evolutionary concept, based on trial and error, was available. David Hume showed that while trade develops, the extension of business professions engenders love of profit and promotes a beneficial change in habits. However, his historical perspective made him worried about the inevitability of the rise and fall of governments due to excessive public debt. Although change is desirable, institutions and the habits of individuals must not be changed at the expense of the past, as learning through trial and error occur naturally, based on memory and habits. Then, in a free market economy, only reasonable investments will survive.

In 1776, the *Wealth of Nations* introduced a new concept of innovation in which people were permanently led by a universal, continual, and uninterrupted effort to better their own condition. As against Hume, for whom reasonable investments survive the progressive mechanism of trial and error, Adam Smith considers that prudence, being an extended virtue, must be fostered by a legal maximum rate of interest. Trial and error is not recommendable, as capital markets may lead to default, and default to resentment. Besides, as in Hume, the rate of interest is for Smith the consequence, not the cause, of investment and growth. So, the fact that the interest rate is low is an unintended, albeit fortunate, consequence of growth. The low rate of interest enables people to repay their debts without concessions on their own freedom. The same happens with innovation. For Smith, it is not the greatest individual inventiveness that increases the amount of capital, but the skill, dexterity, and judgement with which work is customarily done.

A last concept of innovation that emerged in the late eighteenth century encouraged risky entrepreneurs, who operate in new production and distribution areas. It was commenced in 1787 by Jeremy Bentham who published his letter to Smith under the title *Defence of Usury*. According to Bentham, innovation is the driving force behind development and it must go hand in hand with credit. Bentham was not worried about Hume´s prediction of excessive public debt as he was based on an individualistic and atomistic vision of innovation. However, in the period of

the Scottish Enlightenment, other economists put forward a non-individualistic vision of innovation. For example, as explained in this chapter, John Rae defended invention as a key element of technological and institutional change led by credit that transfers the possibilities and capacities of action from the accumulators by abstinence to the creators and transformers of reality. Institutions are clue in this context. They contain rights, obligations, and ideologies and, as Elinor Ostrom will put it, they make the market and the state the face of the same coin as limitations and skills are intertwined. All these concepts evolve into the Institutionalist Political Economy (IPE), which stresses the importance of governance for promoting economic growth and for creating an adequate "social climate" with the protection of property rights and the rule of law.

In Chap. 4, "The Pre-Schumpeterian Conception of Innovation: Friedrich List and Two Pioneer Contemporaries", Pablo José Martínez Rojo jumps from Scottish Enlightenment to the concept of National Innovation Systems. Adam Smith considered that division of labour leads to an increase in productivity due to a greater worker dexterity, time savings, and mechanization. Then, specialization is the seed for a process of accumulation of knowledge and capabilities. The analysis of Smith results in the foundation of the theories of technological progress and R&D innovation. But other theorists, such as Friedrich List, Charles Babbage, and Johann Heinrich Von Thünen, contributed to the understanding of the seminal concept of *National Innovation systems*. Two and a half centuries have gone through, and the economy of innovation and technological change has become one of the most relevant fields of study of economics. Eventually, since the late 1980s of the twentieth century, much attention has been devoted to this concept of *National Innovation Systems*, advocated contemporarily by Freeman in the early 1960s. Actually, the conceptual evolution of the term follows the logical time trajectory defined by several schools of thought: Institutional Economics, which stresses elements such as market development and firms' incentives; Evolutionary Economics, which studies innovation and economic development as a *path-dependent* organic process of accumulation of knowledge; and the New Growth Theory, which focuses on the need to invest in human capital to be able to generate and accumulate knowledge.

In Chap. 5, "Technoscientific Rationality and Capitalist Accumulation. Transhumanism as Alienation in Marx's Humanist Approach", Baruc Jiménez Contreras deals with the transhumanist movement, which aims to liberate the human subject through scientific and technological

development. From Marx's notion of alienation, transhumanism can be conceived as a process that exacerbates the degree of subordination carried out by the capitalist system. For sure, this alienation is different in monopoly capitalism (Baran and Sweezy) or in surveillance capitalism (Zuboff), but Marxian concept of social-ecological metabolism may connect the global contemporary challenges of technology, nature, and work. This chapter shows that transhumanism is based on the utilitarian ideals which coincide with the intensification of the alienating and fetishist condition of the system. Transhumanism has led to the emergence of the cyborg and the aiming to transfer human consciousness into a machine as its ultimate goal. It focuses on using technological and scientific advancements such as artificial intelligence, robotics, cognitive science, information technology, and biotechnology to enhance human physical and intellectual capabilities beyond what has been naturally achieved through evolution. But transhumanism alludes to a Promethean vision that disregards the conditions of domination, inequality, and economic and social subjugation of human beings under capitalism. The movement emerged during postmodernity and shares specific common goals with it, such as the need for "change", the acceptance of multiple "identities" and "bodies", and the opposition to a fixed and universal "human nature". It also exhibits flexibility regarding what "should" be "humans and humanity". However, transhumanism does not question the values of capitalist modernity or the scientific and technological development arising from its historical specificity.

The chapter by Baruc Jiménez, then, explores this contemporary problem using the concept of alienation first introduced in Book V of *The Wealth of Nations*, where Adam Smith stresses the deleterious consequences of division of labour in human abilities. The humanistic fallacy assumes that the substitution of human work by machines will leave most humans with better jobs; however, the possibility that technologies decrease human capacities or worsen chances of leading a good life must be explored. Marx took up the challenge, exploring the subsumption of labour to capital within capitalism, which conquers more and more facets of human existence. In the same vein, the transhumanist movement tries to modify the consumer's decision and human experience to maximize abilities and profit. The ultimate goal of transhumanists is the separation between the human body and consciousness. Therefore, transhumanism represents a contemporary vision of utilitarian values in which Hume's advocacy of suicide obtains a new solution: abandoning the human bodily experience (life itself) through a set of technoscientific goods. The process

is considered an act of alienation in itself, as opposed to achieving human freedom. This analysis by Baruc Jiménez may have further lineaments, as theoretical efforts in economic thought have tried to assimilate human beings to machines that act according to a universal algorithmic procedure. Certain tools developed during the Second World War served as the foundation of an economy dominated by mathematics, crystallizing into a rational choice approach, making economics as a "Cyborg science".

In Chap. 6, "Energy Efficiency, Productivity and the Jevons Paradox", a contribution with José María Vindel shows the importance of the "Jevons paradox" to address the limits of innovation. Jevons, talking about a non-renewable energy resource, such as coal, opened the debate on the limits to growth. Although the emerging literature has discussed the ongoing transition process towards the circular economy mainly from an ecological perspective, the underlying mechanisms of economics, industrial change, and vicious circles of technology have not been much discussed. In 1865, William Stanley Jevons showed that scientific progress in pursuit of an economic use of fuel and new modes of economy will paradoxically lead to an increase in consumption. This "Jevons paradox" is part of a more general criticism of the author to classical economics. According to Jevons, utility, not cost of production, is the final cause of value, and when the cost of production declines due to resource efficiency, the marginal utility of commodities that use the given resource declines, increasing directly the consumption of those commodities and indirectly the consumption of other commodities with which they are exchanged. But, as coal is a non-renewable energy resource, it may be depleted. Then, scientific progress and resource efficiency is not a good path to the lesser use of resources and we cannot analyse science and technology without taking into account human behaviour and the limits of resources. Demand grows exponentially, while supply is limited. Obviously, Jevons underestimated the relevance of coal substitutes; however, in this chapter, the Jevons paradox is studied in the context of the debate on the limits to Growth. Jevons' line of thought led to new areas that imply that economics cannot be fully split from other sciences. In particular, the chapter analyses the emergence of econophysics and the importance of the Jevons paradox at the macroeconomic and microeconomic levels, looking at the relationship between economic growth and energy efficiency. Finally, it comments on the energy policies proposed to avoid the rebound effect, with some concluding remarks on the evolution of the concept.

In Chap. 7, "Max Weber: Science, Technology and Vocation", Alfredo Macías Vázquez opens the sociological view with the Max Weber theory. In 1917, Weber wanted to respond to the question of what can make science attractive as a vocation. Research no longer had anything to do with the passionate dedication to solving a mystery, which required assuming that the universe had been created by God and that knowing nature meant knowing God better. At the beginning of the twentieth century, science was at the service of the rationalization process that dominated Western modernity, giving rise to specialization in autonomous disciplines in a totally disenchanted and soulless world. Individuals were trapped in an iron cage, and allegedly they needed to find a way out. However, Weber considered that the rationalization process should not be avoided, but that the question about its meaning should not be formulated in relation to the general context of life and the value judgements of the world. Science not only derives from some specific set of value judgements, but it is a normative criterion in itself. The Western singularity is better explained by its capacity to regulate greedy impulses and to integrate formal rationality in the calculation of profit. This historical outcome was reached through ethical consensus. The Protestant ethic, particularly its Calvinist version, served this historical function. The paradox lies in that Calvinist asceticism, in its eagerness to separate itself from the world. Unintentionally, it ended up giving rise to the economic system that has historically exerted the largest control over the world. From that moment onwards, human life was considered successful so far as rational calculation was applied, professional specialization increased, scrupulous and tireless work generalized, and hedonistic enjoyment of profit given up. In parallel, this implied the end of the charismatic authority, and the subordination of the individuals to bureaucratic organization. Thus, what started as an ethical choice ended up as a compulsory fate. Weber then wondered how one could passionately give oneself to science in a world dominated by social automatisms and bureaucratic coldness without falling into minority elitism, aristocratism, the defence of ultimate and supreme values. The chapter by Alfedo Macías begins analysing Weber's response to these and other questions, and continues by assessing the feasibility of his proposition in the contemporary context of the techno-scientific revolution. Finally, he critically discusses Weber's postulates in relation to Marx's approach.

In Chap. 8, "The Age of Innovation: More Schumpeter than Keynes", Manuel Santos Redondo reviews the "Era of Schumpeter". Keynes considered two factors that promote economic progress: capital accumulation

and technology. But Schumpeter was one of the economists that most stressed the relevance of technology in the economic process. Capital accumulation depends on profits, interest rate, and stock of capital, and technology depends on the innovation process (that is, technological progress and/or discovery of new resources). Schumpeter considered that entrepreneur activity relies on profits and "social climate", that is, the sociological-economics-institutional aspects of the society. While Keynes tends to reduce the explanation of unemployment to specific "malfunctionings" of the labour market, Schumpeter's notions of temporary and cyclical technological unemployment refer to creative destruction as an economy-wide disequilibrium process. At first, Schumpeter considered the entrepreneur as a superior man; finally, he cuts expectations talking about the function of the entrepreneur, which may be performed by groups, corporations, or countries. The routinization of innovation by corporations will make no room for reward for entrepreneurial aptitude.

According to Manuel Santos, the quarter century after World War II was certainly "the age of Keynes", in both economic theory and policy. During the Great Depression, or at least in the first years, most economists believed that the crisis will be over without large government intervention, but Keynesian stabilization policy seemed to be good for the public, the politicians, and the corporations. Then "liquidationists" began to be in retreat. However, in the 1980s, there was the rise of Schumpeter and his concept of the "creative destruction". Manuel Santos discusses the evolution of his ideas on innovation, entrepreneurship, and creative destruction and what happened in the 1980s to make the last quarter of the twentieth century the "Era of Schumpeter". In macroeconomics and in political and academic influence, Friedman and the Chicago School were very much the winners against Keynesianism, together with Hayek. The fall of the Berlin Wall and the collapse of the Soviet Union reinforced that tendency. But together with this battle of ideas, American industry faced competition from Japan and East Asia through technological innovation. And in the 1980s, innovation economics, in several schools, became the main issue for economist and economic policy. Their aim was to provide an innovation policy, to build an innovation system, with an important role for the government, which can be considered an entrepreneur.

In Chap. 9, "The Crisis of the Neoclassical Framework and the Schumpeterian Echo in the Current Paradigm of the Economic Analysis of Technological Change", Antonio García Sánchez, Luis Palma Martos,

and Ignacio Martínez Fernández go further to explain the attention given by the marginalism-neoclassical approach to innovation. Classical economists were the first to consider the economic impact of technological change, with increases in productivity being its main effect and the division of labour the facilitating element of the generation of new products. But after this contribution, economic thought has relegated the analysis of technological change as an exogenous element to the system, either from the microeconomic or from macroeconomic perspective. It was not until the second half of the twentieth century that Solow and Abramovitz found that more than half of the measured growth was due to elements different from the accumulation of capital and the human factor. Then, economic analysis turned once again to technological change, the residue to which this unexplained growth was attributed. Based on these ideas, this chapter tries to give a "cross fertilization" of the different recent approaches on the topic. The four main paths for the study of technological change considered by the authors are: (a) the one based on the classical legacies of Adam Smith and Karl Marx; (b) the Schumpeterian legacy, which highlights the role of competitive processes and determine the possibilities of growth and income redistribution; (c) the evolutionary models and biological suggestions based on the Marshallian legacy; and (d) some reflections on cultural elements, creativity, and innovation, which fit within the Arrowian legacy.

In Chap. 10, "On the Capital Controversies as a Choice of Paradigms", Ramiro E. Álvarez and Jose A. Pérez-Montiel go into the topic of income (and wealth) distribution that from 2014 has attracted so much attention after Thomas Piketty's work. As against Piketty's methodology, who contrasts predictions and empirical observation, the chapter searches for formal logical consistency of the conventional economic approach. In this sense, the recent debate has not re-addressed the controversies regarding the notion of "Capital", which criticized the neoclassical theory of distribution (1953–1976). Existing literature refers to these discussions as the *Capital Controversies* or the *Cambridge-Cambridge Controversies* (hereinafter CCCs). Then, the chapter analyses how the CCCs arose and evolved, as well as how it apparently came to an end in the 1960s. The authors make use of Thomas S. Kuhn's characterization of the structure of scientific revolutions. They show that the CCCs did not lead to a Scientific Revolution that would bring about the demise of the neoclassical hegemony, but that this was not due to the logical rigour of the competing theories. The phenomena of *re-switching* and *reverse capital deepening*

were *anomalies* not easily assimilated into the marginalism paradigm; but there was a (partial) assimilation that entailed the flexibilization of some of the commitments around which the neoclassical *normal research* was structured.

In Chap. 11, "Technology and Labour Market. Technological Unemployment as a Historical Debate", Elena Gallego makes a broad sweep on the debates on technological unemployment. She makes classical economists discuss with current economists to find possible future scenarios and search for alternative solutions. The fear of the creative destruction of technological progress begun in the sixteenth century, when Queen Elizabeth showed concern with the English population displacement from their jobs which might threaten her political power. From then, technological unemployment was explained in a Ricardian sense: a process of change that is reabsorbed over time. Classical economics, and its neoclassical heirs, assumed the hypothesis of price and wage flexibility that tends to balance markets; however, in the Keynesian perspective, with rigid prices and wages, economies did not return to the path of growth. Technology was for all of them an exogenous variable; only Joseph Schumpeter describes it as endogenous to the system, considering the possibility that monopolistic competition is more efficient than perfect competition in driving the innovative process of the economic cycle and producing greater job creation than job destruction, with a net positive effect.

In Chap. 12, "Humanity Is Facing Its Sustainability: Will Technological Progress Make the Future Unsustainable?" Javier Arribas Cámara talks from the contemporary speech about an innovation that allows us to meet basic human needs rather than encouraging over-consumption and waste. He considers digitalization an ally of sustainability in several ways. But to achieve sustainability, a holistic approach is needed that considers the interaction between the economy, the environment, and the society. In this sense, technology can play a pivotal role in the quest for sustainability; however, more than technology is needed to achieve sustainability. The chapter discusses how advances in artificial intelligence and computing face physical and energy constraints, leading scientists to look to biology for inspiration to design more efficient and sustainable computing systems. Finally, it examines the growing concern over data centre energy consumption and carbon footprint, exploring innovative solutions, such as installing data centres in space to take advantage of low temperatures and reduce energy consumption. Rapid accumulation of e-waste represents an

urgent challenge in terms of sustainability, and policies and regulations at national and international levels are needed.

Last but not least, in Chap. 13, "Why Inventions Fail to Become Innovation? Some Examples from Spain and Italy", Juan Francisco Galán presents some study cases in Mediterranean countries that show that failure of the innovation process may be due to the misunderstanding and ignorance of the concept of innovation. Actually, in Spain and Italy, there are many examples of ingenious inventions that have not become innovations and, therefore, have not contributed to economic development. This chapter takes some of these examples as a starting point and, focusing on the second half of the nineteenth century, reviews the factors that hindered or even prevented innovation. This historical analysis can shed light on the current debate about the best policies that should be applied to promote innovation and, therefore, increase the productivity of our economies. In the period taken, both Spain and Italy had quite favourable conditions for innovation: stability, a liberal legal system suitable for productive activities, and an appropriate legislation on industrial property, in addition to new and modern educational and research institutions which spread scientific and technical training. However, there were three broad instances in which inventions did not transform into innovations: in the first one, the new results were not well received by society; in the second, the industry did not react despite being aware of the "scientific" results; and, finally, in a third case, inventions did produce innovation but only for a short period of time, before being abandoned. The chapter concludes with the case of the invention of the submarine by the Spanish scientist Isaac Peral. Various reasons led to the failure of the invention, but one of the most important was purely conceptual: the confusion between discoveries, inventions, and innovations.

PART I

Classical contributions

CHAPTER 2

Some Misconceptions Regarding Innovation (and How Reading Classical Authors Might Help Overcoming Them)

Thomas Baumert

2.1 Introduction

The economics of innovation has deserved throughout the last decades a preferential attention both by academics and policymakers, derived from the broad consensus about the crucial role that innovation plays as a driver of economic growth, especially in the most advanced economies.[1] As a result, we find that most economic leaders—be it on the national, regional, or municipal scale—bet on their speeches on innovation; that most companies define themselves as innovators and, while the term innovation has also penetrated the consumer base, that a significant number of

[1] Classified by organizations such as the World Economic Forum as "innovation driven."

T. Baumert (✉)
Complutense University of Madrid, Madrid, Spain
e-mail: tbaumert@ucm.es

E. Trincado Aznar, F. López Castellano (eds.), *Science, Technology and Innovation in the History of Economic Thought*, Palgrave Studies in the History of Economic Thought,
https://doi.org/10.1007/978-3-031-40139-8_2

advertisements use this term as catchword to promote their products throughout a great variety of sectors.

The present chapter reunites a series of thoughts regarding innovation that have kept popping up in my writings on this topic over the last 15 years and which I have synthesized here in three "points of debate." The first one refers to the etymology of the word innovation and the fact that, originally, it was used with a negative connotation (in the sense of a subversive change). When did the term innovation appear in Western languages and when did it shift from its originally negative meaning to the current positive one?

A second point deals with the question of whether the well-established concept of innovation system, makes sense. There is no doubt that the innovation system approach is a fruitful one, which I have used myself in many of my research papers. However, looking back at the corpus of empirical works that show a certain stagnation in the innovative output of nations and regions, one might wonder whether they might not result from the fact that innovation is systematic to a lesser degree than so far assumed and actually is a much more spontaneous, unpredictable and, hence, non-systematic matter. This would actually fit—with some nuances—Schumpeter's own view on innovation.

And third—closely related to the previous—a question so far much neglected, namely, who does really innovate in companies?

2.2 On the Origin and Evolution of the Term "Innovation"

Etymologically, *innovation* derives from *innovatio, innovationis*, a late-Latin word which, in turn, has its origin in *novus* (new).[2] One of the earliest uses of the term is to be found in the *Apology* of the Roman author Tertullian (160–220 CE.), a prolific early Christian writer from Carthage. Tertullian uses innovation in the sense of "alteration," with a negative undertone, referring it to a heretic behavior. Up till then, two other nouns—*res nova* and *novitas*—were employed in "classical" Latin alternatively with a meaning similar to that of our modern innovation.

[2] Curiously enough, the Proto-Germanic root (*neuva*) has a very a similar sound to the Latin *nova*.

After Tertullian, the term *innovatio* spread quickly. Centuries later,[3] its use might be found both in the works of Saint Augustine of Hippo (354–430 CE), of Saint Albertus Magnus (1200–1280 CE) and of Saint Thomas Aquinas (1225–1274 CE), to highlight just three. Hence, the former writes in *De moribus ecclesiae catholicae*:

> *[E]t illo sacrosanto lavacro inchoatur innovatio novi hominis, ut profiriendo perficiatur in alliis citius, in alliis tardius."*

And in *In psalmum VI ennaratum*:

> *Qui etiam novus homo propter regenerationem dicitur morumque spiritualium innovationem.*

As an example taken out of Albertus Magnus's works (*Super Lucam*, 22,20):

> *Haec autem innovatio per sanguinem Christi facta est.*

While in the latter's *Suma Teológica* (in the chapter entitled "*De Dei Aeternitate*") the following quote is to be found:

> *Quod quidem manifeste apparet, si innovatio et veteratio referantur ad ipsam mensuram. […] et sic erit innovatio in ipso aevo, sicut in tempore.*

And also in his *Super II Epistolam B. Pauli ad Corintios lectura* we read:

> *Ubi notandum quod innovatio per gratiam dicitur criatura.*

It becomes clear that the early use of the word innovation—*nota bene* that this "early" extends to a period of nearly a millennium—which had not been used in classical Latin, appeared mainly in texts of religious contents and, hence, with a meaning very different from the current one. From then on, the term became consolidated in all Romance languages. The following quotes picked out of the most outstanding works of the Renaissance might serve as examples.

[3] We are aware of the huge lapse of time but did not want to expand this section with too many examples.

Thus, the father of the Italian language, Dante Aligheri writes in the *(Divina) Comedia* (chant XXXII of the "Purgatorio"):

> *men che di rose e più che di viole*
> *colore aprendo, s'innovò la pianta*
> *che la primavera la ramora di sole.*

Dante also frequently employed the word in his Latin works, so in *De vulgari eloquentia libri due* (2, XIII):

> *Licet enim in qualibet stantia rithimos innovare et eosdem reiterare ad limitum […].*

Similarly, Niccolò Machiavelli (1469–1527), writes in his notorious *Il Principe* (Chap. 2):

> *Nella antiquitá e continuazione del dominio sono siente le memorie e le cagioni delle innovazione: perché sempre una mutazione lascia lo addentellato per la edificazione dell'altra.*[4]

And the Spaniard Diego Saavedra Fajardo (1584–1648 CE) wrote in *Idea de un príncipe político cristiano* (Emp. 21):

> *El príncipe prudente gobierna su estado sin innovar las costumbres.* [The prudent Prince governs his State without innovating its customs].

At nearly the same time, the word innovation was adopted in English and spread through British literature. Again, a few quotes from selected authors might serve to support our thesis.

[4] Often another extract taken out of Machiavelli's *Il Principe* (Chapter VI) which is often quoted (as it serves as a piece of advice to all innovators) reads:

> And it ought to be remembered that there is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things, because the innovator has for enemies all those who have done well under the old conditions, and lukewarm defenders in those who may do well under the new.

However, it should be noted that—strictly speaking—the original Italian text does not employ the word *innovatore* but *introductore* [introductor].

William Shakespeare (1564–1616 CE), in his celebrated *Coriolanus* (III, 1)[5]—in which, by the way, reference is made to Machiavelli's *The Prince*—has his character Sicinus Velutus say, when he orders the detention of Coriolanus:

> Go call the people:—
> In whose name, myself
> Attach thee as a traitorous innovator.
> A foe to the public weal: obey, I charge thee
> And follow to thine answer.

And in *Henry IV* (V, 1) we read:

> To Face the garment of rebellion
> […]
> of hurlyburly innovation.

It should be noted that in the previous examples "innovation" is used with a negative connotation, as an equivalent of rebellion or subversion—and it will keep this undertone, referred to in a political or sociological context, until the end of the nineteenth century. However, according to the *Oxford English Dictionary*[6] approximately at the time of Shakespeare's death, the term started to be used in other fields of knowledge in a positive sense. The most evident example of this might be Francis Bacon's (1561–1626 CE) essay "Of innovation" (included in the *Essays* first published in 1625), where he states:

> As the births of living creatures, at first are illshapen, so are all innovations, which are the births of time.

And later:

> Surely every medicine is an innovation; and he that will not apply new remedies, must expect new evils; for time is the greatest innovator [..]

[5] *Coriolanus* has the distinction of being among the few Shakespeare plays banned in a democracy in modern times. It was briefly suppressed in France in the late 1930s because of its use by the "fascist" element, and prohibited in Post-War Germany due to its intense militarism.

[6] Entry "innovation."

> It were good, therefore, that men in their innovations would follow the example of time itself; which indeed innovateth greatly, but quietly, by degrees scarce to be perceived.

And also, in which might be considered the first historical novel, Walter Scott's *Waverley* (published in 1814) we read:

> The others, whose time had been more actively employed, began to shew symptoms of innovation—"the good wine did its good office". (Chapter XI)

However, it should be noted that in German (and related languages), the concept of innovation was described by the word *Neuerung* (the equivalent of the Latin *novitas*, see above). In fact, Schumpeter himself used *Neuerung* and *Neuerer* (respectively for innovation and innovator) in his German works. It is only in 1939, when his book *Business Cycles*—originally written in English—was translated into German, that *Innovation* entered this language[7] (see for details, Chap. 6 in this book).

2.3 Smith vs Schumpeter, or Can Innovation Be Systematized?[8]

According to Schumpeter, it is the process of "creative destruction" that governs the historical evolution of capitalism, differentiating between five types of innovations: the introduction of a new good, the introduction of a new method of production, the opening of a new market, the conquest of a new source of provision of raw materials or semi-manufactured goods, and the creation of a new organization of any industry. However, the Schumpeterian approach is not monolithic, but presents an evolution, so we can distinguish between two types of basic models, which are complementary to each other: the model called MARK I (Fig. 2.1) corresponds to a vision of the innovation as a process that takes place in a competitive environment of capitalist entrepreneurs, characterized by—economically not yet measurable—inventions and exogenous scientific discoveries. The innovative activity of the entrepreneur consists in identifying, among the inventions and new available knowledge, those that entail an economic

[7] Although the German translation was not published until 1961.

[8] This section summarizes the broader analysis presents in Gutiérrez-Rojas and Baumert (2018, 2019).

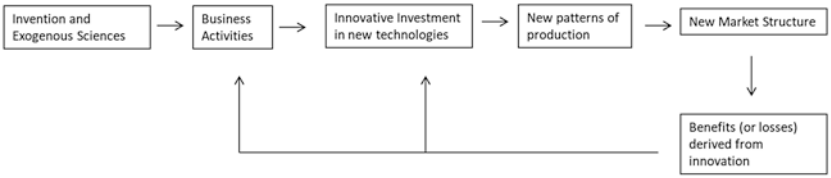

Fig. 2.1 MARK I model. (Source: Muller (2001))

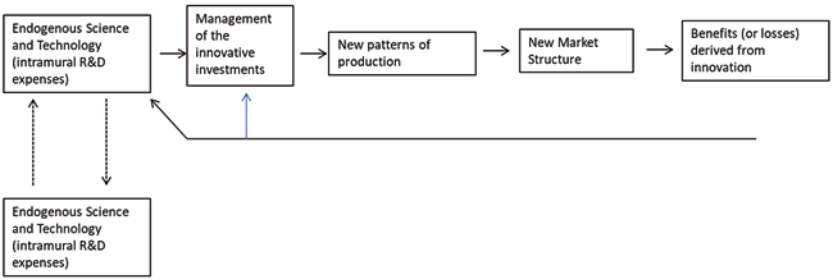

Fig. 2.2 MARK II model. (Source: Muller (2001))

potential, implementing and transforming them into innovations. By acting in this way, the old technologies become obsolete, a process that Schumpeter calls "creative destruction" (cf. for details, Chap. 6).

This initial vision of Schumpeter is complemented by the later model called MARK II (Fig. 2.2), which is characterized by the fact that innovations are endogenous and because in it research and development is carried out mainly in the R&D departments of large companies, in a process called "creative accumulation."

This model would imply, then, the passage of an initial conception focused on the role of the individual entrepreneur, toward a vision that highlights the importance of collective innovation performed within the (large) companies.

However, it should be noted that neither of the two models were explicitly formulated by Schumpeter, nor is the name of MARK I and MARK II. The first model derives from Schumpeter's (1926) book *Theorie der wirtschaftlichen Entwicklung* (originally published in 1912), while the latter model reflects the vision of the innovation process contained in his work *Capitalism, Socialism and Democracy* (1942). In this second work,

Schumpeter also ensures that the socialist system can be (in the best case) as efficient as the free-market capitalist system, because—simplifying its argument—the tendency to the concentration of capitalism leads to large corporations becoming bureaucratic, "strangulating" any innovative and entrepreneurial spirit that made them grow in a moment, leading them to a situation of stagnation. In this sense, the concession made by Schumpeter to the R&D departments of large corporations as advantageous for innovation in the so-called MARK II model, must be taken *cum grano salis*. Instead, it has served to give a Schumpeterian veneer to the concept of innovation system.

The concept of "Innovation System" developed in the context of evolutionary economics, reflects the process of division of labor in the field of innovation with the corresponding participation of a broad set of interrelated agents and institutions, whose activities should generate synergies or save costs, according to the central postulates exposed by Adam Smith. It was first presented by Freeman (1987), to be followed by Nelson (1993) and Lundvall (1992), all mentioning List (1841) as a forerunner.

In this vision, the innovation is an increasingly complex and interdisciplinary activity, so, a priori, it could be assumed that its development requires the interaction of a large number of institutions, organizations, and specialized firms. The advantages of the division of labor apply to the concept of Innovation System in the same way described by Smith, understanding each single workman like an individual actor of the system (firms, universities, public agencies, etc.):

> [F]irst, to the increase of dexterity in every particular workman; secondly, to the saving of the time which is commonly lost in passing from one species of work to another; and lastly, to the invention of a great number of machines which facilitate and abridge labor, and enable one man to do the work of many. (Smith, 1776, Book I)

Moreover, recognizing the difference of 'talents' among the actors of an IS (remarkable among men of different professions in Smith's words), it is possible to glimpse the same disposition which renders that difference useful, identifying the principle which gives occasion to the division of labor.

> Among men […] the most dissimilar geniuses are of use to one another; the different produces of their respective talents, by the disposition to truck, barter, and exchange, being brought, as it were, into a common stock,

> where every man may purchase whatever part of the produce of other men's talents, he has occasion for. (Smith, Idem)

This Smithian vision of the Innovation System is fundamental to understanding the innovative behavior within complex structures and systems, where not only the single actors, but also their interactions and interdependencies are interested. The 'systemic' part of the Innovation System is revealed because many different aspects in different parts of the economy and society in general seemed to behave according to the needs of other parties, as if many positive feedback loops were operating more or less synchronized.

These are the postulates of the generally accepted theory about systems of innovation, based on the principle of division of labor exposed by Smith. Now, the question that arises is to what extent this theory is compatible with the Schumpeterian vision of innovation. In the first place, it is necessary to observe the contradiction inherent when speaking, in a general way, of "innovation systems." If, according to the Austrian economist, innovation is a spontaneous phenomenon, the result of the "creative genius" of the MARK I model, it seems incoherent to assume that it can be the object of, nor be the result of any systematization. It is true that Schumpeter himself was able to consider that large companies—referring to American companies—benefited from having their own R&D departments, while thereby converting innovation into part of their business routine, although in a somewhat less categorical way than what is stated in the so-called MARK II model. The "creative accumulation" would thus accept endogenous innovation, but carried out by the companies themselves, not by different actors of a "system." Thus, a confusion arose between two concepts that continues to this day: R&D and innovation, a disconcertment especially notable in the case of Spain and Latin America, in which both terms are mixed in the erroneous but already deeply rooted expression I+D+I [meaning Research & Development & Innovation].

And we must not lose sight of the fact that, according to Schumpeter himself,

> The making of the invention and the carrying out of the corresponding innovation are, economically and sociologically, two entirely different things. They may, and often have been, performed by the same person; but this is merely a chance coincidence which does not affect the validity of the distinction [...although they might, of course, interact...] invention and

> innovation are entirely different things, not uniquely related to each other, and that only confusion can result from trying to analyze economic processes in terms of the former..[9]

Thus, once inventions and innovations have been delimited and separated and, consequently, the processes that lead to one and another, namely research versus innovation, we can conclude that, while the invention *can be systematized*—and, therefore, it benefits from a division between Smithian-type agents—this is not the case of innovation which, according to Schumpeter's postulates, would be usually spontaneous, that is, *not systematic*.

From the above, a series of conclusions are derived that are worth being analyzed more closely. First, it should be noted that the concept of an innovation system as a regime in which different agents are divided and specialized in different tasks—in line with Smith's division of labor postulates—interacting with each other, has now become diluted. This approach, in any case, can be applied to the field of R&D, but not to innovation. Consequently, it would be more appropriate to talk about (national or regional) R&D systems. In this way, the spontaneity and creativity of innovation is stressed instead of being "lost in the system."

Also, that the disarticulation between the R&D, innovation, and economic growth might lie in a wrong design of the policies of impulse to the innovation, which is the result of a misconception of innovation—instead of R&D—as a systemic process based on a division of labor in a Smithian sense. As a more efficient alternative, we propose a model based on purely Schumpeterian postulates, which will turn innovation into the center of the productive process. For this, it is crucial to understand that although R&D is systemic—and, therefore, it makes sense to speak of a national or regional R&D system—innovation is, in general, a spontaneous process, that is, fruit largely due to chance and, consequently, not systematic. Accordingly, the use of the confusing term "innovation system" should be discarded.

[9] Schumpeter (1939, p. 84 and p. 272). This interrelation was explained some years ago with surprising—for simple—precision by the then Finnish Prime Minister Esko Aho—whose country was then among the leading nations in terms of technological innovation—indicating that "research is to invest money to obtain knowledge; to innovate is to invest knowledge to obtain money."

2.4 Who Does Really Innovate?

It seems to have become a common belief that big business ideas come from scientists or researchers who carry out systematized work in their laboratories or university departments, which are then implemented by companies, thanks to public and private cooperation between universities and companies coordinated by governments. Yet this model might be obsolete (Sala-i-Martín, 2016). Already the study of Bhide (2000) came to show that 72 percent of the ideas that lead to an innovation came from workers not dedicated to R&D; 20 percent of the ideas derive from people (non-scientists) outside the firm; and only 8 percent of the ideas were due to formal researchers. Logically, in sectors such as robotics, ICT, automotive, or biochemistry, and so on, the relevance of R&D remains predominant. But it should not be forgotten that these represent, in most nations, only a relatively small part of the economy. In addition, innovations—both the product and the process—will only affect growth if they positively induce productivity, something that is not always guaranteed with the current definition of innovation that allows to include as such, for example, the implementation of a new version of software by the companies.

"Radical" innovations are only rarely the result of a systematic R&D activity. Let us take as an example the own inventions and innovations that set in motion the industrial revolution: Henry Cort (1740–1800), who in 1783 patented the system of puddling and running in—which allowed steel to work industrially—was marine. James Watt (1736–1819), manufacturer of devices for mathematical calculation, discovered the possibility of using steam power when he was called to the University of Glasgow to repair the model of a "latent heat" machine that Professor Joseph Black (1728—1799) used in his classes. It is well known that Watt continued many conversations with Black and with two other professors (John Anderson and John Robinson), without them coming up with the solution to the key problem of a steam engine: how to maintain a cold condenser even when the cylinder is hot. The solution—the true beginning of the industrial revolution—came with Watt in 1765: the only one in the group who did not belong to the university's teaching staff. Similarly, another of the emblematic machines of the industrial revolution, the mechanical weaver, was designed and brought to the market by Richard Arkwright (1732—1792),[10] a barber and wig maker and John Kay, a

[10] Which Schumpeter himself cites as an example of an innovative entrepreneur (Schumpeter, 1939, p. 272).

watchmaker. Later, Edmund Cartwright, an Anglican priest and poet, developed the first loom that could be handled entirely without human force. And it is worth noting that even the last of the great challenges of the textile sector—the infinite coil that did not require stopping the machine to replace the empty bobbins of thread—was resolved two centuries later by Julius Meimberg (1917—2012), who had been a famous fighter pilot during the Second World War, awarded with the highest military honors, and who, at the time of this invention, was the owner of a travel agency (Holtz-Honig, 1997).

2.5 Conclusions

The present chapter has overviewed three topics of discussion regarding innovation on which re-reading the works by classical authors (also, but not exclusively economists!) might shed new light. First, we have dealt with the genesis and evolution of the word innovation, which only recently acquired the positive value that we associate nowadays with it. The second critically discussed the innovation-system framework, arguing that innovation might in fact—according to Schumpeter's concept of the term—be systematical to a much lower degree than commonly expected. Replacing the "innovation system" approach by a "Research & Development" one might represent a more efficient and realistic analytical framework. Finally, we have questioned who actually innovates, as there are many historical examples that show that innovation—not invention—did take place outside the R&D-circle. Of course, we are aware that even a high number of examples is not enough to set a principle. But we believe that it might justify further exploring the question. And we also believe that when discussing topics as the ones exposed here, it is fruitful not only to rely on empirical analyses, but also to look back at "the giants on top of whose shoulders we are standing."

References

Bhide, A. (2000). *The Origins and Evolution of New Businesses.* Oxford University Press.

Freeman, C. (1987). Technical Innovation, Diffusion, and Long Cycles of Economic Development. In *The Long – Wave Debate* (pp. 295–309). Springer.

Gutiérrez-Rojas, C., & Baumert, T. (2018). Smith, Schumpeter y el estudio de los sistemas de innovación. *Economía y política, 5*(1), 93–111.

Gutiérrez-Rojas, C., & Baumert, T. (2019). *"Smith, Schumpeter y el estudio de los sistemas de innovación". Tecnología y Sociedad: una mirada multidisciplinaria*. USC.

Holtz-Honig, W. (1997). *Vater spinnt – Der Weg zum Endlosgarn*. Langen-Müller/Herbig.

List, F. (1841). *Das Nationale System der politischen Ökonomie*. Cotta.

Lundvall, B. A. (1992). *National Systems of Innovation*. Pinter.

Muller, E. (2001). *Innovation Interactions Between Knowledge – Intensive Business Services and Small and Medium – Sized Enterprises. An Analysis in Terms of Evolution, Knowledge and Territories*. Springer.

Nelson, R. R. (Ed.). (1993). *National Innovation Systems: A Comparative Analysis*. Oxford University Press.

Sala-i-Martín, X. (2016). *Economía en colores*. Conecta.

Schumpeter, J. A. (1926). *Theorie der wirtschaftlichen Entwicklung*. Duncker & Humblot.

Schumpeter, J. A. (1934). *The Theory of Economic Development*. Harvard University Press.

Schumpeter, J. A. (1939). *Business Cycles*. McGraw-Hill.

Schumpeter, J. A. (1942). *Capitalism, Socialism and Democracy*. Harper and Brothers.

Smith, A. (1776). *An Inquiry into the Nature and Causes of the Wealth of Nations*. Strahan et al.

CHAPTER 3

Invention, Institutional Change, and Economic Development: From Scottish Enlightenment to the IPE

Estrella Trincado Aznar and Fernando López Castellano

3.1 Introduction

Since the start of the Industrial Revolution in eighteenth century, many economists have extolled the need for constant innovation; however, many others have pointed out the risks of innovation. Jeremy Bentham started this debate when he published his letter to Adam Smith in 1787 under the title *Defence of usury*. For Bentham (1787), usury or the high rate of interest, fosters innovation, since the innovative and the saver spirits arise from different inclinations that do not have to come together in the same

E. Trincado Aznar (✉)
Department of Applied Economics, Structure and History, Complutense University of Madrid, Madrid, Spain
e-mail: etrincad@ucm.es

F. López Castellano
Department of Applied Economics, University of Granada, Granada, Spain
e-mail: flopezc@ugr.es

E. Trincado Aznar, F. López Castellano (eds.), *Science, Technology and Innovation in the History of Economic Thought*, Palgrave Studies in the History of Economic Thought,
https://doi.org/10.1007/978-3-031-40139-8_3

person. Then, innovation must go hand in hand with credit. Innovation is the driving force behind development because "what is now an institution was once innovation" (Stark, 1952, p. 355). For Bentham, designers venture into unknown paths by expanding the scope of consumer utility (Trincado, 2005). Bentham praises the designer for breaking away from routine patterns of behaviour, standing out from the crowd, and viewing risk as a "pleasure" (Dube, 1991, p. 97).

The topic of the interest rate had already generated copious literature. Sir Josiah Child (1689) was in favour of lowering the legal interest rate, arguing that high rates encourage the rich to live without working and not to invest their wealth productively. William Petty (1690) considered it futile to try to fix interest rates by law; and many since the late seventeenth century suggested that interest rates were determined by the supply and demand of capital: North (1691), Barbon (1696), Massie (1750), Turgot (1766), Hume (1964c). For example, David Hume showed that while trade develops, the extension of business professions engenders love of profit; and the income received by the merchant (compared to that of the lawyer and doctor) promotes an increase in production (Hume, 1964b, p. 326). By treating these elements in historical perspective, in *Of Public Credit*, evoking Cicero he made a pessimistic prediction about the inevitability of the rise and fall of governments due to excessive public debt—although it was also optimistic about the inevitability of its resurgence. This precludes the possibility of major political or institutional reforms. Although change is desirable, it should not be at the expense of the past, since institutions and the habits of individuals come into play. These are products of human invention, not super or subhuman forces that gradually develop their effects in history (McRae, 1951). A wise magistrate should only make gentle innovations within the old constitution and its pillars so that learning through trial and error occurs naturally (Rotenstreich, 1971).

As against Hume's ideas, for whom the crisis can be an opportunity for learning—only reasonable investments will survive the progressive mechanism of trial and error—Smith considers that the error, which in capital markets may lead to the non-payment of loans, can create resentment. Smith advocates usury law and the setting of a legal maximum interest rate a little above the minimum market price customarily paid by prudent men. If the interest rate is higher, only *prodigals* and *projectors* would take loans, and the idle creditor would take advantage of the former while the latter loses the capital accumulated with the effort of his savings. Maintaining

low interest rates—or achieving mild inflation—is for Smith an insurance against credit default (Trincado, 2023). Smith intended to dissuade men from taking out consumer loans, since the person who asks for subsistence cannot ensure a repayment in the future unless he loses his freedom (Smith, 1988, pp. 450–451). Thus, Smith speaks of a positive freedom that can be lost in the exercise of the negative freedom, that is, without any interference at all. However, it is not to be ignored that for Smith, the dynamics of transformation of institutions also affects innovation and economic and human development. For Smith, institutions sometimes seem like restrictions on individual action; but, as was the case in the Scottish Enlightenment, sociability is not a by-product that restricts individual action. Rather they apply the maxim of Ortega y Gasset (1914) of "I am I plus my circumstance; and, if I do not save it, I do not save myself." Personal identity is not only a habit or desire of the isolated man but also the circumstances, the reality that men share and that enable them to change the world. For Smith, it is not the greatest individual inventiveness that increases the amount of capital, but the skill, dexterity, and judgment with which work is customarily done. For this reason, he gives importance to the role of capital—physical and human—based on abstinence (Khan, 1954, pp. 337–342).

In fact, in the period of the Scottish Enlightenment, other economists put forward a non-individualistic vision of innovation. For example, John Rae defended invention as a key element of technological and institutional change, on which economic development depends (Hamouda & Omar Lee, 2005). Rae considered that credit leads to institutional change that, as Bentham would put it, transfers the possibilities and capacities of action from the accumulators by abstinence to the creators and transformers of reality. In development theory, Rae's view is related, in its most favourable version, to Amartya Sen's theory of capabilities, and in its most unfavourable view, to Berlin's idea of positive freedom, which he himself linked to authoritarianism of collectivities (Cohen, 1960).

This idea of expansion of capacities has entered into the recent developments of the institutionalism approach at the hands of Institutional Political Economy by authors such as Hodgson, Lazonick, Evans, Rutherford, Burlamaqui, and Toye, among others, with a broader vision of institutions and a more systematic and general explanation of institutional change (Chang & Evans, 2005). As for ECE, institutions contain rights, obligations, and ideologies, their success or failure must be evaluated according to their own objectives (Lazonick, 1991). The idea of

institutional innovation rejects the concept of equilibrium in favour of the process. The theory of Elinor Ostrom (Delgado, 2015) is also in this line, as it shows that the market and the state are nothing more than the face of the same coin where limitations and skills are intertwined, contrasting with Robbins' idea of scarcity.

For all these reasons, this chapter relates the pioneers of the study of economic innovation with current theorists on institutional change and economic development, who have a non-individualistic vision of innovation promoted by the institutions.

3.2 The Concept of Innovation in the British Economy of the Eighteenth Century

As Galindo (2008) claims, classical economists do not normally use the word "innovation," but they prefer terms such as "mechanical advances," "inventions," and so on. David Hume linked the progressive march of science and civility with innovations in industry: "We cannot reasonably expect, that a piece of woollen cloth will be wrought to perfection in a nation, which is ignorant of astronomy, or where ethics are neglected. The spirit of the age affects all the arts; and the minds of men, being once roused from their lethargy, and put into a fermentation, turn themselves on all sides, and carry improvements into every art and science" (Hume, 1964c, *Of Refinement in the Arts*, 270–71).

However, for Hume, innovation in industry is a consequence, not a cause of competition and the accumulation of capital. In fact, Hume raised his theory of real interest within his general objective of establishing the temporality of causes (Trincado, 2019). Indeed, forcing down the interest rate and the rate of profit is for Hume a consequence of growth, not its cause; luxury is a consequence, not a cause, of wealth, and, in the same way, innovation is a consequence of competition and capital accumulation, not its cause (Schabas & Wennerlind, 2020, p. 45). Hume leaves innovation in the hands of the entrepreneur who he compares to the hunter, whose pleasure consists "in the action of the mind and body; the motion, the attention, the difficulty, and the uncertainty" (Hume, 1964a, p. 226). For Hume, businesspersons need action, they are restless, and they cannot rest for a long time without falling into a state of languor (Trincado, 2009).

For Hume, action in the economic sphere stands on three different motives: action for its own sake, habit, and imitation. The first two, action

and habit, can be considered constant over time (Trincado, 2009). Therefore, it is imitation what promotes differential growth between historical stages, stimulating the entrepreneurial spirit or imitative demand. "Commerce encreases industry, by conveying it readily from one member of the state to another, and allowing none of it to perish or become useless" (Hume, 1964b, p. 325, *Of Interest*). But Hume considered that any attempt at political innovation must take into account the need to maintain the necessary conditions for a civilized coexistence (Gill, 2000, pp. 87–108).

> Violent innovations no individual is entitled to make: they are even dangerous to be attempted by the legislature: more ill than good is ever to be expected from them: and if history affords examples to the contrary, they are not to be drawn into precedent, and are only to be regarded as proofs, that the science of politics affords few rules, which will not admit of some exception, and which may not sometimes be controuled by fortune and accident. (Hume, 1964c, p. 478, "Of the original contract")

According to Hume, we must assess institutions for their survival. He points to tradition as a moderator of the possibilities of reason, a means of institutional learning based on an evolutionary epistemology (Gauthier, 1979, pp. 3–38.). This implies a path dependency; therefore, Hume seeks the historically fixed or invariable psychological foundations of human nature, and from uniformity arises his concern for consolidating politically and socially a high civic morality (Phillipson, 1979, p. 140).

According to Hume, as above said, the interest rate is a consequence of the advance of the economy, of the dispositions towards frugality and investment, and of the accumulation and distribution of capital. Therefore, he adhered to the law of the decreasing rate of profit in *Of Public Credit* (Hume, 1964c). Hume and Smith agreed on this point. Considering interest rates as a product of economic growth, Hume's theory gives great importance to the influence on the interest rate of the concentration of capital in the hands of the rich while trade and industry develop. Hume believed that technological diffusion and the international factor flows makes poor regions benefit more when they trade with rich ones (he was thinking on the effect of the union of England and Scotland, Berdell, 1996, pp. 107–126). For him, the main benefit of trade is the international diffusion of technology. However, in the case of rich countries, not only their interaction spreads technology but it also gives an impetus to

the overall rate of innovation. Relating this to Hume's science of man and the role he gives to imagination, technical change is shown to increase knowledge and changes customs, conventions, and laws (Norton, 1993, pp. 148–182). Thus, his theory of interest proves that the phenomenon can be reduced to changes in manners and customs, an argument that forces us to accept that the interest rate can be used as an instrument of economic policy, helping to produce changes in spending and saving models that lead to a fall in the interest rate (Trincado, 2005).

Although Hume witnessed and recognized the rise of the consumer society, he was unable to understand the extent to which the British economy was to grow during the last third of the eighteenth century, becoming the Workshop of the world (Schabas & Wennerlind, 2020). For example, he noted the importance of wool, linen, and silk, but not the increased production of cotton cloth that occurred in the 1780s, largely facilitated by the steam engine. In 1752, he could not anticipate the dramatic changes that were coming, something that neither Adam Smith could foresee in 1776. In fact, the use of steam only came after the improvements of James Watt and Matthew Boulton in 1776. In this sense, Hume and Smith analysed a proto-industrial commercial world in which artisanal production tended to take place on a smaller scale without additional sources of energy.

All the crises of the time, despite the economic prosperity, led both Hume and Smith to express their concern about the emergence of an idle rentier class that lives by giving credits (Trincado, 2023). They recognized that credit markets tend to create an imbalance of power such that modest lenders and borrowers are more likely to be at the mercy of those with large sums of capital. Both Hume and Smith articulated the prediction that in the event of a collapse of public credit, the majority of the population would be in debt to a small but powerful group of financiers. Smith expressed great faith in the frugality of common people, and therefore blamed any credit fiasco on the extravagant spending misconduct of landowners, bankers, and politicians (Smith, 1988, 1, pp. 345–47).

In this sense, Smith is especially critical of the figure of the greedy *projector*, and compared to Hume, for whom the crisis can be an opportunity for learning, Smith considers that the error can create resentment in case of non-payment of the loans, and the resentment, dissolution. It is not to be forgotten that justice, according to Smith, emerges from the propensity of a spectator of offences to feel resentment or indignation (Trincado, 2004). Smithian moral theory of sympathy underlies Smith's economic

theory of innovation, which in this sense can be considered an alternative theory based on Responsible Innovation. Individuals create useful innovations because they are constantly imagining themselves in other people's shoes (Hühn, 2018). The division of labour leads men to put their abilities in common for the public good.

> Among men, on the contrary, the most dissimilar geniuses are of use to one another; the different produces of their respective talents, by the general disposition to truck, barter, and exchange, being brought, as it were, into a common stock, where every man may purchase whatever part of the produce of other men's talents he has occasion for. (Smith, 1988, I, ii, 30)

Adam Smith tended to ignore the historical and psychological influences in his treatment of political economy. For Smith, natural freedom is beyond utility; the natural is opposed to the historical, as men are not determined by history or conventions (Griswold Jr, 1999, pp. 349–354). Smith argues that there is no reason why all groups should not always be equally frugal, because people rely on their "universal, continual, and uninterrupted effort to better their own condition" (Rotwein, 1970, p. 109, Berry, 1997, pp. 68–70). Smith's growth arises from the natural tendency to increase productivity because of the division of labour, with progress in one sector being a prerequisite for progress in others (Berg, 1994). According to Smith, continued growth is necessary to unleash the rivalry between the captains of industry. And the effort to improve one's condition, protected by law, and permitted by liberty to be exercised to the most advantageous manner, is "which has maintained the progress of England towards opulence and improvement in almost all former_ times, and which, it is to be hoped, will do so in all future times" (Smith, 1988, II, iii, p. 345). It may be necessary to adjust the legislation to the interests and temperaments of the time, but Smith presents habit and prejudice only as an obstacle. Therefore, Smith considers productivity as an essential factor, the result of specialization that allows workers to increase their skills (García Leonard & Sorhegui, 2018). There is expansion of production if productivity increases, and the machinery invention flows from the skills and abilities of workers, product of specialization and division of labour, and thanks to manufacturing secrecy. Thus, Smith introduced the problem of knowledge and the learning abilities for the development of technology, basic pillars of the current concept of innovation. For Smith, the only means of promoting inventions is by creating an intellectual

property right for a reasonable time, without which they would be discouraged (Smith, 1978: LJ (B), 175: 472, 1109).

Thus, for Smith, the division of labour is an innovation that occurs unintentionally and gradually, and no larger share should be forced into any channel than would naturally flow into it spontaneously. Entrepreneurial risk seeking innovations can only pay off temporarily, as shortly other firms will take over the innovation and competition will reduce the profit margin (Smith, 1988, p. 173). Smith places more emphasis on the automaticity of the market in restoring the balance than on the importance of the innovative function. For Smith, the man of progress, slowly but surely, carries out his projects with enough information. Therefore, what increases the amount of capital is not the exceptional man, but the ability, dexterity, and judgment with which the work is usually carried out, besides the parsimony or abstinence (Khan, 1954, pp. 337–342). In this way, even the invention becomes one more specialty. "These different improvements were probably not all of them the inventions of one man, but the successive discoveries of time and experience, and of the ingenuity of many different artists" (Smith, 1988, Early Draft of Part of the Wealth of Nations, para. 18, 570). The inventor is a worker who, by continually using a machine, imagines a new means to reduce his labour and improve the mechanism. "And there is none of the inventions of that machine so mysterious that one or other of these could not have been the inventor of it" (Smith, 1978: LJ (A): VI: 4: 346).

According to Ricoy (2005), in Smith, the invention and use of machinery in the different productive activities depend, first, on the progressive specialization and simplification of its operations that result from the extension of the division of labour. "As the operations of each workman are gradually reduced to a greater degree of simplicity, a variety of new machines come to be invented for facilitating and abridging those operations" (Smith, 1988, p. 292). Secondly, technical progress, the invention of new machines and the improvement of existing ones, is the result of (technological) learning by doing and the effective use of machines in production processes. This is, in turn, a consequence of the progressive subdivision and specialization of the processes that the division of labour creates that leads some worker to find easier and more direct methods to carry out their work (Smith, 1988, p. 13). Following Smith's idea, James Steuart (1767) pointed out not only to the positive effects that mechanization would have on employment due to lower prices but also to the negative effects on unemployment of the introduction of machinery that

replaced workers (Mokyr et al., 2015; 33–34). Ricardo expresses himself in the same vein (1821, pp. 388–39; Mejía, 2017). However, among other things, the fact that innovation is the consequence of a social process delegitimizes the maximization of the value for shareholders as the business objective. For this paradox of illegitimate and non-sympathizers stockholders, Smith did not trust governance through corporations. For Adam Smith, innovation is not the consequence of the individual invention of great geniuses, but of the progressive change of institutions. In this sense, this perspective of Smith that pervades the classical economists allowed them to articulate a critique of the conservatives who, in the nineteenth century, called classical economics the "Dismal science." The historian Thomas Carlyle praised the deeds of great heroes as history makers, but spoke of capitalism as a way of "benevolent slavery" of the ungovernable mass and offered racial explanations for unemployment. In addition, he praised the idea of the nation and social policies of the government as a benevolent master of workers (Levy, 2001).

Adam Smith's vision is present in recent studies such as those by Collier (2019), Mazzucato (2019), and Mayer (2018), for whom the generation of innovations is a collective process that must be reflected in payment and governance. The value that the companies provide to society is not only the quantifiable price of their product but dynamism and growth created. In addition, Smith denounces the excessive financialization of the economy that leads to living on income or subjects the economy to uncertainty. He certainly would not have celebrated the hypertrophy of the financial system or the excess of rent-extracting activities. The deterioration of wage income compared to benefits, synonymous with economic decline, is the sign for Smith of a lack of dynamism (Sebastián, 2022, 187–8).

In Defence of Usury, Jeremy Bentham wanted to criticize Adam Smith by boasting of being more liberal than Smith himself was. Capping interest rates, says Bentham, will decrease the number of potential lenders and bankers will be more cautious in setting risk margins or a black market for credit will emerge. Loans will only be granted to entrepreneurs who operate in known production and distribution paths, with low risk. Thus, Bentham considers that the effect of law will be to block any innovation and the development mechanism itself, as he defined it. His conclusion is that it is necessary to trust market forces and deregulate the economy. Bentham reproached Smith for having underestimated the role of those "men of genius" who, through their invention and imagination, are responsible for the progress and wealth of nations, since they find new

channels of trade. In this case, he extends his utilitarian habit of projecting into the future to businesspersons' activity. Even if their companies fail, society as a whole remains intact because others will try to avoid making the same mistakes and the innovations introduced by projectors in the production process will expand through the economic system, whatever the fate of its original promoter—in short, it is the argument of trial and error. Therefore, productivity will increase by new arrangements of the means of production, especially in manufacturing, and of growth by abrupt changes, based on uncertainty, typical of disruptive innovation and contrary to Hume's or Smith's vision (Kline & Rosenberg, 1986).

3.3 Innovation at John Rae

After the death of Adam Smith, Scottish theory of innovation evolved in a very original way. In particular, John Rae, a Scotsman born in Aberdeen in 1796, published a *Statement of Some New Principles on the Subject of Political Economy* in 1834, in which he presented a sociological theory of capital. John Stuart Mill (1848, 72, Book I, Ch XI) quotes him in *Principles of Political Economy with Some of Their Applications to Social Philosophy*. For Rae, growth is function of innovation, and Smith was confusing effects with causes (Coccia, 2017). Smith held that division of labour leads to the creation of new machinery and therefore to inventions, Rae held that it is inventions which lead to the division of labour. For Rae, invention is the only independent cause of wealth and income growth, and all other factors, including accumulation, are simply their consequence (Brewer, 1991). Rae charges Smith with attributing economic growth solely to capital accumulation, which in turn depended on individual saving decisions. According to Brewer (1991), Rae was the first economist to see technological change as the main cause of economic growth. Savings are invested but they are not an exogenous variable, just like population and invention. In Rae's opinion, invention itself does not promote thrift; its causes are independent of individual decisions and are open to the influence of the legislator. Thus, he supported protection on the infant industry and believed that progress in science and technology should be supported by the funds from tariffs on the imports of luxury goods as a way to increase savings. Rae tried to put together a knowledge-based theory of growth, that is, an endogenous model of growth. So, he began to talk about the learning process, which over time has become one of the cornerstones of the evolutionary theory of economic change. (Nelson &

Winter, 1982, 2002). Rae's theory of capital had a strong influence on the Austrian Economics school (Roll, 1954).

John Rae has been recently rediscovered not only as a true precursor of endogenous growth theory but also for his contribution to understanding the economic role played by innovation and technological change within the economic system. Rae distinguished (like Bentham) men of genius from common people who were characterized by a natural inclination towards imitation (according to Hume, the differential factor between historical stages). However, Rae also considers the scarcity of certain materials and the application of principles from already known fields or principles to new fields to be the cause of the progress of invention, generating synergies thanks to cross-fertilization phenomena. Therefore, invention arises from science and necessity. According to Rae, this effect, as well as technological progress, is easier where there are constant commercial and financial relationships between men belonging to different cultures. Thus, he proposed a multi-ethnic environment similar to the global village. Finally, according to Rae, there must be social changes capable of shaking the immobility of the systems and stimulating the inventive and creative faculties of men to find a momentum towards development. In this sense, Rae talks about the spatial diffusion of innovation from one country to the other where there are different cultures, climates, and socioeconomic conditions. There have not only been incremental improvements due to technology in relation to products but also in relation to services, such as banking trade. It needs to be said that the origins of the economics of technology is assigned by Grandstrand (1994) to Babbage's work written in 1832, two years before Rae's work. However, Babbage's analysis followed mechanical principles with an engineering twist, examining the improvement of division of labour and increasing economies of scale from the application of machinery to manufacturing (Rosenberg, 1971), while Rae's writings had a strictly economic focus related to growth. As we can also see, Rae tries to link Hume's historical vision with Bentham's psychological theory to overcome Smith's mechanistic explanation, which, however, surpasses Bentham in his non-individualistic perception of innovation.

3.4 Subsequent Holistic Views of Innovation and Historical Change

Subsequently, the authors of the German Historical School (Adam Müller, Wilhelm Roscher, Bruno Hildebrand, Karl Knies or Gustav Schmoller) gave a meaning to history other than the sum of its parts, which states that economic laws are not absolutely and permanently valid. For historicists, history, science, technology, and innovation depend on multiple causes, not only economic but also political, sociological, or psychological. They had an organic and biological approach to social sciences based on the statistical method, in contrast to the individualist vision of philosophical and social problems that classical economics presented. Schmoller insists that we should not deduce general rules from reason, as "Manchesterian liberalism" does, but we need to record the "unique" in its infinite historical variation. We can only make a probabilistic analysis from its occurrence, a sociology of the historical spirit (Cardoso & Psalidopoulos, 2016).

In England in the nineteenth century, a British historicism also arose as a critique of classical economics. Richard Jones, John K. Ingram, T. E. Cliffe-Leslie, Walter Bagehot, or Arnold Toynbee were based on Auguste Comte's theories that described social change heading towards a predictable end. British historicism tried to support the theory with statistics, bringing economics closer to sociology. Jones insisted on the evolutionary character of national economies. Similarly, Bagehot claimed that classical economic theory was not of general applicability and that, given institutional differences; it was of no use outside England. In fact, in North America, classical economics did not catch on very much. The American Economic Association was based on a branch of British historicism, Veblen's institutionalism, which studied the interrelationship between institutional structures and the economy. Borrowing from Spencer the idea of quasi-random evolutionism, Veblen considered that the end of history was not predictable and the different historical stages were not comparable. Institutions seal human beings with preconceptions of time and place, which depend on the constantly changing technological system. Therefore, man is not a rational homo oeconomicus equal at all times, but he is curious and creative, although also accommodating and vain. The theory is based on behaviourism, on instinct and on the habits that institutions generate (Veblen, 1899). Nevertheless, according to Veblen (1904), a gradation of institutions may be done. In particular, institutions are of two types: technological and dynamic; or ceremonial

and static, which are dependent on the former. Veblen saw industry as progressive for society and culture and a technological characteristic of it; and business as a ceremonial and inhibitory institution to society and culture (Klosterman, 2016). The first determine preconceptions and generate progress and innovation; the latter block progress. The former depend on science, on the producers or engineers who invent cheap technology and determine economic and social relations based on the instinct of workmanship and idle curiosity, or pursuing knowledge for its own sake. The second are the entrepreneurs moved by the instinct of emulation and mere self-preservation. Armed with their property rights, they boycott the introduction of inventions, creating monopolies and increasing production costs to keep profits high. In this sense, Veblen anticipates the theory of regulation and criticizes the relationship between entrepreneurs and government, who agree to protect their interests at the expense of the public. Veblen created an important heterodox school in the United States, with followers such as John R. Commons, Wesley Mitchell, John M. Clark, Clarence Ayres, and John Kenneth Galbraith (Trincado, 2014). Commons proposes to establish a legislation for social change with the new notions of transaction, collective action (especially union), and conflicts of interest. Mitchell bases the dynamics of capitalism on endogenous economic cycles that lead to recurring crises. Finally, Ayres talks about technology as an element that overcomes superstition and transforms sociocultural institutions.

3.5 From Innovation as a Rational Process to the Economics of Innovation

Although classical economists do not link invention to the figure of the businessman and Ricardo points out the problem of technological unemployment, many classical economists have a positive perception of the invention. Jean Baptiste Say supports in the momentary imbalance notion, the introduction of machinery in industry. Machinery saves labour and increases production and, in his opinion, it does not harm employment, except in the case that capital remains idle, as it creates activity in another industry. In a nation in the midst of the capital accumulation phase, the invention of new machines has few drawbacks, since although the labour force increases, the new capital offers them the means to employ themselves. Classical economics revealed that the new technology resulting

from inventions had effects on labour productivity and economic growth, and that the latter did not depend solely on the three productive factors (land, labour, and capital), as it would later be generalized by the neoclassical school. For neoclassical economics, technological change is the result of the rational agent's choice among a set of scarce resources in order to maximize benefits. For neoclassical economics, technology is the flow of information and knowledge that can be applied to the production of goods and services, based on possible production plans suggested by engineers. The economic problem consists of choosing the best combination of means to obtain the maximum number of products, with technology as an exogenous factor in the process (Gallego, 2003).

For this reason, models where technology is an exogenous factor had to move to models of endogenous growth closer to the pioneers of the eighteenth century. In particular, there are two major trends in technological change in the second half of the twentieth century, which have led to the construction of exogenous and endogenous growth models. The neoclassical models of exogenous growth (Solow, 1957) consider that the variables included in them must be exogenous and technology is a residual variable of the model. Solow (1957) questions the fundamentalism of capital as a magic word for development. He stated that technological change was what explained most of growth, and advanced the idea that "improvements in education of labour force" would be considered as technical change.

In the endogenous growth models, concepts such as learning and increasing returns to scale are introduced. Economic growth draws from the existence of externalities linked to investment in physical or human capital. In this sense, they break with the traditional neoclassical models of growth and maintain that growth is driven by technological change, which originates from "an intentional investment decision made by agents to maximize their utility" (Romer, 1990). The most recent studies on the role of innovation in the growth process include aspects such as "learning by doing" (Romer, 1994), human capital (Lucas, 1988), research and development (R&D) (Romer, 1990; Aghion & Howitt, 1997), and public infrastructure (Barro, 1997; Galindo, 2008; García Leonard & Sorhegui, 2018; Jimenez-Barrera, 2018; Olaya, 2008).

The economics of innovation and technological change or neo-Schumpeterian economics arises from various schools of thought such as the above-mentioned theory of endogenous growth, but also the new institutional economics, evolutionary economics and, above all, the

theoretical approaches of Joseph Schumpeter on long-term business cycles to explain the relationships between innovation, technological change, and economic development (Parayil, 1991). These approaches began in the Böhm-Bawerk seminar of 1905–6, where Emil Lederer, a friend of Schumpeter at the University of Vienna and influenced by Marx, also presented a theory of cycles based on dynamic disequilibrium that suggests that it is the excessive speed of technical progress which produces technological unemployment (Benchimol, 2019; Hagemann, 2015). Also, according to Michał Kalecki, capitalist investment entails innovation in profit and in the power that affects the evolution of economic cycles (Courvisanos, 2012).

According to Schumpeter, innovation and industrial change are clues in the field of economic analysis. Innovation is the engine of economic development and the main cause of the cyclical fluctuations. Both growth and the cycle are inextricably linked with the capitalist mode of production understood as an evolutionary process of continuous innovation and creative destruction. The innovative entrepreneur is the key figure in the innovation process, who alters the course of the circular flow by reforming or revolutionizing the modes of production introduced by an invention (García Leonard & Sorhegui, 2018; Jimenez-Barrera, 2018; Schumpeter, 2010; Yoguel et al., 2013). Schumpeter's theory of economic development is based on Innovation processes and sociocultural changes (Quevedo, 2019). In his *Theory of Economic Development* (Schumpeter, 1934), he stresses the importance of the social environment in which the entrepreneur carries out his activity, the "social climate", which includes aspects of a sociological, institutional, and economic nature (Galindo, 2008; Nissan et al., 2012).

In the early 1980s, Nelson and Winter (1982) vindicated Schumpeterian thought and explained competition within an innovative environment as a change in routines through the integration of incremental innovations. Technological change explains, in their opinion, the long-term structural evolution. Based on a dynamic, evolutionary, and essentially qualitative approach, they put a lot of weight in institutions, since they can speed up or slow down innovative processes. The existence of technological revolutions, like a gale of creative destruction, leads capitalism to overcome the recessive phases of the economic cycle, and to readjust the socioinstitutional framework with the techno–economic paradigm (Jimenez-Barrera, 2018). The object of study of the evolutionary conception of technological development is economic change, in the short and long terms.

Evolutionary economics applies to the field of economic science a plurality of possible evolutionary paths, given that agents act in a framework of uncertainty similar to that of biological evolution. On the other hand, evolution can be guided by economic policy measures, which modify the context in which they operate (Espinosa et al., 2021).

The evolutionary line of the neo-Schumpeterian trend of innovation economics questions the neoclassical postulate of equilibrium and rejects the production function as an instrument to delimit the state of technological knowledge, as they deny that companies have at their disposal a panoply of techniques. Despite the fact that "evolutionary economics" uses analogies from the natural sciences, as Hodgson (2004) emphasizes, the term describes a wide variety of points of view and approaches, some of which do not use such analogies, and proposes a not "deterministic" or "mechanistic" vision of the Darwinian theoretical approach. Evolutionary theory understands technological change as a product of the process of variation and selection, and not as a rational choice process, that assumes technology as given. In the words of Lewis and Steinmo (2011), it provides a good meta-theoretical framework to understand the institutional dynamics and the mechanisms of gradual change. From this, we can trace an evolutionary macroeconomics, which is based on the post Keynesian theory of credit and money creation by banks, that is, on endogenous money. So, Keynesian monetary policy does not work as a stimulus for investment, innovation, and structural changes (Sawyer, 2020). Neoclassical policies on science, technology, and innovation do not seem applicable to developing countries as against evolutionary theories that take into account path and theoretical pluralism (Dolfsma & Seo, 2013; Moreau, 2004). Nevertheless, it seems that both policies tend to converge, even though their basis is different (Ghazinoory et al., 2017). In this sense, evolutionary theory of growth is another scientific research programme in the sense of Lakatos (Silva, 2009).

On the other hand, the emergence of new productive ideas is not something external to growth models, but rather depends on economic incentives that, in turn, are determined by institutional contexts. Hence, North's contribution, which lies in emphasizing that institutional public policy, is an essential determining factor for growth and that political changes condition the incentives of economic agents to develop new ideas. For North (1990), the "institutional framework" is determinant in the long-term functioning of the economy. North (1990) argues that neoclassical theory emphasizes technological development and human capital

investment, but ignores institutions and time. In the static world of neoclassical theory, the exchanges happen without friction, property rights are perfectly delimited and information has no costs, so we cannot analyse development policies within this framework. To understand the differential performance of economies over time, North examines the nature of institutions and their consequences for economic or social performance, outlining a theory of institutional change. In his opinion, institutional change is the result of the interaction between institutions and organizations in an economic framework of scarcity and competition. Competition forces organizations to invest constantly in knowledge in order to survive. The institutional framework provides the incentives that encourage the type of skills and knowledge perceived to yield maximum rewards; perceptions are determined by the mental structures of the players. Economic change is a ubiquitous, continuous, and cumulative process that results from the different individual decisions of actors and businessmen of the organizations.

McCloskey (2017, 2018, 2020, 2021; McCloskey & Silvestri, 2021) has recently refuted developmental neo-institutionalism. She considers that the most feasible cause of the "Great Enrichment" that occurred in the Netherlands and Great Britain, and was later spread to the rest of the world, is the change of the ideological change, which is actually the so-called liberalism. To build on that idea, Professor McCloskey stresses that the liberation in ethics and ideology produced Innovism, not 'capitalism', which was a long-standing phenomenon. By Innovism, she means the accumulation of ideas, not of capital, hence the sequence she proposes is that liberalism led to Innovism and, therefore, to the Great Enrichment.

In recent years, New institutionalism has gradually reconsidered their concept of institutions, taking them as embedded in the broader institutional milieu of a political organization, as a "social regime" constituted by a set of rules that define behaviour. There is also a broad consensus that institutions, ideas, and the environment change in a coevolutionary process (Hodgson, 1993, 2000; Lewis & Steinmo, 2011). For complexity theories, innovation is the result of a transforming process of social institutions defined as emerging patterns of human interaction (Guia et al., 2009).

From another perspective, and with a clear Marxian resonance, the Regulation Theory proposes an institutional explanation of the transformations of capitalism, underlying the interpretative function of the class struggle for the role of institutions and "social commitments." The theory tries to explain capitalist reproduction by emphasizing the influence of the

changes in the functioning of political regimes, and by studying the incidence of the institutional context in innovation (Boyer, 1988). For Katz (1997), however, the Marxian institutional explanation of technological change is insufficient, as it only emphasizes the influence exerted by political and social organizations on economic activity and not on the laws of capitalism. In his opinion, technology is a social productive force, which acts through innovations subject to the contradictory dynamics of the laws of capital, hence the fundamental role of class struggle in technological change. In short, he says, if the role of class struggle is taken by the role of institutions, as defended by Regulation Theory, the social meaning of innovation is distorted. Indeed, as various authors have underlined, in Marx's theory, technological change and class struggle are the driving force of historical change. The Marxist school analyses technological change as part of the qualitative development of the productive forces, within current production relations, closely linked to the laws of accumulation and surplus value. The development of technology is a way to increase surplus value, increase capitalist benefits, and maintain the expanded reproduction scheme, which shows the endogenous nature of technical progress (Elliot, 1980; García Leonard & Sorhegui, 2018). In this sense, technology makes us evolve to a cognitive capitalism, to a common intellect capable of overcoming the contradictions of the previous mode of production (Vercellone, 2007).

3.6 Innovation, Institutions, and Development: The Approach of the Institutionalist Political Economy

We end this chapter by focusing on a school that we consider to have great projection since it includes part of the ideas raised by classical economists but solves some of the problems that arise from their theory, Institutionalist Political Economy (IPE). The IPE proposes an analysis that goes beyond the conventional view of institutions as "constraints" and a more systematic and general explanation of institutional change (García Quero & López Castellano, 2016). Individual motivations are fundamentally formed by institutions that surround the individuals, but human motivations are varied and interact with each other in complex ways. There is no need for selfish motivations to dominate behaviour in the public sphere of the state, and even in the private sphere the importance of self-seeking

motivation is much less than what neoclassical economics believe. For the IPE, institutions are more than restrictions; they are "constitutive," because they inculcate certain values, and "enabling" instruments. Institutional change, for its part, implies a change in the rules that constrain or encourage social behaviour and a transformation of the visions of the world (Chang & Evans, 2005).

The IPE, unlike the so-called neo-institutionalism, is very close to Classical Political Economy, but also to the German Historical School and the Old Institutional Economics. From the German Historical School, the IPE draws its critique of abstraction, the deductive method, and the idea of individual interest as a regulator of economic action from the neoclassical school. He also shares Schmoller's idea of an interventionist State in social matters, guarantor of the principle of redistributive justice. From the old institutionalism, amplified by the work of John K. Galbraith and Gunnar Myrdal, and recent studies by Greoffrey Hodgson and William Kapp, IPE draws its emphasis on studying the structure and functioning of economic systems and processes, the use of historical and empirical material, the critique of the idea of equilibrium and of the utilitarian behaviour of the individual and the methodological individualism of neoclassical economics.

IPE also has a certain affinity with evolutionary or Schumpeterian economics, fleeing from simplistic models of rational individual behaviour and adopting a clearly interdisciplinary approach. From this view, later expanded by Simon, Nelson, and Winter, both Reinert and Lazonick adopt the argument that innovation is a fundamental element of economic development that implies certain routines, capabilities, and replication (Salter & McKelvey, 2016). For Lazonick (2006), neoclassical theory does not allow us to understand the innovation process. He argues that a framework of the innovative company integrated into comparative-historical analysis is needed so as to analyse the relationship between corporate governance and economic development and to know which institutions will promote or hinder innovation and development. Also, we need to define the concept of Development. If this is understood as a growth process capable of permanently raising the standard of living of an increasing number of people over time, the corporate governance institutions that in different times and territories fostered economic development must be made explicit. As Hoff and Stiglitz (2001) underline, development cannot be seen as a process of capital accumulation, but as a process of organizational change.

Precisely, the main limitation of the analysis by North and other neo-institutionalism economists is that they assume that the fundamental measure of development is income growth, estimated using market indices. For Evans (2004, 2005), Amartya Sen's approach to capacity allows an escape from this reductionist approach, because it emphasizes the institutions that facilitate choices on the goals of development. Based on the idea that without innovation, without investment in productive capacities, there can be no economic development, Lazonick (2006, 2011) argues that the design of public policies to shape processes and results of investment in innovation requires building an economic theory of "organizational success":

The theory of organizational success is based on two premises. The first is that the neoclassical description of the company is a non-innovative theory of the company, which makes it incapable of analyzing what kind of corporate governance institutions can promote innovation and economic development (Lazonick, 2006). The second is that investment in innovation is not a market process, but an organizational process carried out by three social actors (households, governments or companies), who invest in the human capital that constitutes the basis of the productivity growth necessary to achieve a higher standard of living (Lazonick, 2011).

A reflection on the relationship between innovation, institutions, and development requires, therefore, working out a theory of the innovative company and another theory of the investment of households, governments, and companies in innovation that goes beyond the conventional view of the role of public policy in mitigating market imperfections and failures. This new theory highlights the importance of households as centres of production of future workers, more or less qualified; the role of government in developing the future workforce by investing in and subsidizing the public education system, and creating new skills that can be vital for economic growth; and the work of the innovative company when integrating the skills and efforts of the workforce to undertake organizational learning processes that transform the available productive capacities and access new markets.

For a developing nation, the innovative firm theory coincides with the infant industry argument and tariff protection. For its part, the State model capable of investing in the knowledge base of a society coincides with the so-called developmental State, one of the institutions with the greatest role in reformulating the national trajectories of economic growth during the twentieth century (Chang & Evans, 2005). As Lu (2000)

showed for the Chinese case, the analysis of the complementary functions of the innovative company and the developmental State in the generation of economic growth is essential for a theory on the functioning and results of the economy.

3.7 Conclusions

In this chapter, we have studied the difficult emergence of a view of change and innovation from common knowledge. David Hume already introduced historical and psychological factors in his analysis, although he starts from a fear of dissolution, which points to tradition as a moderator of the possibilities of reason. Institutional learning is based on an evolutionary epistemology. However, the mechanistic vision could not be overcome with an individualist perspective since institutions are not only restrictions to individual action but rather they are the world shared by all men. Since the Scottish Enlightenment, an attempt has been made to establish these principles of non-individual change, first following Adam Smith's theory, who supposes that it is collective innovation and development, not the individual invention of great geniuses, which encourage the evolution of institutions. Classical economists, based on Smith's theory, were able to articulate a criticism on the conservative movement who defended "benevolent slavery." However, classical economists who consider invention as the key to development, such as Jean Baptiste Say or Jeremy Bentham, made their approach from the utilitarian and atomistic vision of human being—"methodological individualism"—which does not solve the problem of institutional change and common knowledge. John Rae, however, managed to introduce invention as a key element of technological and institutional change, on which economic development and the increase in human capabilities depend. This implies a new rethinking of "freedom in context." This idea of expansion of capacities is present in the historicists and the American institutionalism, and has entered into the recent developments hand in hand with Institutionalism Political Economy, with a broader vision of institutions and a more systematic explanation of change that rejects the concept of equilibrium in favour of the process.

Besides, classical economics suggests that the relationship between savers and investors can lead to an excessive financialization of the economy, subjecting the economy to uncertainty. From the Scottish Enlightenment, we see that the imbalance of power can lead to social imbalance and a collapse of public credit. In this sense, the proposals of Collier (2019),

Mazzucato (2019), and Mayer (2018) attribute the generation of innovations to a collective process and lead to a rethinking of governance problems where we need to reinforce justice and social inclusion. Social value is not the same with societal value and the ownership of companies. Development and growth are collective processes and natural justice in the retribution is basic to create the greatest incentive for innovation and creativity. In short, dynamism and innovation are subject to a general principle of social change, whose basis continues to be social responsibility, dignity, and indignation.

References

Aghion, P., & Howitt, P. (1997). *Endogenous Growth Theory*. MIT Press.

Barbon, N. (1696). *A Discourse Concerning Coining the New Money Lighter, in Answer to Mr. Locke's Considerations About Raising the Value of Money*. Richard Chiswell.

Barro, R. (1997). *The Determinants of Economic Growth: A Cross-Country Empirical Study*. MIT Press.

Benchimol, P. S. (2019). Innovation and National State in the History of Economic Thought: Marx, Schumpeter and Neo-Schumpeterians in Retrospective. *Iberian Journal of the History of Economic Thought, 6*(2), 103–114.

Bentham, J. (1787). *Defence of Usury: Shewing the Impolicy of the Present Legal Restraints on the Terms of Pecuniary Bargains. In a Series of Letters to a Friend. To Which Is Added, a Letter to Adam Smith, Esq; ll. d. on the Discouragements Opposed by the Above Restraints to the Progress of Inventive Industry*. Printed for T. Payne, and Son.

Berdell, J. F. (1996). Innovation and Trade: David Hume and the Case for Freer Trade. *History of Political Economy, 28*(1), 107–126.

Berg, M. (1994). *The Age of Manufactures, 1700–1820: Industry, Innovation, and Work in Britain* (2nd ed.). Routledge.

Berry, C. L. (1997). *Social Theory of the Scottish Enlightenment*. Edinburgh University Press.

Boyer, R. (1988). Technical Change and the Theory of Regulation. In G. Dosi, C. Freeman, R. Nelson, G. Silverberg, & L. Soete (Eds.), *Technical Change and Economic Theory*. Pinter Publishers.

Brewer, A. (1991). Economic Growth and Technical Change: John Rae's Critique of Adam Smith. *History of Political Economy, 23*(1), 1–11.

Cardoso, J. L., & Psalidopoulos, M. (Eds.). (2016). *The German Historical School and European Economic Thought*. Routledge.

Chang, H. J., & Evans, P. (2005). The Role of Institutions in Economic Change. In G. Dymski & S. de Paula (Eds.), *Reimagining Growth: Towards a Renewal of Development Theory*. Zed Books.

Child, J. (1689). *A Discourse Concerning Trade and that in Particular of the East-Indies*. Printed and sold by Andrew Sowle, 2.

Coccia, M. (2017). The Origins of the Economics of Innovation: John Rae (1824). *CocciaLab Working Paper* 2017 – No. 17. Available at SSRN: https://ssrn.com/abstract=2966955 or https://doi.org/10.2139/ssrn.2966955

Cohen, M. (1960). Berlin and the Liberal Tradition. *The Philosophical Quarterly, 10*(40), 216–227. https://doi.org/10.2307/2216936

Collier, P. (2019). *El futuro del capitalismo. Cómo afrontar las nuevas ansiedades*. Debate.

Courvisanos, J. (2012). *Cycles, Crises and Innovation: Path to Sustainable Development – A Kaleckian-Schumpeterian Synthesis*. Edward Elgar.

Delgado, A. (2015). *La conciencia de lo común frente a la falsa dicotomía estado-mercado. Análisis de la perspectiva de Elinor Ostrom (1933–2012)*, Tesis doctoral: Universidad Complutense de Madrid.

Dolfsma, W., & Seo, D. (2013). Government Policy and Technological Innovation – A Suggested Typology. *Technovation, 33*(6–7), 173–179.

Dube, A. (1991). *The Theme of Acquisitiveness in Bentham's Political Thought*. Garland Publishing.

Elliot, J. S. (1980). Marx and Schumpeter on Capitalism's Creative Destruction. *Quarterly Journal of Economics, 94*, 45–68.

Espinosa, M. T., Carvajal-Ordoñez, V. F. M., & Pesantez, J. C. (2021). Teoría evolucionista, revolución tecnológica y paradigma tecno-económico: una mirada a la economía de la innovación. *Revista Dilemas Contemporáneos: Educación, Política y Valores*, no. 2.

Evans, P. (2004). Development as Institutional Change: The Pitfalls of Monocropping and Potentials of Deliberation. *Studies in Comparative International Development, 38*(4), 30–52.

Evans, P. (2005). The Challenges of the 'Institutional Turn': New Interdisciplinary Opportunities in Development Theory. In V. Nee & R. Swedberg (Eds.), *The Economic Sociology of Capitalism*. Princeton University Press.

Galindo, M. A. (2008). La innovación y el crecimiento económico una perspectiva histórica. *Economía industrial, 368*, 17–25.

Gallego, J. (2003). El cambio tecnológico y la economía neoclásica. *Dyna, 70*(138), 67–68.

García Leonard, Y., & Sorhegui, R. A. (2018). La innovación en el pensamiento económico. Un debate abierto. *ECOCIENCIA, 5*, 1.

García Quero, F., & López Castellano, F. (2016). La economía política institucional: balance y perspectivas. *Iberian Journal of the History of Economic Thought, 3*(2), 188–200. https://doi.org/10.5209/IJHE.54625

Gauthier, D. (1979). David Hume, Contractarian. *The Philosophical Review, 88*, 3–38.

Ghazinoory, S., Narimani, M., & Tatina, S. (2017). Neoclassical Versus Evolutionary Economics in Developing Countries: Convergence of Policy Implications. *Journal of Evolutionary Economics, 27*, 555–583. https://doi.org/10.1007/s00191-017-0490-z

Gill, M. (2000). Hume's Progressive View of Human Nature. *Hume Studies, 26*(1), 87–108.

Grandstrand, O. (1994). Economics of Technology, North-Holland.

Griswold, C., Jr. (1999). *Adam Smith and the Virtues of Enlightenment*. Cambridge University Press.

Guia, J., Prats, L., & Comas, J. (2009). Innovación como cambio institucional: una aproximación desde las teorías de la complejidad. *Investigaciones Europeas de Direccion y Economia de la Empresa, 15*(2), 93–104.

Hagemann, H. (2015). Capitalist Development, Innovations, Business Cycles and Unemployment: Joseph Alois Schumpeter and Emil Hans Lederer. *Journal of Evolutionary Economics, 25*, 117–131. https://doi.org/10.1007/s00191-014-0358-4

Hamouda, C., & Omar Lee, D. M. (2005). *The Economics of John Rae. Routledge Studies in the History of Economics*. Routledge.

Hodgson, G. M. (1993). *Economics and Evolution*. Policy Press.

Hodgson, G. M. (2000). *Evolution and Institutions: On Evolutionary Economics and the Evolution of Economics*. Edward Elgar.

Hodgson, G. M. (2004). Darwinism, Causality and the Social. *Journal of Economic Methodology 11:2, 175–194*, (June).

Hoff, K., & Stiglitz, J. (2001). Modern Economic Theory and Development. In G. Meier & J. Stiglitz (Eds.), *Frontiers of Development Economics*. Oxford University Press.

Hühn, M. P. (2018). Responsible Innovation: A Smithian Perspective. *Philosophy of Management, 17*, 41–57. https://doi.org/10.1007/s40926-017-0057-

Hume, D. (1964a). *The Philosophical Works, Vol. II*. Scientia Verlag.

Hume, D. (1964b). *The Philosophical Works. Essays Moral, Political and Literary, Vol. I*. Scientia Verlag Aalen.

Hume, D. (1964c). *The Philosophical Works. Essays Moral, Political and Literary, Vol. II*. Scientia Verlag Aalen.

Jimenez-Barrera, Y. (2018). Aproximación crítica a las principales teorías sobre el cambio tecnológico. *Revista Problemas del Desarrollo*, 171–191.

Katz, C. (1997). Discusiones Marxistas sobre tecnología, Teoría. *Razón y Revolución*, n. 3.

Khan, M. S. (1954). Adam Smith's Theory of Economic Development (in Relation to Underdeveloped Economies). *Indian Journal of Economics, 34*, 337–342.

Kline, S. J., & Rosenberg, N. (1986). An Overview of Innovation. In R. Landau & N. Rosenberg (Eds.), *The Positive Sum Strategy: Harnessing Technology for Economic Growth* (pp. 275–304). National Academy Press.

Klosterman, M. (2016). Mills and Veblen: An Institutional Analysis. *University Honors Theses*. Paper 236. https://doi.org/10.15760/honors.237

Lazonick, W. (1991). *Business Organization and the Myth of the Market Economy*. University Press.

Lazonick, W. (2006). *"Corporate Governance, Innovate Enterprise, and Economic Development", WIDER Research Paper 2006-71*. Helsinki.

Lazonick, W. (2011). The Innovative Enterprise and the Developmental State: Toward an Economics of "Organizational Success". *The Academic-Industry Research Network* (www.theAIRnet.org) and University of Massachusetts Revised April 2011 Paper Prepared for: Institute for New Economic Thinking Annual 2011 conference Crisis and Renewal: International Political Economy at the Crossroads Mount Washington Hotel Bretton Woods, NH April 8–11, 2011.

Levy, D. M. (2001). *How the Dismal Science Got Its Name: Classical Economics & the Ur-Text of Racial Politics*. University of Michigan Press.

Lewis, O., & Steinmo, S. (2011). Tomemos en serio la evolución: Análisis institucional y teoría evolutiva. *Revista de Economía Institucional, 13*(24), 111–151.

Lu, Q. (2000). *China's Leap into the Information Age: Innovation and Organization in the Computer Industry*. Oxford University Press.

Lucas, R. E. (1988). On the Mechanics of Economic Development. *Journal of Monetary Economics, 22*, 3–42.

Massie, J. (1750). *An Essay on the Governing Causes of the Natural Rate of Interest; Wherein the Sentiments of Sir William Petty and Mr. Locke, on That Head, Are Considered*. John Dawson.

Mayer, C. (2018). *Prosperity. Better Business Makes the Greater Good*. Oxford University Press.

Mazzucato, M. (2019). *El valor de las cosas. Quién produce y quién gana en la economía global*. Taurus.

McCloskey, D. N. (2017). Neo-Institutionalism is Not Yet a Scientific Success: A Reply to Barry Weingast. *Scandinavian Economic History Review, 65*, 116–123.

McCloskey, D. N. (2018). Why Liberalism's Critics Fail. *Modern Age, 2018*, 13–21.

McCloskey, D. N. (2020). Fukuyama Was Correct: Liberalism Is the Telos of History. *Journal of Contextual Economics, 139*(2–4), 285–304.

McCloskey, D. N. (2021). The Statist Neo-Institutionalism of Acemoglu and Robinson. *Rivista di storia economica, Società editrice il Mulino, 2*, 151–189.

McCloskey, D. N., & Silvestri, P. (2021). Beyond Behaviorism, Positivism, and Neo-institutionalism in Economics: A Conversation with Deirdre Nansen McCloskey. *Journal of Institutional Economics, 17*(5), 717–728.

McRae, R. (1951). Hume as a Political Philosopher. *Journal of the History of Ideas, 12*(2), 285–290.

Mejía, A. G. (2017). The Concept of Technology in the History of Economic Thought. From the Classics to Schumpeter, Evolutionism and Today. *Libre Empresa, 14*(2), 199–214.

Mokyr, J., Vickers, C., & Ziebarth, L. (2015). The History of Technological Anxiety and the Future of Economic Growth: Is This Time Different? *Journal of Economic Perspectives, 29*(3), 31–50.

Moreau, F. (2004). The Role of the State in Evolutionary Economics. *Cambridge Journal of Economics, 28*, 847–874.

Nelson, R. R., & Winter, S. G. (1982). *An Evolutionary Theory of Economic Change*. Harvard University Press.

Nelson, R. R., & Winter, S. G. (2002). Evolutionary Theorizing in Economies. *Journal of Economic Perspectives, 16*(2, Spring), 23–46.

Nissan, E., Galindo, M. A., & Picazo, M. T. M. (2012). Innovation, Progress, Entrepreneurship and Cultural Aspects. *International Entrepreneurship and Management Journal, 8*, 411–420. https://doi.org/10.1007/s11365-012-0229-0

North, D. (1691). In J. H. Hollander (Ed.), *Discourses Upon Trade*.

North, D. (1990). *Institutions, Institutional Change and Economic Performance*. Cambridge University Press.

Norton, D. F. (1993). Hume, Human Nature, and the Foundations of Morality. In D. F. Norton (Ed.), *The Cambridge Companion to Hume* (pp. 148–182). Cambridge University Press.

Olaya, A. (2008). Economía de la innovación y del cambio tecnológico: Una aproximación teorica desde el pensamiento shumpetariano. *Revista de Ciencias Estrategicas, 16*(20), 237–246.

Ortega y Gasset, J. (1914). *Meditaciones del Quijote: meditación preliminar, meditación primera*. Ser. Publicaciones de la Residencia de estudiantes. serie ii, 1.

Parayil, G. (1991). Schumpeter on Invention, Innovation and Technological Change. *Journal of the History of Economic Thought, 13*(1), 78–89.

Petty, W. (1690). *Political Arithmetick, Or, a Discourse Concerning the Extent and Value of Lands, People, Buildings*…. Printed for Robert Clavel and Hen. Mortlock.

Phillipson, N. (1979). Hume as Moralist: A Social Historian's Perspective. In S. C. Brown (Ed.), *Philosophers of the Enlightenment* (pp. 140–161). The Harvester Press.

Quevedo, L. F. (2019). Aproximación crítica a la teoría económica propuesta por Schumpeter. *Revista Investigación y Negocios, 12*(20).

Ricardo, D. ([1821] 2010). *On the Principles of Political Economy and Taxation*. Liberty Fund.

Ricoy, C. J. (2005). La teoría del crecimiento económico de Adam Smith. *Economía y Desarrollo, 138*(1), 11–47.

Roll, E. (1954). *A History of Economic Thought*. Faber and Faber.

Romer, P. M. (1990). Endogenous Technological Change. *Journal of Political Economy, 98*, 171–102.

Romer, P. M. (1994). The Origins of Endogenous Growth. *Journal of Economics Perspectives., 8*(1), 3–22.

Rosenberg, N. (1971). *The Economics of Technological Change*. England, ed. Penguin Books.

Rotenstreich, N. (1971). The Idea of Historical Progress and Its Assumptions. *History and Theory, 10*(2), 197–221.

Rotwein, E. (Ed.). (1970). *David Hume. Writings on Economics*. The University of Wisconsin Press.

Salter, A. J., & McKelvey, M. (2016). Evolutionary Analysis of Innovation and Entrepreneurship: Sidney G. Winter – Recipient of the 2015 Global Award for Entrepreneurship Research. *Small Business Economics, 47*, 1–14. https://doi.org/10.1007/s11187-016-9702-4

Sawyer, M. (2020). The Past, Present and Future of Evolutionary Macroeconomics. *Review of Evolutionary Political Economy, 1*, 37–54. https://doi.org/10.1007/s43253-020-00003-6

Schabas, M., & Wennerlind, C. (2020). *A Philosopher's Economist: Hume and the Rise of Capitalism*. University of Chicago Press.

Schumpeter, J. A. (1934 [2008]. *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest and the Business Cycle*. Transaction Publishers [original 1911].

Schumpeter, J. A. (2010). *Capitalism, Socialism and Democracy*. Routledge.

Sebastián, C. (2022). *El capitalismo del siglo XXI. Mayor desigualdad, menor dinamismo*. Galaxia Gutemberg.

Silva, S. T. (2009). On Evolutionary Technological Change and Economic Growth: Lakatos as a Starting Point for Appraisal. *Journal of Evolutionary Economics, 19*, 111–135. https://doi.org/10.1007/s00191-008-0115-7

Smith, A. (1978). Lectures on Jurisprudence. In R. L. Meek, D. D. Raphael, & P. G. Stein (Eds.), *The Glasgow Edition of the Works and Correspondence of Adam Smith* (Vol. V). Oxford University Press. (LJ (A) de 1762–3; LJ (B) de 1766).

Smith, A. (1988). *Investigación sobre la Naturaleza y Causas de la Riqueza de las Naciones*, Edición a cargo de R. H. Campbell y A. S. Skinner, W. B. Todd, editor literario, Vol 1 y 2. Barcelona: Oikos-Tau [1776].

Solow, R. (1957). Technical Change and the Aggregate Production Function. *Review of Economics and Statistics, 39*, 312–320.

Stark, W. (1952). *Jeremy Bentham's Economic Writings. Critical Edition Based in his printed Works and unprinted Manuscripts, Vol. 2*. Published for The Royal Economic Society by George Allen & Unwin LTD.

Steuart, J. (1767). *An Inquiry into the Principles of Political Oeconomy: Being an Essay on the Science of Domestic Policy in Free Nations, in Which Are Particularly Considered Population, Agriculture, Trade, Industry, Money, Coin, Interest, Circulation, Banks, Exchange, Public Credit, and Taxes*, A. Millar, and T. Cadell.

Trincado, E. (2004). Equity, Utility and Transaction Costs in Adam Smith's Theory. *Storia del Pensiero Económico, 1*, 33–51.
Trincado, E. (2005). Utility, Money and Transaction Costs: Authoritarian vs Libertarian Monetary Policies. *History of Economic Ideas, XIII*(1), 57–77.
Trincado, E. (2009). Teorías del valor y la función empresarial. *Investigaciones de Historia Económica, 5*(14), 11–38. https://doi.org/10.1016/S1698-6989(09)70101-8
Trincado, E. (2014). Socialistas utópicos, Karl Marx y los historicistas. *Historia del pensamiento económico*, UCAV, Ávila, 131–178.
Trincado, E. (2019). *The Birth of Economic Rhetoric. Communication, Arts and Economic Stimulus in David Hume and Adam Smith.* Palgrave Macmillan.
Trincado, E. (2023). La innovación en la economía británica en el siglo XVIII: Hume, Smith, Bentham. *Cuadernos de Estudios del Siglo XVIII,* (33), 45–75. https://doi.org/10.17811/cesxviii.33.2023.45-75
Turgot, A. R. J. (1766). *Reflections on the Formation and the Distribution of Riches.* Par. M. Y.
Veblen, T. (1899). *The Theory of the Leisure Class: An Economic Study of Institutions.* Macmillan.
Veblen, T. (1904). *The Theory of Business Enterprise*. Martino Fine Books.
Vercellone, C. (2007). From Formal Subsumption to General Intellect: Elements for a Marxist Reading of the Thesis of Cognitive Capitalism. *Historical Materialism, 15*(1), 13–36. https://doi.org/10.1163/156920607X171681
Yoguel, G., Barletta, F., & Pereira, M. (2013). De Schumpeter a los postschumpeterianos: viejas y nuevas dimensiones analíticas. *Revista Problemas del Desarrollo, 174*(44), 35–59.

CHAPTER 4

The Pre-Schumpeterian Concept of Innovation: Friedrich List and Two Pioneer Contemporaries

Pablo José Martínez Rojo

When time shall have revealed the future progress of our race, those laws which are now obscurely indicated, will then become distinctly apparent; and it may possibly be found that the dominion of mind over the material world advances with an ever-accelerating force.
—Babbage (1832)

4.1 Preface

At the dawning of the First Industrial Revolution, Adam Smith, in his reference work *The Wealth of Nations* (1776), defined three production improvements, which resulted in increases in productivity that were possible through *specialization*: worker dexterity, time savings, and

P. J. M. Rojo (✉)
Complutense University of Madrid, Madrid, Spain
e-mail: pabloj07@ucm.es

E. Trincado Aznar, F. López Castellano (eds.), *Science, Technology and Innovation in the History of Economic Thought*, Palgrave Studies in the History of Economic Thought,
https://doi.org/10.1007/978-3-031-40139-8_4

mechanization. According to the last, incremental specialization through division of labour becomes easier and more consistent as new techniques and machineries based on new technologies are introduced in the production processes. This leads to a process of accumulation of knowledge and capabilities which results in the foundation for innovation and long-term growth.

This way, his emphasis on the importance of specialization may be seen as a very early precedent to the theories of technological progress and innovation, which suggest that this specialization through the division of labour and the accumulation of knowledge are significant factors in the development of new technologies and the basis of economic progress.

Over the two and a half centuries since then, the economy of innovation and technological change has become one of the most relevant fields of study of economics, especially in recent years. Since the late 1980s of the twentieth century, much attention has been devoted to it, especially around the concept of *Innovation Systems* and, more specifically, *National Innovation Systems* and its later evolutions. This concept, although limited in space, and even despite the growing trend of globalization over the last few decades, has remained robust and has even specified its scope, including both geographical and sector-specific fields of study.

As the most remote precedent, as Godin (2009) notes, Freeman had been advocating for systems analysis since the early 1960s:

> There is no reason why these methodologies (operations research, systems analysis, and technology forecasting), developed for military purposes but already successfully used in fields such as communication and energy, cannot be adapted to the needs of civilian industrial technology. (OECD, 1963)

According to OECD, in one of their seminal publications in this field (1999), it is possible to affirm that the conceptual evolution of the term follows the logical time trajectory defined by several schools of thought, which converge in a better understanding of innovation and technological change processes. These schools unite the theoretical basis of the systemic analysis of innovation and technological change, which leads to the definition of National Innovation Systems.

- Institutional Economics focuses on the organization of institutions, formal and informal, and how they are interconnected and affect innovation processes (North, 1990). Elements like market develop-

ment and firms' incentives, laws, regulations, and policies or demographic characteristics, as well as other less tangible, like culture, are key institutional elements to understand the relation between institutions and innovation (He & Tian, 2020).

- Evolutionary Economics is in line with the paradigm of *organic* processes. This school studies how agents exploit resources and existing knowledge to produce new one that leads to innovation and economic development. Therefore, the resultant process of accumulation of knowledge is *path-dependent* and it is determined by previously defined trajectories throughout time, usually during long periods of time.
- Finally, the New Growth Theory focuses on the need to invest in human capital to be able to generate and accumulate knowledge, which also leads to increasing economic value and innovation.

As the most accurate definition to our purposes, according to Metcalfe, National Innovation Systems are defined as follows:

> …the set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies, and which provide the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technologies. (Metcalfe, 1995)

The concept of National Innovation System (Freeman, 1991; Lundvall, 1992; Nelson, 1993) may be also seen as a research model that helps to explain and understand the level of development of a nation in general terms, the state of its production systems, as well as their evolution over time. The concept has evolved into more concise spatial (regional, local) and sectorial ranges, considering specifications which are closer to the reality and necessities of the innovation process.

Hence, National Innovation Systems have been a subject of intense academic debate for the last decades, and the concept continues to evolve as scholars and policymakers seek to understand the factors that promote innovation and economic growth across nations, regions, and sectors.

In some few pages, this chapter aims to recover and spotlight the main ideas of some thinkers of the economic science in the origins of the

nineteenth century who, in the field of what we know today as *economics of innovation*, set a relevant academic precedent that has not been recognized.

It is not unreasonable to say that, on not infrequent occasions, the classic economists are not what they seem to be, even sometimes the opposite; more or less voluntarily, their postulates are often the seed of later ones, not always close to the field they sought to dominate, but which, in their seminal character, are the foundation of diverse ones.

Thus, these are the basis for the first references to the concept of National Innovation Systems and their set of elements and interactions, also including the figure of the entrepreneur, who is the lead actor. These all are conceived as a necessary environment to facilitate innovation, technological change, and long-term economic growth.

4.2 Friedrich List (1789–1846)

Friedrich List must be considered as a relevant figure in the history of economic thought, especially the European, for his definition of a new model of political economy and national scope which has not been postulated so far. This is the foundation of later theories, schools of thought, such as the German Historicist school, as well as economic models and policies of great historical impact, such as those implemented in Germany since the middle of nineteenth century.

Friedrich List was born in 1789, in Reutlingen, Germany. He came from a family of merchants, and after completing his education, he worked in the family business. List was interested in economics and politics and became involved in the nationalist movement of his time, which aimed to unite the fragmented German states and create a powerful united nation. In the early nineteenth century, List moved to the United States, where he became interested in Alexander Hamilton's work and the American economic model of protectionism and the use of tariffs to protect domestic industries. He saw protectionism as a means to promote economic development and industrialization in Germany, which he believed was necessary for the country's political and military strength.

List became a prominent advocate of protectionism and economic nationalism and his ideas influenced economic policies in several European countries, including Germany, Italy, and Russia. He wrote several influential books, highlighting the *Outlines of American Political Economy* (1827), in which he argued for a strong role of the state in promoting

economic development, and his main work *The National System of Political Economy* (1856).

His theory is characterized by advocating for the protection of what he called *nascent industries* and by his critical view of Adam Smith's open and free trade approach, against his consideration that this openness benefited both developed nations, such as England, and laggards such as Germany.

Friedrich List referred to nascent industries as emerging industries that are in the early stages of development. These industries are characterized by a lack of established infrastructure, knowledge, and experience, which can make it difficult for them to compete with established industries in other countries. List believed that nascent industries were essential for future economic growth and development of nations. He argued that protecting and promoting them through government policies was necessary to help them develop and compete with established industries from other countries, given that nascent industries needed special protection as they faced significant challenges in their early stages, such as limited access to capital, insufficient infrastructure, low knowledge accumulation, and lack of experience.

In this regard, List emphasized the importance of the development of national institutions that favoured the accumulation of knowledge, that he specifically called *mental capital*[1] and, with it, economic growth and development, as opposed to the classic *laissez-faire* and the Smithian *invisible hand*.

His primary purpose was to create the conditions for Germany to close the gap and, subsequently, surpass England which, at that time, was the undisputed leading industrial nation. Thus, for the least developed countries, as Germany was in relation to England, he proposed a model based on the protection of national industries, most of them in a very incipient stage in order to promote their growth; as well as on various policies designed to boost and accelerate Germany's industrialization and economic growth in a context of comparative backwardness.

In this way, his theoretical proposal is summarized in the idea that free trade should be delayed until involved countries had achieved a more equal level of development and industrialization in order to compete

[1] According to List, mental capital refers to the skills, knowledge, and abilities that individuals possess and can use to contribute to the growth and prosperity of a country. This includes education, training, experience, and the ability to learn and adapt to new technologies and processes.

under similar conditions. This proposal was quickly adopted in terms of practical policy in much of Europe, as well as in the United States and other Western countries (Reinert, 2004).

In direct relation to the concept of National Innovation System, his postulates are rescued by Freeman (1995). Similarly, Lundvall (1992) points out that the idea of the National Innovation System dates back, at least, to the conception of Friedrich List in his work of 1841 *The National System of Political Economy*.

List, in his work, analysed more than a century in advance some of the characteristics of the contemporary National Innovation System, highlighting:

- The great importance of education and training institutions, particularly to generate knowledge in the scientific and technical fields,
- the need for knowledge and adaptation of imported technology,
- based on the two previous, the great importance of knowledge accumulation, and
- the promotion of national strategic industries according to internal strengths and nascent industries.

Around this, he placed great emphasis on the role of the state in the coordination and application of policies to favour industry and the economy in the long term, with a significant part of these focused on attracting and learning about new technologies and their application. This learning process was key in his proposal, and it is thanks to List's defence, as well as the Prussian reform of institutional system already initiated in previous decades, that Germany developed one of the best scientific–technical education and training systems in the world.

Not only did List anticipate these essential features of recent work on National Innovation Systems but also argued the interrelationship of foreign technology imports and domestic technological developments. So, nations should not only assume the technical achievements of more advanced ones but increase and improve them with their own efforts. In essence, List emphasized the vital significance of strategic industries by combining technology imports with local activities and implementing proactive interventionist policies to promote technological and knowledge accumulation.

His proposal finds some parallel in the Schumpeter–Arrow debate on monopoly in innovation activities. *Ex ante*, it must be a priority to

safeguard the incentives of companies to carry out research activities, which are better guaranteed under a situation of protectionism. *Ex post*, on the contrary, it is desirable that, once a certain degree of development has been achieved, external competition in more equal conditions and capabilities is viable.

Thus, in List's view, protectionism was necessary to preserve local industries from foreign competition, which he believed would stifle innovation and hinder economic development. He argued that tariffs could be used to raise the prices of foreign imports, making them less competitive and encouraging domestic production, and considered that subsidies may be used to support local industries and promote innovation among them.

List believed that a strong National Innovation System required a coordinated effort between the state, the private sector, and academia. He argued that the state had a key role to play in creating an environment that encouraged innovation by providing funding for research and development, protecting intellectual property rights, and promoting the diffusion of new technologies and ideas.

This national system promoted by List must be considered one of the main factors why Germany surpassed England in the second half of the nineteenth century, as well as the basis for the higher skills and higher productivity of the German labour force in many industries for decades (Prais & Daly, 1981). List's *Nationalökonomik*[2] also paved the way for the German Historical School, which, although did not deviate from the foundations of classical political economy in its early stages, helped to reshape its implications in terms of national identity.

In summary, List argued that a nation's economic success depended not only on its own resources and labour but also on its ability to innovate and compete globally. His key for innovation was a strong national system, which he defined as the set of institutions, policies, and relationships that support the development and diffusion of new technologies and ideas. According to List, and unlike Smith, a National Innovation System must be created and supported through state intervention and protectionist policies, such as tariffs and subsidies, that encouraged local production and innovation, which would lead to the development of a strong

[2] "Nationalökonomik" is a German term that refers to the study of economics, often translated as "economics" or "political economy." It is a social science that examines how societies allocate their scarce resources to satisfy their unlimited wants and needs.

domestic industry that may compete with foreign producers and drive economic growth.

Friedrich List's original ideas about National Innovation Systems and the role of the state in fostering innovation continue to inform debates about economic policy today. While his views on protectionism are somehow controversial, his emphasis on the importance of innovation and the need for a coordinated effort between the state, the private sector, and academic institutions has become widely accepted.

4.3 Contemporaries: Charles Babbage and J. H. von Thünen

List was not the only economist thinking on technological change and its impact in the early nineteenth century. He is a contemporary of, even precedented by some others of lesser historical and academic recognition in this field, not without deserving it, though some of whose theories are noteworthy.

Johann Heinrich von Thünen (1783–1850), in addition to defining the first aspects of the economy of location, that has subsequently had multiple applications as a seminal contribution to the economic theory, is also a primary reference in the definition of the figure of the entrepreneur, much later adopted by Knight (1921) and Schumpeter almost a century later.

On the other hand, Charles Babbage (1791–1871) made an important and very advanced contribution to the relevance of some of the key elements of National Innovation Systems. He was, in fact, a precursor to List by more than a decade. *On the Economy of Machinery and Manufacture,* written in 1832, explored the impact of technological change on the economy, with a particular focus on the division of labour, the development of machinery, and their implications for manufacturing production. Babbage argued that the introduction of machinery could lead to greater efficiency and productivity in manufacturing, but also highlighted the potential negative effects on workers and the need for social and economic policies to address these issues. Overall, the book is a seminal work in the field of technology and economics and remains influential in very contemporary discussions of automation and its impact on the labour market.

4.4 Johann Heinrich von Thünen (1783–1850)

Schumpeter (1954) said that von Thünen was an economist ahead of his time. Thanks to his analytical abilities, fundamentally based on observation, as well as his quantitative analysis capacities, he understood, like few other economists in the history of this science, the correlation between facts and theory, which is a key element of scientific research.

Johann Heinrich von Thünen was a German economist and agriculturalist born in 1783 in Mecklenburg, Germany. He came from a family of landowners and grew up on a farm, where he developed a deep interest in agriculture and the economy of rural areas. In addition to his work in agricultural economics, von Thünen was also involved in politics and public service. He served in the Mecklenburg state parliament and was appointed as an advisor to the Ministry of the Interior. He also worked to promote land reform and the rights of small farmers.

von Thünen, who anticipated the marginalist revolution, did not achieve success in his lifetime. His thinking and analytical developments were too personal and biased, as well as somewhat unrefined and eccentric, coming from a farmer who physically and intellectually lived far from academic circles. However, he was a precursor in various areas of economic science; at least, in the study of econometrics, the marginalist theory and, especially, in spatial studies. Although he was forgotten in his time and his contribution was not recognized until many decades after, von Thünen is today considered a great economist for his anticipation of very relevant theoretical concepts such as economic rent or the theory of wages based on marginal productivity. Thereby, some of his statements were the basis of much later economic postulates.

Paul Samuelson, in his article commemorating the bicentenary of his birth in 1983, states that von Thünen "not only created marginalism and managerial economics, but also elaborated one of the first models of general equilibrium and did so in terms of realistic econometric parameters."

More specifically, Samuelson (1983) states that von Thünen's model has elements of all the following later theories and economic systems throughout history:

1. The Ricardo-Torrens theory of comparative advantage
2. The Malthus-West-Ricardo theory of rent
3. The Hecksher-Ohlin and Stolper–Samuelson theory of factors and-goods pricing

4. The Marx-Dimitriev–Leontief–Sraffa system of input–output

Fujita (2012) also indicates that von Thünen is also a precursor of three other theories:

5. The Marshall–Weber theory of industrial agglomeration
6. The Christaller–Lösch theory of central place system
7. The recent development of new economic geography

To the previous, we incorporate an eighth theory based on our approach that, although crosswise, relate von Thünen's model to the economy of innovation:

8. The Freeman-Lundvall-Nelson theory of National Systems of Innovation

Either way, previously to any theoretical development, it must be said that the circumstances of the time when von Thünen, as well as Friedrich List, postulated their theories are not irrelevant, as Germany was seeing a great institutional advance that sowed the foundations of the subsequent and intense economic growth.

> The slow pace of development was reflected in the fragmentation of the country: as of 1789 there existed 314 independent territories and more than 1400 imperial knighthoods. Many of the territories had their own laws, currency, weights and measures, taxes, and custom tolls. The way to unification was cumbersome. The Napoleonic wars and the Congress of Vienna reduced the number of territories to 39 by the year 1815. In 1834 Prussia with some other German states formed a customs union to which most other German states acceded until 1867. Political union was eventually achieved in 1871. (Nelson, 1993, p. 116)

At the end of the Napoleonic Wars (1803–1815), most of the German states had abolished serfdom and made deep improvements in the administration model and education system, thus, removing ancient obstacles to economic growth.

Driven by the creation of the free trade area of *Deutscher Zollverein*,[3] in 1834, and the first developments of transport infrastructures, among other developments, during this pre-industrial period there was a significant institutional and social transformation that fulfilled most of the necessary conditions for the German economic take-off.

4.5 Innovation in von Thünen's Thought

von Thünen, due to his most renowned contribution, is the father of the theory of classical location. However, its relationship with innovation is not misconceived, at least in relation with some of the key elements that are fundamental to the economics of innovation as it has evolved in the last few decades of academic relevance.

As noted by Fujita (2012), von Thünen achieved two pioneering theoretical advancements; one is the theory of land use and rent in the agricultural hinterland, and the other is the lesser-known work on the mechanics of industrial agglomeration and the formation of urban centres.

His interest is twofold in the reflection that concerns us, for being a precursor to the theory of classical location, specially related to his pioneer *agglomeration* approach, and for his definition of the figure of the entrepreneur as a key actor, and factor, of innovation and technological change. His most well-known contribution is the first one; the question about what the role of location is in shaping innovation and entrepreneurship can find an initial answer in his main work *The Isolated State*, published in1826.

It must be mentioned, in our previous correlation between von Thünen's ideas and those of much later scholars of National Innovation Systems, that the first theorists on economics and technological change, such as Schumpeter, did not place much value on the spatial aspect or its scope and implications. This way, while the Schumpeterian framework helps to focus on time, that is to say, those forces that determine the cyclical patterns of economic growth, it fails to address the spatial dimension that explains where innovation and technological change can take place

[3] The *Deutscher Zollverein* was a customs union formed in 1834 (replacing smaller previous customs unions) among many German states to create a free trade area and facilitate economic integration by eliminating customs barriers and establishing a uniform tariff policy. It played a crucial role in the economic unification of Germany and the development of the German economy in the nineteenth century.

and why it differs from one country to another, or within countries, from one region to another. This gap can be better closed by combining the Schumpeterian framework with the seminal spatial model defined by von Thünen.

In this manner, von Thünen's location theory and the innovation systems approach are two distinct frameworks that address different aspects of economic activity; however, there are some ways in which they can be correlated. The location theory is primarily concerned with explaining the spatial distribution of economic activities based on the availability of resources and transportation costs. This theory assumes that producers are rational actors who seek to minimize their costs and maximize their profits, and that they make decisions about where to locate their activities to be more productive based on these main considerations. In contrast, the Innovation Systems approach is concerned with the factors that influence the creation and diffusion of new technologies and innovations. This approach recognizes that innovation is a complex process that involves interactions among a wide range of actors and elements, including firms, universities, government agencies and policies, and other factors. So, the innovation systems approach emphasizes the importance of these interactions in driving innovation and economic growth.

It is possible to correlate von Thünen's location theory with innovation systems considering the role of proximity in facilitating innovation. The innovation systems approach assumes that proximity can facilitate the flow of knowledge and ideas among different actors, which can lead to the creation of new technologies and innovations. Similarly, von Thünen's location theory suggests that proximity to markets and transportation networks can reduce costs and facilitate economic activity.

This way, the distribution of economic activities across space can affect innovation systems by influencing the interaction and knowledge-sharing abilities of different actors. When firms cluster together in a particular industry or technology are able to generate a considerably higher amount of expertise and resources, which encourage collaboration and innovation within these firms. As a result, spatially located innovation systems may emerge, contributing to local, regional, and national economic growth.

The theoretical foundations of the importance of this spatial framework and the existence and importance of externalities were postulated by neoclassical economists such as Marshall (1890) and later revisited by the literature, among others, of the new growth theory (Romer, 1986). However, it was von Thünen (1966) who pioneered this interest and its

first theoretical conceptualization, being considered the author who initiated the theory of classical location.

To achieve this, he employed the construction of theoretical models to analyse and discuss the effect of different variables on various equilibria. These models, based mainly on his personal experience as a farmer, aimed to explain the location of agricultural activities. On the basis of his own interests, he attempted to define how a system should be configured and integrated to achieve the highest productivity of the land and best output results. Although his assumptions were quite restrictive, he nevertheless made a significant beginning in the analysis of location economics.

Later, his theory was disseminated and utilized both by geographers and economists from different schools. von Thünen dealt mainly with agricultural economics, but his theories served also as a precedent to later industrial location techniques. Beyond the agricultural issue, which was typical of his time and his own knowledge, his most important contribution lies in his insights into the location of economic activities, which consider productivity differences as a fundamental key. von Thünen also recognized that there is a complementarity between rural and urban systems, and that a sustainable agricultural economy could not exist without an urban system. In his discussion of the urban system, von Thünen highlighted the advantages of agglomeration in the location of industrial activities. As a result, he created the idea of *territorial structures.*

Based on his theory, the strengths and advantages of a specific spatial location are determined by the fact that this is able to generate potential externalities or *spillovers* towards the organizations located in it. At the same time, *agglomeration effects* are generated, being those able to facilitate the attraction and accumulation of production factors to this spatial location. This has a feedback effect that, subsequently, attract more capital and investments. Within this agglomeration effect, von Thünen considers the linkage or *association* between industries:

> ….Since it takes machines to produce machines, and these are themselves the product of many different factories and workshops, machinery is produced efficiently only in a place where factories and workshops are close enough together to help each other work in unison, i.e., in large towns. Economic theory has failed to adequately appreciate this factor. Yet it is this which explains why factories are generally found communally, why, even when in all other respects conditions appear suitable, those set up by themselves, in isolated places, so often come to grief. Technical innovations are

> continually increasing the complexity of machinery; and the more complicated the machines, the more the factor of association will enter into operation. (1966, p. 289)

These processes of association and accumulation leads to the geographical concentration of economic activity in growth poles, which, at the same time, gives rise to the generation of more externalities. This concept of agglomeration will be a precursor to the theorization of clusters based on Porter's studies, especially applied afterwards to the context of innovation in the systemic concept of this. Specifically, von Thünen remarks that the more sophisticated the technical innovations are, the more the factor of association is needed.

As underlined by Parr (2015), von Thünen's analysis anticipated the ideas of academics on regional and urban analysis. Consequently, although his study focused mainly on agriculture, later works investigated location in the secondary and tertiary sectors, as well as in the activity of innovation itself. Therefore, his postulates laid the basic foundations for subsequent theoretical contributions on the concentration of innovation, such as industrial districts (Becattini, 1987), the mentioned Porter's cluster theory (1990), or the National Innovation System approach itself.

Following von Thünen's location theory, it is possible to anticipate that an integrated innovation system is an interconnected and coordinated spatial network of entities which derives in a complex interaction of forces that involve production costs, value creation processes, and other market elements, resulting in a dynamic structure over time.

These complex interactions have been the focus of many researchers over a very long time, considering that innovative entrepreneurs locate where rent opportunities and knowledge accumulation are the highest, the spatial context being one of the key insights of the innovation process.

4.6 von Thünen and the Entrepreneur

Another of von Thünen's key contributions focuses on his description of the figure of the Entrepreneur. In relation to the previous location theory, entrepreneurs can be seen as the agents who identify and exploit market opportunities. von Thünen's location theory implies that entrepreneurs create economic value by locating their businesses in areas where they can access markets most efficiently; by doing so, they can reduce costs and increase profitability. In this manner, von Thünen's ideas on economic

rent and market location can be relevant to understanding the role of entrepreneurs in creating value through market access and location decisions.

On the other hand (Hérbert and link, 2006), von Thünen attended to the matter of the role of entrepreneurs in the economic activity, defining them as the agents who take risks and do it under uncertainty conditions. To understand the motivation of the entrepreneur, he considered a sort of concept of *opportunity costs* and their implication as an investment incentive and wondered what these incentives may be for the entrepreneurs to take risks.

> He who has enough means to pay to get some knowledge and education for public service has a choice to become either a civil servant or, if equally suited for both kinds of jobs, to become an industrial entrepreneur. If he takes the first job, he is guaranteed subsistence for life; if he chooses the latter, an unfortunate economic situation may take all his property, and then his fate becomes that of a worker for daily wages. Under such unequal expectations for the future what could motivate him to become an entrepreneur if the probability of gain were not much greater than that of loss? (von Thünen, 1960, p. 246)

In the words of Leigh (1946), von Thünen criticized Adam Smith and other contemporaries for "*lumping together as 'profit' the interest on invested capital and the profit of the entrepreneur.*" On the contrary, he made a distinction between the nature of capital investment and the entrepreneur investment, as well as the profit obtained from each. von Thünen defined the difference between the two elements of entrepreneurial income, the return to entrepreneurial risk and the return to genius and ingenuity, and according to this, determined what the different roles of capitalists and entrepreneurs are.

According to Hébert and Link (2006), what turns von Thünen's mention to entrepreneurs into a significant step in entrepreneurship theory is that he connected two different ideas, in order that, on the one hand, characterized the entrepreneur as the owner of risk (capital) and, on the other hand, as an innovator (ingenuity). It is, actually, the last which really characterizes the entrepreneur as such.

Though this difference may seem obvious now, it is to be noted that, even a century later, Schumpeter did not consider this distinction, narrowing the figure of entrepreneur as an innovator. Even so, in his theoretical

reflection, von Thünen also prematurely understood the concept of innovation itself, as the successful social and market application of inventions.

> Necessity is the mother of invention; and so the entrepreneur through his troubles will become an inventor and explorer in his field. So, as the invention of a new and useful machine rightly gets the surplus which its application provides in comparison with an older machine, and this surplus is the compensation for his invention, in the same way what the entrepreneur brings about by greater mental effort in comparison with the paid manager is compensation for his industry, diligence, and ingenuity. (von Thünen, 1960, p. 247)

von Thünen's contribution lies in his earliest characterization of entrepreneurial profits and their incentive and motivational role. He explicitly stated that entrepreneurial returns are not derived from capital, but rather from ingenuity and the tendency of the entrepreneur to face the risks that are derived from uncertainty. Therefore, he set the difference between management, investment, and entrepreneurship. In many ways, von Thünen's work anticipated both Knight's (1921) and Schumpeter's work almost a century in advance.

While von Thünen's location theory and the innovation systems approach address different aspects of economic activity, they can be correlated by recognizing the role of proximity in facilitating economic dynamism and innovation. Location theories, of which von Thünen was a precursor, emphasize the importance of geographic factors in the concentration of economic activities and the generation of externalities that can boost innovation. These theories provide insights into the spatial distribution of innovation and the advantages of clustering activities in specific regions.

On the other hand, von Thünen provided an early description of the nature of entrepreneurial profits and their inventive quality. In his characterization, he emphasized that this entrepreneurial return is not simply the return from invested capital, but also, the return from ingenuity, uncertainty and the risk undertaken. von Thünen's contribution was significant because it connected two distinct strands of entrepreneurial theory, one that characterized the entrepreneur as a risk-taker, and another that characterized the entrepreneur as an innovator.

4.7 Charles Babbage (1791–1871)

If it is our aim to talk about the origins of the conceptualization of innovation as a key element in economic science, as well as the foundation for the understanding of economic development and growth, Charles Babbage must be considered. Although less known, and even less cited in this field of study, his thought contributed to the economy of innovation and technological change, at least in its original conception, in a relevant manner.

His conception in relation to technological advances dates to the thirties of the nineteenth century, being considered as a relevant precursor. It will be, in fact, a pioneer influence on scholars studying the confluence between economics and technological development that followed.

Schumpeter (1954, p. 541) described Babbage's work as a "*remarkable performance of a remarkable man*" and recognized him in the same way as an economist. Likewise, Rosenberg (2000, p. 24) says of Babbage that "*lived a furtive, almost fugitive in the history of the literature of economics*," and that his work "*contains important contributions to economics which have received unduly short shrift*."

Babbage, born in 1791 in London, was a mathematician, inventor, and mechanical engineer who is best known for his contributions to the development of early computers. Babbage's fascination with machines and their potential for solving complex mathematical problems began in his youth, and led him to study mathematics at Trinity College, in Cambridge.

Because of that, he is possibly most cited for being the inventor of the so-called *analytical engine*, a mechanical general-purpose computer and a very original foundation and precedent of modern computing, making him widely regarded as one of the pioneers of computer science and a key figure in the development of computing technology. The analytical engine was designed to be programmed using punched cards, which were also used in the Jacquard loom, a mechanical weaving machine. The concept of using punched cards for programming was a significant innovation, as it allowed the machine to be reprogrammed to perform different tasks. However, Babbage never completed an engine that worked as intended, possibly because its technical pretension was more advanced than the available means of his time to make it possible.

In addition to his work on computing, Babbage was also interested in economics and social reform, and he wrote extensively on topics such as education, poverty, and public health. He was a founding member of the Royal Astronomical Society, he was also elected a fellow of the Royal

Society in 1816. Despite his many achievements, Babbage was also known for his prickly personality and his tendency to clash with colleagues and government officials.

Babbage was a keen observer of economics, writing about the nature and implications of technological change and, particularly, of mass production based on Smith's division of labour. The main objective of his work is referred to the development of manufacturing and the advances of mechanization, main object of the contributions of the Industrial Revolution to economic development.

4.8 Innovation in Babbage's Thought

The work *Reflections on the Decline of Science in England*: *And on Some of Its Causes* (1830), along with the particularly noteworthy *On the Economy of Machinery and Manufacture* (1832), provide a systemic vision, in line with that of List, in which the economic role of science and technology is analysed in detail, while policies related to both are considered.

On the Economy of Machinery and Manufacture (1832) is structured into a series of passages, which develop ideas and principles that Babbage understood necessary to regulate and sustain the industrial economy in a revolutionary context, as well as provide a prospective vision of it. Nonetheless, this cross-cutting work also covers other areas of the economics of technological change and entrepreneurship, framing a compendium of his eclectic ideas.

As noted by Ozgur (2010) in his review of Babbage thought as a precedent of development economics, other authors have highlighted these transverse contributions of Babbage's ideas. Goldman (1983) described Babbage's work as an "*influential study of technology, the organization of production, and the division of labour.*" Stigler (1991) noted that Babbage's book "*presented a most attractive introduction to the technology and the economics of production and marketing*," *and* McCorduck and Cfe (2004) and Lewis (2007) have stated that Babbage deserves recognition as a pioneer in the field of operations management, and may be the first scholar of what is being later called *operations research.*

According to Rosenberg (1994), another major milestone in Babbage's forward-thinking is that he believed technological change to be an endogenous phenomenon, that is, technological advances are *affected by input prices and demand for goods produced in a particular sector; while technological improvements reduce costs and increase production.*

Babbage focused on the reconsideration of Smith's conception of the division of labour as the most relevant principle to be addressed.

> Perhaps the most important principle on which the economy of a manufacture depends, is the division of labour amongst the persons who perform the work. (Babbage, 1832, p. 169)

He deemed necessary this review under the increasing applications of new technologies in the production processes and their enormous capacity to boost mass production through mechanization.

> The advantages which are derived from machinery and manufactures seem to arise principally from three sources: The addition which they make to human power.—The economy they produce of human time.—The conversion of substances apparently common and worthless into valuable products. (Babbage, 1832, p. 6)

Babbage's contribution to the economic analysis of technological change, in different perspectives and applied to the national economy, is especially relevant, highlighting the fact that his work already combines the systemic analysis with the study of national scope as an antecedent, even prior to List's own, of the much later so-called concept of National Innovation System.

Thus, Babbage mentions in his works several key elements of this. He believed that innovation was not the result of individual genius or inspiration, but rather the product of a collaborative process involving a network of people, organizations, and institutions. Babbage recognized the importance of creating an environment that would foster innovation, and he himself worked intensely to establish networks of support for inventors and entrepreneurs. As mentioned before, he was a founding member of several *Royal Societies*, all of them dedicated to promoting innovation and scientific progress. In this manner, Babbage's ideas about innovation and national systems were ahead of his time, though they have not become increasingly relevant until the modern era of technology and globalization.

As noted by De Liso (2006), one of the main points to highlight in Babbage thought is the link between the production system and both the education and the science and research systems. On the other hand, it is

also relevant to the link between these last and the institutional framework and its configuration.

In his institutional perspective of the economy, Babbage wonders whether a government should intervene, as well as when and under what conditions and scope it may do so. He considers that consumers must be the most convenient supporters to determine the goodness of an invention, although he remarks that natural market forces will not always be entirely able to enforce it. Here, Babbage precedes what has traditionally been the main purpose of governments in the field of innovation, which is to intervene to address market failures, as well as systemic failures. Both block the efficient performance of innovation systems, as they hinder the flow of knowledge and technology transfer, what limits the overall efficiency of research and development efforts, which are themselves particularly risky.

Science and technology, Babbage notes, must be financed directly by the state when private actors and their incentive to do so is not enough. In this end, he defined the need for what he calls *peculiar institutions* in the promotion of science and technology.

> If, therefore, it is important to the country that abstract principles should be applied to practical use, it is clear that it is also important that encouragement should be held out to the few who are capable of adding to the number of those truths on which such applications are founded. Unless there exist peculiar institutions for the support of such inquirers, or unless the Government directly interfere, the contriver of a thaumatrope may derive profit from his ingenuity, whilst he who unravels the laws of light and vision, on which multitudes of phenomena depend, shall descend unrewarded to the tomb. (Babbage, 1830, p. 19)

Without them, through direct intervention of active public policies, practical results will not be enough, or not often enough to make of a nation a reference in scientific and technical development, nor to feed it at the pace necessary to compete with other growing nations.

> (…) Triumphs like these are necessarily 'few and far between if nor can it be expected that that portion of encouragement, which a country may think fit to bestow on science, should be adapted to meet such instances. Too extraordinary to be frequent, they must be left, if they are to be encouraged at all, to some direct interference of the government. (Babbage, 1830, p. 22)

Therefore, it is necessary for Babbage that a solid institutional context exists, which intervenes on the system when it does not revert the benefits of science and research in the market and in society, recognizing the high risk and uncertain returns of these activities.

Babbage locates his analysis in the national context, focusing his ideas and proposals within its limits, also in order to make comparisons with other nations and to emphasize national achievements. Babbage takes pride in his country when referring to England's technological capabilities, noting that not only did England benefit from these capabilities but also other countries that came into contact with them.

> There exists, perhaps, no single circumstance which distinguishes our country more remarkably from all others, than the vast extent and perfection to which we have carried the contrivance of tools and machines for forming those conveniences of which so large a quantity is consumed by almost every class of the community. (Babbage, 1832, p. 3)

To emphasize the national scope of his view, Babbage compares England with other close nations, like France or Prussia, by calculating the percentage of scientists to the total population using the year 1830 as a reference. This comparison explains the technological superiority of England, with a ratio of 1 scientist per 32,000 inhabitants, compared to France with 1 per 427,000 or Prussia with 1 per 300,000. Despite the simplicity of these figures, based on very basic statistics, indeed, they emphasize the national relevance of his comparative analysis, that is defined around the availability of specialized human capital in knowledge intensive activities. Nowadays, we refer to the same as Research and Development (R&D)-dedicated resources, which is one of the main indicators to compare nations on innovation.

Babbage also believed that England's superiority would have long-term sustainable consequences and would continue for a long period because, according to him, the inexhaustible existent source of research and the advantages derived from the technical capacity already achieved, which at that moment was dramatically changing the whole economic structure, would provide durable wealth and prosperity to England. This may be also seen as a precedent of *path-dependent* growth theories, as Babbage considered that the actual trajectory would have a solid influence to the future, as evolutionary economists would later affirm.

Therefore, Babbage believed that knowledge and the generation of knowledge are the central axis to explain the foundation of economic progress, and it is, in fact, human capital and its capabilities which are at the centre of the production process.

> The experience of the past, has stamped with the indelible character of truth, the maxim, that 'Knowledge is power'. It not merely gives to its votaries control over the mental faculties of their species but is itself the generator of physical force. The discovery of the expansive power of steam, its condensation, and the doctrine of latent heat, has already added to the population of this small island, millions of hands. (Babbage, 1832, p. 388)

That is why Babbage outlined the importance of education, as he was critical of the national system, and also saw the need for science as a necessary and basic branch of knowledge for economic development. While he was proud of England's technical capabilities and progress in previous decades, he was not satisfied with the state of science and its teaching.

> It is therefore not unreasonable to suppose that some portion of the neglect of science in England, may be attributed to the system of education we pursue. (Babbage, 1830, p. 3)

Babbage believed that only through a system that facilitated universal education was it possible to extend equally and sufficiently the needed knowledge and scientific capabilities throughout the nation, in order that results were enough for social development.

> It is in some measure to be attributed to the defects of our system of education, that scientific knowledge scarcely exists amongst the higher classes of society. (Babbage, 1830, p. 8)

> Thus, then, it appears that scarcely any man can be expected to pursue abstract science unless he possess a private fortune, and unless he can resolve to give up all intention of improving it. (Babbage, 1830, p. 38)

He also recognized that a better-educated and skill-qualified workforce specializing in industrial and mechanized production was necessary to reduce the vulnerability of the working class to economic crises, as well as for the fact that transitions to new production processes necessarily result in hard times for them. This premise is, indeed, very suitable to our time.

> In countries where occupations are divided, and where the division of labour is practiced, the ultimate consequence of improvements in machinery is almost invariably to cause a greater demand for labour. Frequently the new labour requires, at its commencement, a higher degree of skill than the old; and, unfortunately, the class of persons driven out of the old employment are not always qualified for the new one; so that a certain interval must elapse before the whole of their labour is wanted. This, for a time, produces considerable suffering amongst the working classes; and it is of great importance for their happiness that they should be aware of these effects, and be enabled to foresee them at an early period, in order to diminish, as much as possible, the injury resulting from them. (Babbage, 1832, p. 335)

In *On the Economy of Machinery and Manufactures,* Babbage expands Smith's exposition of division of labour and specialization to include the need for systemic coordination through what he calls the *mental division of labour*.

> We have seen, then, that the effect of the division of labour, both in mechanical and in mental operations, is, that it enables us to purchase and apply to each process precisely that quantity of skill and knowledge which is required for it: we avoid employing any part of the time of a man who can get eight or ten shillings a day by his skill in tempering needles, in turning a wheel, which can be done for six pence a day; and we equally avoid the loss arising from the employment of an accomplished mathematician in performing the lowest processes of arithmetic. (Babbage, 1832, p. 201)

Babbage noted that research and development activities in the private sector were necessary for generating technological advances and economic development. He also recognized that these activities were more profitable, and then, more likely to occur in larger companies with more physical and human capital. So, this systemic coordination through *mental division of labour* becomes a precedent of operations and human capital management.

These two factors, technological, through mechanization, and human, through mental division of labour, outline the path of economic growth through increasing production scales. This provides the first elements of the economics of innovation framework, in which the innovative entrepreneur is the economic agent who introduces these process innovation mechanisms under uncertainty conditions. As noted before, this framework is established within evolutionary economics tradition, in which time

is crucial as change alters the existent reality and creates uncertainty, but also the conditions to foster innovation.

> Perhaps to the sober eye of inductive philosophy, these anticipations of the future may appear too faintly connected with the history of the past. When time shall have revealed the future progress of our race, those laws which are now obscurely indicated, will then become distinctly apparent; and it may possibly be found that the dominion of mind over the material world advances with an ever-accelerating force. (Babbage, 1832, p. 390)

Thereby, Babbage thinking reveals a strong interaction between innovation, based on science and knowledge generation, on the one hand, and the scale of productive fabric, on the other, where public support and active public policies are needed to successfully connect both.

Charles Babbage was not only a brilliant inventor and engineer, but also a pioneer of the idea of innovation systems. He believed that innovation was not the result of individual genius or inspiration, but rather the product of a collaborative process involving a network of people, organizations, and institutions.

Babbage's ideas about innovation systems were ahead of his time, but they have become increasingly relevant in the modern era of technology and globalization. Today, as he did, we recognize that innovation is a complex process that involves many different actors and factors, including research and development, education and training, financing, regulation, and intellectual property protection.

There are three keys to be highlighted in Babbage's vision and its relationship with the field of what we now know as economics of innovation:

- the study of the role of technology and mechanization in the economy,
- the need for development of science and its relationship with the industry and the technological advancement of a nation, and
- the importance of knowledge and human capital for the development of the above.

By analysing the characteristics of the English economy of the time, Babbage offered novel proposals on how to maintain the position that England had reached as a world leader, taking the need for a coevolution between knowledge (science) and the productive system (technology) as a starting point.

Finally, Babbage noted that if a nation seeks to maintain its advantage over its competitors, particularly in a complex and evolving global system, it must implement active policies and take advantage of research and development; so, to respond to international competition, the government must become both a regulator and a promoter.

All in all, his ideas about collaboration and support networks for innovators and entrepreneurs remain relevant today and continue to influence our thinking about how to foster innovation and drive economic growth.

4.9 Epilogue

The study of innovation, in a pre-Schumpeterian conception, and in the context of the transition between the First and Second Industrial Revolutions, finds contributions in different authors who show interest in the economic transformation that these revolutions were bringing to Europe.

The concise study of the work of economic thinkers throughout time lets us explore and reassess some ideas and principles that, otherwise, maybe considered much later. Innovation and technological change are concepts usually associated with certain economists, but in reality, they have been a subject of reflection since the origins of the Industrial Revolution, of which they are both the foundation and the consequence.

The three authors presented in this chapter, contemporaries of the early stages of the aforementioned Revolution, even some of them in a superficial or tangential way, represent progress in the basic tenets of the later economics of innovation, born well into the twentieth century.

If Friedrich List is the most cited of the three in the manuals of the history of economic thought, it is fair to place him in this study as the first, although not necessarily the pioneer, of relevant contributors to this current of economic thought, particularly to the concept of National Systems of Innovation and their elements. List's seminal ideas about this and the role of the state in fostering innovation is still relevant for economic policy definition today. His emphasis on the importance of innovation and the need for a coordinated effort between the state, the private sector, and academia is the basis of the concept of innovation system itself.

Johann Heinrich von Thünen defined the first elements of localization economics, also relevant to the very concept of the National Innovation System. Early theorists on economics and technological change, such as Schumpeter, gave no importance to the spatial aspect or its implications;

however, von Thünen was a pioneer on this topic and help us to understand its special approach. Besides, his description of the person of the entrepreneur was a key contribution which connects two different views of entrepreneurship, that characterize the entrepreneur as the holder of risk and defines him as an innovator. von Thünen, an alternative and eclectic scholar due to his condition and habits, is a reference for the use of observation as a tool of economic thought, as well as an early proponent of the definition of the entrepreneur as the *animal spirit* of the innovative process and promoter of the whole economic progress.

Charles Babbage mentions in his works several of the key elements of National Innovation Systems too. One of the main points that emerges in his thought is the triple link between the industry, the education system, and science development, all of them under the same institutional framework. Babbage believed that governments should intervene and considered that science and research must be financed directly by the state when private incentive is not enough. To this end, he defined the need for what he calls *peculiar institutions* in the promotion of scientific knowledge and innovation development. Babbage, *Renaissance man,* for his wide interests and concerns, is devoted to the defence of social and economic reform, focusing its success on knowledge and innovation.

This chapter aims to briefly highlight not only the figure of the three authors considered but also, and above all, the importance and pioneering nature of their thinking, which was innovative, groundbreaking, and ahead of its time. They represent an original and significant departure from established or conventional mindset and pave the way to later advances in the nascent field of Economics.

Finally, they also highlight, as well as this modest contribution to this work tries to do, the inner value of Economics as a social science, derived from its transversal and interconnected nature, as well as its interdependence with many other subjects, which leads to a better understanding of the world around us and its constant evolution.

References

Babbage, C. (1830). *Reflections on the Decline of Science in England: And on Some of Its Causes.* B. Fellowes.

Babbage, C. (1832). *On the Economy of Machinery and Manufactures.* R. Clay Printer.

Becattini, G. (Ed.). (1987). *Mercato e forze locali: il distretto industrial.* il Mulino.

De Liso, N. (2006). Charles Babbage, Technological Change and the 'National System of Innovation'. *Journal of Institutional and Theoretical Economics (JITE), 162*(3), 470–485.

Freeman, C. (1991). Networks of innovators: a synthesis of research issues. *Research Policy, 20*(5), 499–514.

Freeman, C. (1995). The National System of Innovation in Historical Perspective. *Cambridge Journal of Economics, 19*, 5–24.

Fujita, M. (2012). Thünen and the New Economic Geography. *Regional Science and Urban Economics, 42*(6), 907–912.

Godin, B. (2009). National Innovation System: The System Approach in Historical Perspective. *Science, Technology, & Human Values, 34*(4), 476–501. https://doi.org/10.1177/0162243908329187

Goldman, L. (1983). The origins of British 'social science': Political economy, natural science and statistics, 1830–1835. *The Historical Journal, 26*(3), 587–616.

He, J., & Tian, X. (2020). Institutions and Innovation. *Annual Review of Financial Economics, 12*, 377–398.

Hébert, R. F., & Link, A. N. (2006). The Entrepreneur as Innovator. *The Journal of Technology Transfer, 31*, 589–597.

Knight, F. H. (1921). *Risk, Uncertainty and Profit* (Vol. 31). Houghton Mifflin.

Leigh, A. H. (1946). Von Thünen's Theory of Distribution and the Advent of Marginal Analysis. *Journal of Political Economy, 54*(6), 481–502.

Lewis M. A. (2007). Charles Babbage: Reclaiming an Operations Management Pioneer. *Journal of Operations Management, 25*,(2), 248–259.

List, F. (1856). *National System of Political Economy*. JB Lippincott & Company.

List, F., Austin, B., Ingersoll, C. J., Jefferson, T., & Madison, J. (1827). *Outlines of American Political Economy: In a Series of Letters*. Samuel Parker, no. 48, Market Street.

Lundvall, B. A. (1992). *National Systems of Innovation: towards a Theory of Innovation and Interactive Learning*. Pinter Publishers.

Marshall, A. (1890). Principles of economics, by Alfred Marshall. Macmillan and Company.

McCorduck, P., & Cfe, C. (2004). *Machines Who Think: A Personal Inquiry into the History and Prospects of Artificial Intelligence*. CRC Press.

Metcalfe, S. (1995). The Economic Foundations of Technology Policy: Equilibrium and Evolutionary Perspectives. In *Handbook of the Economics of Innovation and Technological Change* (pp. 409–512). Blackwell Publishers.

Nelson, R. R. (Ed.). (1993). *National Innovation Systems: A Comparative Analysis*. Oxford University Press.

North, D. (1990). *Institutions, Institutional Change and Economic Performance* (Political Economy of Institutions and Decisions). Cambridge University Press. https://doi.org/10.1017/CBO9780511808678

OECD. (1963). *Science, Economic Growth and Government Policy*, C. Freeman, R. Poignant and I. Svennilson.
OECD. (1999). *Managing National Innovation Systems*. OECD Publishing. https://doi.org/10.1787/9789264189416-en
Ozgur, E. (2010). Charles Babbage: an inadvertent development economist. Charles Babbage, 1000–1021.
Parr, J. B. (2015). Exploring the Urban System of von Thünen's Isolated State. *Papers in Regional Science, 94*(1), 161–175.
Porter, M. E. (1990). *The Competitive Advantage of Nations* (p. 564). The Free Press.
Prais, S. J., & Daly, A. (1981). *Productivity and Industrial Structure: A Statistical Study of Manufacturing Industry in Britain, Germany and the United States*. Cambridge University Press.
Reinert, E. (2004). How rich nations got rich: Essays in the history of economic policy. Working paper, http://urn. nb. no/URN: NBN: no-3600.
Romer, P. M. (1986). Increasing Returns and Long-Run Growth. *Journal of Political Economy, 94*(5), 1002–1037.
Rosenberg, N. (1994). Charles Babbage: Pioneer Economit. In N. Rosenberg (Ed.), *Exploring the Black Box: Technology, Economics, and History* (pp. 24–46). Cambridge University Press. https://doi.org/10.1017/CBO9780511582554.004
Rosenberg, N. (2000). Charles Babbage in a Complex World. In *Complexity and the History of Economic Thought* (pp. 59–69). Routledge.
Samuelson, P. A. (1983). Thünen at Two Hundred. *Journal of Economic Literature, XXI*, 1468–1488.
Schumpeter, J. A. (1954). *History of Economic Analysis*. Psychology Press.
Stigler, G. J. (1991). Charles Babbage (1791+ 200= 1991). *Journal of Economic Literature, 29*(3), 1149–1152
Thünen, J. V. (1960). *The Isolated State in Relation to Agriculture and Political Economy*, vol. 2, translated by BW Dempsey. The Frontier Wage.
von Thünen, J. H., Wartenberg, C. M., & Hall, P. (1966). Von Thünen's Isolated State: An English Version of Der Isolierte Staat. Oxford: Pergamon press.

CHAPTER 5

Technoscientific Rationality and Capitalist Accumulation. Transhumanism as Alienation in Marx's Humanist Approach

Baruc Jiménez Contreras

In early April 2021, images of a monkey trained to play video games via a subcranial chip went viral. This project was carried out by NeuraLink, a company co-founded by Elon Musk. The company aims to make these implants available soon, creating the expectation that the emergence of a kind of brain-machine hybrid is possible (Whitwam, 2023). Integrating implants to enhance human abilities has gained significant traction in recent years. When humans unite with these artefacts to improve their

This chapter was written as part of the Complutense University of Madrid and the Banco Santander Foundation's predoctoral scholarship program.

B. J. Contreras (✉)
Complutense University of Madrid, Madrid, Spain
e-mail: barucjim@ucm.es

E. Trincado Aznar, F. López Castellano (eds.), *Science, Technology and Innovation in the History of Economic Thought*, Palgrave Studies in the History of Economic Thought,
https://doi.org/10.1007/978-3-031-40139-8_5

physical and intellectual capabilities, they become known as cyborgs. Some humans have begun to consider themselves cyborgs, such as the artist Neil Harbisson who describes himself as a "cyborg activist" (Gartry, 2015). Over a decade ago, he had an antenna implanted in his skull by an anonymous doctor to "hear" a broader spectrum of colours (Gartry, 2015). The emergence of the cyborg and the general conception of enhancing human capabilities are based on a philosophical movement called transhumanism, which aims to transfer human consciousness into a machine as its ultimate goal.

Transhumanism is a philosophical movement that aims to continuously evolve human life beyond its current form. It focuses on using technological and scientific advancements such as artificial intelligence, robotics, cognitive science, information technology, and biotechnology to enhance human physical and intellectual capabilities beyond what has been naturally achieved through evolution (More & Vita-More, 2013, p. 1). This approach has been made possible by the increasing adoption of utilitarian rationality and market values in the scientific field.

Transhumanism alludes to a Promethean vision that disregards the conditions of domination, inequality, and economic and social subjugation of human beings under capitalism and attempts to promote "principles and values" about the supposed centrality of human life (More & Vita-More, 2013, p. 1). The movement emerged during postmodernity and shares specific common goals with it, such as the need for "change," the acceptance of multiple "identities" and "bodies," and opposition to a fixed and universal "human nature" (More & Vita-More, 2013, p. 1). It also exhibits flexibility regarding what "should" be "humans and humanity." However, transhumanism does not question the values of capitalist modernity or the scientific and technological development arising from its historical specificity. Instead, it relies on them to achieve its objectives.

The futuristic vision of transhumanism began to gain ground in the first half of the twentieth century. The existence of companies at the forefront of scientific and technological research related to the transhumanist project has contributed to the further growth of transhumanism today. These companies have translated their research into tangible results, which are already being commercialised. Additionally, these corporations plan to expand the consumption of their products shortly. This situation has raised questions about the impact of technoscientific goods that use human enhancement technologies.

The Sienna project, which aims to generate research leading to an ethical, legal, and regulatory framework for using and developing human enhancement technologies, presented a report in 2018 that warns about the repercussions of using these commodities (Jensen et al., 2018, p. 6). The study's findings reveal significant impacts related to the historical phenomena of human alienation in capitalism resulting from increased capital reproduction. The first consequence suggests that humans could become increasingly reliant on technology, gradually altering the current perception of human nature (Jensen et al., 2018, p. 6). Additionally, human enhancement technology could limit individual freedoms, particularly freedom of choice (Jensen et al., 2018, p. 6). This process is linked to rising social inequalities and new challenges in wealth distribution due to longer life expectancies.[1]

In Book V of *The Wealth of Nations*, Adam Smith (1776) detected the concept of alienation within the History of Economic Thought. On the other hand, Marx delved deeper into the intricacies of alienation in capitalism in his *Manuscripts* and *Capital* works. He analysed the complex relationship between human beings and their transformation as commodities, the impact of technological advancements in capitalism, and the potential conflict between such progress and human freedom. Marx also explored how the concentration and centralisation of capital help pursue technological advancement for capitalist accumulation. Marx's idea of formal and real subsumption of labour to capital reflects how capitalism conquers more facets of human existence. This notion aligns with the transhumanist movement and the increasing prevalence of technoscientific products, such as chips, antennas, and sensors. These commodities explore a new realm of alienation and capitalist accumulation through the consumer's decision to modify their human experience and maximise their abilities.

In contrast to Marxism's idea of overcoming alienation, there have also been theoretical efforts in economic thought that have promoted it by assimilating human beings to machines that must constantly act according to a universal algorithmic procedure. Philip Mirowski's studies (2002, p. 157) have shown that historically, dominant economic thought

[1] The study considers "social disruptions" and "negative consequences" on vulnerable or historically marginalised groups as minor impacts (Jensen et al., 2018, p. 6). Adverse health effects are characterised as having a moderate impact compared to other issues (Jensen et al., 2018, p. 6). Results of "low significance" are related to changes in commercial relationships and environmental damage from the increased production of toxic technological waste (Jensen et al., 2018, p. 6).

maintained a reciprocal relationship to assist the US Army during World War II. The tools developed during the war served as the foundation for an economy dominated by mathematics, crystallising into the "operations research" supported by efforts in computational innovations (Mirowski, 2002, p. 209). These processes led to the predominant methodological union in contemporary economics. First, all social or economic phenomena can be explained by individual decisions, which are exclusively driven by choosing the best options (Boland, 2006, p. 481). Secondly, the fundamental idea is that individuals can be modelled as "machines" (Boland, 2006, p. 481), giving rise to a rational choice approach based on methodological individualism, which is gradually replaced by "methodological cyborgism," constituting economics as a "Cyborg science" (Mirowski, 2002, p. 99, 441).

The neoclassical economics via the Nash theorem directly connect to the goal of turning humans into cyborgs (Mirowski, 2002, p. 146). Mirowski (2002, pp. 80, 343) argues that the Nash equilibrium, in which competitors use a profit maximisation process (ensured through the minimax method) based on the strategies of others, necessarily implies the perception of the strategy as an algorithmic programme. This programme monitors the "domain" of one's plan and involves surveillance of the other's plan (Levy, 2004, p. 424). It is not a process of interaction, cooperation, or communication but enables the individual to "internally reproduce" the opponent's intentionality to choose the best response (Levy, 2004, p. 424). The equilibrium is attained when the individual reaches the "infinite regression of simulation," leading to a single interpretation: maximising profits (Mirowski, 2002, p. 344)

According to Mirowski (2002, p. 6), contemporary economists have played a crucial role in developing cyborg sciences, and the principles of these sciences have influenced the economic orthodoxy. However, if we examine Marxism's perspective on alienation and the critiques made by Engels, Marx, and Adam Smith of utilitarian economists, we can see that the transhumanist project is intrinsic to the life's perspective promoted by classical utilitarians. This approach was disseminated by orthodox political economists. Transhumanism can be conceived as the materialisation of a utilitarian economic project for human beings, in which the elimination of physical obstacles that prevent the achievement of maximum individual benefit is sought. The fundamental idea of transhumanism finds a meeting

point in the worsening of utilitarian values.[2] The ultimate goal of transhumanists is the separation between the human body and consciousness. The body is conceived as a burden that tends to degrade. Maximising individual benefit for human beings is achieved by abandoning the body (or the total minimisation of physical pain). An extreme version of utilitarianism becomes a reality through technoscientific goods,[3] leading to questioning life's fundamental role for the transhumanist movement and for technoscientific companies that generate these goods for a supposed contribution to human development. Therefore, transhumanism represents a contemporary vision of utilitarian values in which Hume's (2005) advocacy of suicide (understood as the human duty to minimise individual pain) obtains a new solution: abandoning the human bodily experience (life itself) through a set of technoscientific goods. The process is considered an act of alienation in itself, as opposed to achieving human freedom. From a Marxist perspective, critical of utilitarianism, freedom can only be achieved if the human being overcomes the condition of being a commodity (linked to capitalist reproduction).

The process of alienation of individuals leads to a crucial question: is the human being capable of facing technoscientific developments? In line with Günter Anders (2011) in his book *The Obsolescence of Man*, published in 1956, the current development of technoscience has created a "Promethean gap" where "we are not up to the Prometheus within us." This thesis asserts that our intellectual and human capabilities dissolve in the face of technological development. As a result, technoscientific rationality exerts a significant transformative force on individuals. This situation leads to alienation caused by the chaotic advancement of productive forces and the focus on profitability and maximising utility that

[2] Susan Levin (2020, p. 131) explained that Utilitarianism is a well-known form of consequentialist philosophy that holds that the moral value of any action is determined by its consequences. This applies not only to individual actions but also to larger entities such as institutions, laws, and practices. Transhumanists, who advocate for the use of technology to enhance human capabilities, employ a similar consequentialist argument (Levin, 2020). They argue that therapy and enhancement offer comparable benefits, and thus, it is better to enhance rather than just treat or avoid disease. This argument is based on the "moral continuum" that links value and action, as noted by Malmqvist (2014, p. 44; Levin, 2020, p. 132).

[3] Technoscience is the union of (capitalist) technique and science that emerged as part of neoliberal public policies in the early 1980s in the United States. This model is characterised by generating commodities that have been the product of strong investment in research and development.

characterises contemporary capitalism. Following this line, the first section of this chapter aims to demonstrate that capitalism and its alienating dynamics have led, since its inception, to a devaluation of life that has resulted in human commodification. The idea of the human being transformed into a "thing" arises from the capitalist seeking to constantly increase their surplus value (or, in utilitarian terms, maximise profits and reduce the costs). In this sense, the utilitarians' theory has ethically supported the capitalist approach to devaluing life. Transhumanism appears as a falsified (or fetishised) reality in which the logic of capitalist instrumentalisation seeks support for accepting technoscientific commodities that increase capitalist reproduction under the guise of human enhancement and the attainment of greater freedom. The second section discusses Marx's concept of the subsumption of labour under capital, and how the utilitarian values of capitalist reproduction, developed during the Industrial Revolution, have been taken to an extreme based on efficiency. This has led to the primary objective of the transhumanist project becoming the efficient consumption of technoscientific commodities, ultimately enhancing only the reproduction of capitalism.

5.1 Challenging the False Reality of Capitalism and Transhumanism

Reflecting on current technoscientific development undoubtedly brings to mind Marx's concerns about alienation, the status of human beings in capitalism, and the centrality of life in the face of the values promoted in capitalist society at the end of the nineteenth century. Marx's vision of human alienation generates a theory identifying factors in contemporary capitalism's economic development that intensify this phenomenon. At the same time, the processes documented by Marx represent an analytical framework that clarifies the need for profound transformation in economic thinking, which critically questions the reproduction of capitalism. Furthermore, movements such as transhumanism that apparently aim to reproduce human capacities raise questions about their compatibility with Marx's views on life, alienation, and capitalism.

In the *Economic and Philosophic Manuscripts* (published in 1932), Marx proposes investigating the origin of social bipolarity in capitalism through the category of alienation. He identifies one of the actual results of his research as the deepening of his studies on the emergence of private

property (Marx [1932] 1980, p. 104). Marx ([1932] 1980, p. 104) explains that under capitalist circumstances, individuals lose physical and intellectual abilities. For Marx, labour is the fundamental relationship that mediates the metabolism between individuals and nature. It is through labour that the subject can achieve ontological and teleological realisation.

Marx ([1932] 1980, p. 106) elucidates that society undergoes a process of devaluation of the human world, in which their vital activity, labour, is reduced to the role of a mere "thing," or, as later explained in *Capital*, to the condition of a commodity. It is identified as a historical pattern in capitalism that the devaluation of the human world grows in direct proportion to the valorisation of the world of things ([1932] 1980, p. 106). This idea indicates that the development of the "world of commodities" is opposed to the realisation of the human subject because it always involves transforming humans into commodities.

The distortion that occurs in capitalism, by transforming the subject who produces values into a "commodity," arises from the transformative capacity of labour. In the production of commodities, labour can reproduce itself and generate a surplus value that appears within the legal framework as a legitimate appropriation by the subject who owns the means of production (Marx [1932] 1980, p. 106). The worker's existence is subject to the same dynamic as the other commodities, so the capitalist dynamic drives their physical, intellectual, and spiritual development. Therefore, the social perpetuation of the subject is directly linked to the replication of commodities (Marx [1932] 1980, p. 106).

In the *Manuscripts*, alienation can be identified at the first level by separating the producing subject and the product of their labour. At a second level, Marx recognises that alienation also manifests itself in the impossibility of the beings controlling the labour process. In this sense, the vital function of labour as a mechanism for interaction between human beings and nature is frustrated and under capitalist circumstances, labour is conceived as the "de-realisation of the worker" (Marx [1932] 1980, p. 106). There is a gradual effect that tends to increase the alienation of the subject, as the worker, to meet the increasing demands for commodity production, becomes increasingly disconnected from their "humanity" (Marx [1932] 1980, p. 106). In this situation, their living conditions become unfavourable due to heightened labour productivity resulting in a wage decline (Marx [1932] 1980, p. 107).

Marx spots a set of circumstances in which social interaction and the metabolism of individuals with nature are transformed under capitalist

conditions of alienated labour. First, the process of alienation entails that the natural resources that make up the "means of subsistence" for humanity are now alienated since they have been commodified (Marx [1932] 1980, p. 107–108). Second, the productive activity of the subject increasingly restricts their existence, with the labour performed by the worker constituting a process of "active alienation" (Marx [1932] 1980, p. 108). Third, the subject's inability to direct their own lives is a significant consequence of this situation since, for Marx, life is "production," and therefore, their life and productive activity do not concern them and are directed against them (Marx [1932] 1980, p. 110–111). Fourth, human existence lacks an ontological and teleological purpose, and this is reflected in a society of individuals who are pitted against each other, limiting their "generic qualities" to "individual existence" (Marx [1932] 1980, p. 114). Finally, this inaugurates a dynamic in society in which social relations appear objectified, and individuals relate to each other as commodities.

Marx maintained that private property results from labour that have become alienated. As capitalism advances and accumulation takes centre stage, a dialectical relationship exists between private property and labour. The process of capitalist accumulation increases human alienation while transforming various aspects of social development into commodities. In the transhumanist endeavor, which is heavily invested in capitalist accumulation and guided by utilitarian economic theory, it can be inferred that the production of technoscientific commodities results in an increased number of labour-derived products alien to the worker, intensifying alienation, which is the opposite of "freedom." Despite the project's emphasis on "freedom," it remains a subjective, abstract, and rhetorical proposal that fails to suggest any actual transformation of the material conditions of production and the social relationships inherent in capitalism.

The transhumanist movement's capitalist circumstances entail several implications. Firstly, acquiring technoscientific capabilities is reserved for those who possess the necessary purchasing power, resulting in increased conflict among individuals. Secondly, there exist individuals who have technoscientific goods that enable a general redesign of the "human condition" by preventing "ageing," "suffering," and "confinement of life on earth" while also allowing access to "enhancing physical and mental abilities (including productive qualities)" of those who can afford these commodities (Bostrom, 2005, p. 21). Thirdly, as this is a "radical change" (Bostrom, 2005, p. 21) that transforms the human condition, the advantages of those individuals who possess the benefits acquired by

technoscientific commodities would increase the gap in capitalist social bipolarity, creating two distinct states of existence in the same planet: the current human existence, which still maintains the experience of life through the body, despite the transhumanist aspirations to transcend it, and the fetishistic condition (H+)[4] (through technoscientific commodities) pursued by transhumanism, which seeks to minimise the physical limitations imposed by corporeality.

Marx's analysis ([1867] 2014) of human alienation is not limited to the *Manuscripts* and is unfolded in *Capital* in the exposition of a humanistic study of the Political Economy. It is possible to see that the examination of alienation commences the investigation of the capitalist system in the "commodity" category. Through studying the separation of the human subject and the products of labour related to this concept (Marx, [1867] 2014, p. 41), the analysis delves into the changes experienced by human nature[5] and the process of labour in a social environment where the concept of "exchange value" takes precedence over "use value."

Notably, the human condition is in a relationship of subordination and alienation, ultimately expressed in the price of labour power in the market. This reduction of life to a quantitative manifestation means that the value of a person's creative and productive activity is measured solely by the exchange value assigned to their labour power. The simplification of life to a commodity and its subordination to capital accumulation highlights the fundamental flaws of the capitalist system, as it fails to value life beyond its ability to generate profit.

Marx showed that capitalism undermines human life by disrupting the subject's metabolism with nature, questioning the survival of individuals, and denying the ontological and teleological possibility of human realisation. Marx's investigations into the role of commodities reveal that the subject (transformed into a commodity) alienates their teleological qualities, which are expressed in the execution of concrete labour and, in the capitalist production process constitute the part of the commodity known as use value (Marx, [1867] 2014, p. 52). On the other hand, the

[4] H+ is the symbol that has been disseminated by the Humanity+ platform and refers to the human condition that subjects will acquire through the advances provided by technoscientific commodities. Cfr. https://humanityplus.org

[5] Byron's studies (2016, p. 375) demonstrate that Marx's investigation into human nature and alienation are interdependent and complementary concepts. Therefore, in *Capital*, when exploring the transformations of human nature associated with capitalism, Marx also delves into examining alienation.

ontological potentialities of labour are also utilised by the system, as the faculty of abstract labour is used to form the exchange value incorporated into each commodity (Marx, [1867] 2014, p. 61). Thus, the effects of capitalist production lead to a loss of the subject's "humanity" (Marx, [1867] 2014, p. 107), assuming that their existence is restricted to the development imposed by market forces.

The transhumanist project presents a contradiction, as its philosophical underpinnings consider it a continuation of humanism. Marx ([1932] 1974, pp. 118–119) revealed that in Ricardian economics, an epistemic "truth" valid within the current capitalist legality existed. However, this "truth" lacked humanity, and to denounce it for its inhumanity, one needed to resort to a humanist argument (beyond the political economy and capitalism) proposed by philosophy. However, the philosophical roots of the transhumanist project falsely depict capitalism as having a fetishistic appearance of "humanity," in which the intensification of the phenomena of alienation and objectification of human beings and nature is perceived as a degree of attainment of greater freedom. Rather than dismantling the notion of "commodity" in the social and human panorama, the transhumanist project can increase the risks in vital progress, exacerbating the subject's vulnerability.

The assertions regarding the interaction between individuals as objects, the estrangement, and social division caused by alienated labour are expressed in the thesis on commodity fetishism in *Capital*. This proposal delves into the humanist denunciation of labour alienation outlined in the *Manuscripts*. It presents the functioning of the market based on the fact that individuals and commodities relate to each other equally as "things." Marx explains that the commodity has a very complex character. He associates the "fetishistic" characteristic, derived from the religious panorama, in which products of the human head appear as independent figures endowed with a life of their own and demonstrate the ability to relate with one another and human subjects. Marx uses this analogy and suggests that something similar happens with the products elaborated by workers in capitalism (Marx, [1867] 2014, p. 73). Marx states that, in the capitalist system where alienated labour produces commodities, social relations between private labourers emerge not as direct social relations between persons, but as relations between things. Capitalism is a reification system that aims to transform facets of human life into commodities. This notion expresses the purposes of transhumanism, completely identifies it with the

capitalist processes of alienation, and denounces the false idea of freedom that its defenders try to spread.

According to Fitzsimons 2016, p. 56), Marx views fetishism as a type of consciousness that emerges from the private character of labour and plays a crucial role in constructing the commodity. The value category in Marx's analysis is not solely a "form of social relation" but also an "externalised and objectified form of consciousness" employed by commodity producers to organise social production. Hence, if humans were to forsake their bodies and transform them into machines completely, they would objectify the values that underpin capitalist reproduction, notably the utilitarian values that the economic theory promotes in its algorithmic perception of human beings (Mirowski, 2002).

Marx explains that the benefits achieved through the development of technology and science within capitalism are contradictory for human beings. This thesis is demonstrated through the "general law of capitalist accumulation" and "the tendency of the rate of profit to fall." Capitalism is characterised by enriching an increasingly smaller number of individuals who own the means of production and proletarianising a large mass of individuals who only own their labour power. As technological development escalates through more significant investment in constant capital (intending to enhance their possibilities of competing in the market and amplifying their relative surplus value), this dynamic acquires a self-destructive for the subject because it drives the social reproduction of an abstract object (capital) and denies social and human development. This objective involves society as a whole, to the point that the direction of public policies in capitalism is predominantly aimed at maintaining a high rate of profit (and trying to recover it in times of crisis), even at the cost of social degradation and human alienation.

The concept of alienation is particularly significant when analysing the material conditions of the contemporary technological world because the "availability sought by technological reason transforms the way individuals perceive the world, leading them towards a way of life focused specifically on pragmatic goals" (Linares, 2008, p. 382). This emphasis on availability intensifies that "human beings are continually reduced to available objects" (Linares, 2008, p. 382). The rationality of technology and science drives "decision-making that increasingly prioritises immediate economic, political, and military concerns, often at the expense of social and environmental costs" (Linares, 2008, p. 382).

Anders' proposal does not advocate for a technological determinism of capitalism over human beings. Instead, both Anders and Marx highlight the objective situations that can be transformed through human action. As such, the dominant economic thought's promotion of utilitarian values is questionable. It is also problematic that some Marxist schools do not denounce human commodification, which restricts human beings to merely documenting the logic of capitalist accumulation and accepting technoscientific commodities' fetishistic reality instead of striving to transform it.

5.2 The Utilitarian Value of Technoscientific Commodities: Subsumption Efficiency and Rationality

Marx's unpublished Chapter VI (in Volume I of *Capital*), titled "Results of the Direct Production Process," offers a unique perspective on the crucial role that technique, science, and their inherent rationality play in the dynamics of capitalist accumulation. In this chapter, Marx delves into the process of subsuming labour under capital, which inevitably leads to the field of "ontology" as there is a "methodological interest in presenting labour in its essential and abstract form" (Palacios, 2019, p. 135). As a result, the epistemic explanation of the human subject's alienation process is tied to the historical gestation of the alienating relationship between labour and capital (Palacios, 2019, p. 135).

Marx organised the subsumption of labour under capital into two thematical moments in *Capital*. The first moment is "the process of formal subsumption of labour under capital," and the second is "the process of real subsumption of labour under capital." While the concept of alienation serves as a thread of argumentation in the relationship between labour and capital, it also reveals more sophisticated categories of study resulting from the reflexive analysis of capitalism.

The emergence of capitalism precedes the establishment of new social relations, as the separation of the individual from their means of production leads to a transformation in the concept of labour and as a result, its main objective—"the reproduction of life." According to Marx, "the capitalist begins by taking labour power … as it is found on the market, and … as it existed in a period when there were no capitalists." In the unpublished Chapter VI of *Capital*, this process is referred to as the formal subsumption of labour under capital (Marx, [1969] 1971, p. 54). This

particular phase is distinguished by the fact that the process of labour becomes subservient to capital, with the capitalist assuming the role of its director and supervisor (Marx, [1969] 1971, p. 54). This means that the process of labour, as it existed under the feudal system, is transformed to fit the requirements of capitalist reproduction, which prioritises the attainment of absolute surplus value over the reproduction of human life. Consequently, the focus shifts from meeting human needs to producing more commodities.

Marx describes how the bourgeoisie deliberately aimed to revolutionise and fully integrate the labour process into a specifically capitalist model. These actions fundamentally transformed the labour process, ultimately leading to the Industrial Revolution. Marx argues that the "real subordination of labour to capital" marks labour and means of the production revolution. This fact implies that a technical revolution process arises, which widens the possibilities of surplus value acquisition, leading to the emergence of relative surplus value within the productive forces. This new surplus value approach relies on the ability to create a larger quantity of commodities through technological progress. At this point, a connection starts to establish between technological activity and the dynamics of capitalist accumulation. The technological rationality of capitalism is chiefly based on the capacity to continuously revolutionise the labour process via innovation in the means of production and the general conditions of capitalist reproduction. Consequently, all human needs are turned into commodities.

The Industrial Revolution gave rise to a set of requirements in capitalist competition, all related to increasing relative surplus value through technological innovations. As the productive forces advanced, the sphere of capitalist production underwent significant modifications, resulting in the growth of commodities produced by the most cutting-edge capitalists, who gained a competitive race in the market. The consequences of this technological race were primarily reflected in the tendency towards monopolies that characterise capitalism, marked by capital concentration and centralisation processes, with repercussions on social polarisation and the pursuit of relative surplus value. Although innovations originate in the scientific field, their development is not solely motivated by the capitalist dialectic. Instead, an indirect influence is characterised by technological advances from science to production, driven by the need to boost capitalist productivity. This dynamic shapes how technical rationality, derived

from scientific research, becomes integrated into the investment decisions of the capitalist system.

During the twentieth century, the crisis of 1929 represented a reformulation of the liberal accumulation pattern. From this crisis, guidelines for state intervention were gradually established. By the 1950s, the outcome of the new international economic order generated after the two world wars allowed the United States to emerge as the hegemonic power of the capitalist system worldwide. These events are identified explicitly with the breakdown of the liberal accumulation pattern and the beginning of the Fordist-Keynesian model, which brought a set of rethinking about new ways of holding hegemony worldwide.

In the interventionist phase of the State, the emergence of *megascience* marked a significant turning point that illustrated the new degree of subsumption of social reality to capitalism.[6] This development signified that capital was exploiting scientific activity more directly and paved the way for patterns that shaped the international socioeconomic landscape in the years to come. It is worth noting that this phenomenon was predominantly happening in the United States, indicating its rising power in the global arena. These activities highlighted state intervention as a crucial factor in the capitalist system's operation, ushering in a new level of subsumption of social reality.

According to Javier Echeverría (2003, p. 26), *megascience* refers to an activity that took place in the United States within the realm of militarised physics–mathematics under four projects: the Lawrence Berkeley National Laboratory (formerly known as the Berkeley Radiation Laboratory), the M.I.T. Radiation Laboratory, the ENIAC project (the Electronic Numerical Integrator and Computer) of the Moore School of Pennsylvania, and above all, the Manhattan Project (Los Alamos). These initiatives, as Echeverría explains, led to the production of the first atomic bombs. The significance of state funding in driving technoscience is underscored in the race that established the United States as a political, economic, and military power. This investment was more significant than in some European countries, such as Germany and Great Britain, which directed their resources towards reconstruction programmes (Echeverría, 2003, p. 26).

[6] According to Diéguez (2017, p. 109), the term "m*egascience*" refers to how scientific research has evolved to require the use of expensive and sophisticated technology, the involvement of large research teams, and the acquisition of significant financial resources for its successful execution.

During the post-war period, the interventionist policy became increasingly evident. The parameters of system reproduction were established, as well as the renewed ways social reality is subsumed to the logic of accumulation. Javier Echeverría (2003, p. 27) explains that "the new organisational structure of *megascience* during the post-war period" was created "using significant public funds," mainly in the United States, gradually leading that country to become a global hegemonic power. This pattern of state investment and intervention extends as a model of economic development in capitalist countries and in the "actually existing socialism," turning scientific and technological development into an instrument of power (Echeverría, 2003, p. 27).

During this period, there was tension in the international economic and political arena due to the competition between the United States and the USSR. This rivalry was sustained by the production and development of scientific and technological devices, as they were seen as crucial for achieving global dominance. As Javier Echeverría (2003, p. 27) points out, the competition for space exploration was a prominent field for this contention, and it exemplifies the development of *megascience*. In this new aspect of capitalist social reality, science shifted from seeking knowledge to directly pursuing capitalist profitability, primarily supported by state investment (Echeverría, 2003, p. 28).

The funding during the 1940s and 1950s was mainly driven by the State for military purposes, remaining "stable until the mid-1960s, reaching its peak under the Kennedy administration" (Echeverría, 2003, p. 63). The decline of this policy coincided with the failure of the Vietnam War and the dissatisfaction of American society with science, combined with the deterioration of the state intervention model that significantly reduced the budget invested in such projects (Echeverría, 2003, p. 63).

During Reagan's presidency, a fresh approach to capitalist accumulation emerged, emphasising reduced state intervention and free market promotion. As Javier Echeverría noted, this new neoliberal model fostered a "new social agreement for science" which gave rise to "technoscience" that entailed more subsumption of capitalist social reality (Echeverría, 2003, p. 63). The scientific activity became directly linked to the dynamics of capitalism, revealing a hitherto unknown potential for accumulation within the system. There was a rapid increase in private funding for research and development (R&D) as a result of the liberalisation of patent law and a new fiscal policy that allowed for a 25% tax credit on private R&D investments (Echeverría, 2003, p. 63). The political priority changed

towards technological development and the private sector was seen as the driving force behind it (Echeverría, 2003, p. 63).

Knowledge has been increasingly commodified, detached from its creators through the application of patents and the formation of new technoscientific firms (Echeverría, 2003, p. 64). This commodification has been subjected to the interests of capitalist accumulation, which has impregnated scientific dynamics, effectively transforming significant parts of its pursuits into technoscience. The perception that knowledge creates value, combined with its gathering, generates a mechanism that seeks to control humanity by reducing it to a mere commodity, perpetuating the alienating effects previously described. It can be explained by Marx's concept of commodity fetishism, where the denunciation of Feuerbach and the role of religious imagery that originated from human consciousness ultimately took over the lives of those it was created. Marx's insight reveals a pattern in the capitalist system where false theoretical foundations are generated that ultimately act as a tool to subjugate human beings in favour of capitalist reproduction. As a result, technoscience, which produces commodities for capitalist accumulation, operates under "economic values of profitability" based on "the exploitation of patents, industrial secrecy, and competitiveness" and "not solely on the epistemic values" (Echeverría, 2003, p. 68).

The concept that "knowledge generates values" (inherently), the activity of technoscience, and the prevailing rationality in the technological realm have resulted in a complex array of possibilities for the transformation and domination of nature. Jorge Linares clarifies that this technological field is distinguished as a "unitary totality," or rather, a "system of systems" that manifests as a "novel artificial environment," within an "internal dynamic concerning external factors" (Linares, 2018, p. 27). Thus, the technological world is a system that exists within the capitalist system itself, having its dynamics and sharing, as a result of subsuming social reality, utilitarian values of profitability, efficiency, and innovation based on technoscientific (pragmatic-instrumental) rationality.

The capability of technology and technoscience to transform the world is accompanied by their potential to provide a new approach to understanding and orienting oneself in it. Capitalism exploits "the incessant pursuit of greater operational efficiency" while simultaneously providing consumers and producers with "a system of artefacts" that can efficiently guide them towards their utilitarian objective of obtaining capitalist profitability (Linares, 2008, p. 381). In other words, the constant introduction of utilitarian values in society leads to the production, consumption, and

use of technoscientific commodities that serve the purpose of efficiency itself. Achieving efficiency is human beings' objective through producing technoscientific goods.

Jorge Linares argues that this "effectiveness" tends to manifest itself under a "technological imperative," which dictates "do everything that is technologically possible" (Linares, 2008, p. 382). This approach restricts the possibilities of human liberation, assuming that the production and consumption of commodities are the only options for individuals (Linares, 2008, p. 382). As a result, technoscientific human beings, operating within the capitalist system, entrust the system with the belief that "what is currently unfeasible will be achieved in the future through technological progress" and will be obtainable in the form of "commodities," regardless of the effects on the vital conditions of existence, "justifying" this behaviour "for immediate pragmatic purposes and benefits" (Linares, 2008, p. 382).

The current state of technoscientific activity has strengthened the utilitarian values historically promoted by capitalism and amplified its negative effects on both society and the environment. The consequences have become more complex due to increased social alienation, the dominance of the technological world, and the "Promethean gap" promoted by the system. The "era of bio-artifactuality" is characterised by "the new and powerful technical capacity to transmute living matter, as well as to introduce significant changes in social representations and theoretical conceptions of living beings, and human nature itself" (Linares, 2018, p. 87). It reflects an "aspiration of technoscientific self-propulsion" of being seeking to redesign the human species (Linares, 2018, p. 87) for capitalist profitability, which is championed by the values of utilitarianism and transhumanism.

5.3 Conclusions

Economic thought has dedicated much time and effort to justify a mechanistic stance on humans and nature. The mechanisation hypothesis has resulted in the endorsement of situations where human beings dominate and exploit nature and each other. Given the current state of technological progress in implants, chips, and antennas that offer objectively transhumanist capabilities to human beings, it is essential to reconsider the role that economics has played in establishing the ethical framework for a

situation that is untenable if we do not take into account the utilitarian principle of maximising benefits.

The conflict between instrumentalisation and the pursuit of virtue has occurred in economic thought since its inception. The utilitarian principles of transhumanism highlight this dilemma, as contemporary capitalist reality and the economic theory that underpins it have pushed for an instrumentalist approach that aligns with the abstract foundations of the theory, particularly in human behaviour. The subjective nature of economic theory is not accidental and acknowledges its aim to shape the subject and their reality.

Transhumanism can be seen as a modern version of Hume's defence of suicide, where leaving the physical body is inconsequential as long as pleasure is maximised and pain is minimised, regardless of the subject's inability to experience it after death. This comparison between transhumanism and suicide highlights the trajectory of economic thought that prioritises utilitarian values, resulting in the dissolution of the subject and the abandonment of the pursuit of their development. This dilemma also avoids addressing the search for virtue and what is desirable for human beings in economic thought.

Capitalism promotes the idea that human beings can be treated as commodities, which is a falsified reality that is both theoretically and legally justified in social fact. Additionally, the system perpetuates different mythologies that further reinforce this idea, even to the extent that technoscientific commodities can objectively invade the human body and create a divide between those who have access to them and those who do not. The reification of the human body raises concerns about the purpose of turning not just the workforce but also human existence and experience into commodities.

The process of capitalist accumulation and the perception of the formal and real subsumption of labour to capital warns about how far the human being could go in the search for the maximisation of utility, or in any case, responds objectively to the fact that technoscientific commodities have invaded the human being in its corporeality. The Marxist denunciation of objectification, alienation, and processes of subsumption to capital should also not be taken as an object of instrumentalisation, in which the humanistic argument that denounces an alienating reality is used exclusively for the study of capitalist reality without pretending to transform it.

References

Anders, G. (2011). *La obsolescencia del hombre. sobre el alma en la época de la segunda revolución Industrial* (Vol. 1). Pre-textos.

Boland, L. A. (2006). On Reviewing Machine Dreams: Zoomed-In versus Zoomed-Out. *Philosophy of the Social Sciences, 36*(4), 480–495. https://doi.org/10.1177/0048393106293458

Bostrom, N. (2005). A history of transhumanist thought. *Journal of Evolution and Technology, 14*(1), 1–25.

Byron, C. (2016). Essence and Alienation: Marx's Theory of Human Nature. *Science & Society, 80*(3), 375–394. https://doi.org/10.1521/siso2016803375

Diéguez, A. (2017). *Transhumanismo: la búsqueda tecnológica del mejoramiento humano*. Herder Editorial.

Echeverría, J. (2003). *La revolución tecnocientífica*. Fondo de Cultura Económica.

Fitzsimons, A. L. (2016). ¿Qué es el 'fetichismo de la mercancía'? un análisis textual de la sección cuarta del capítulo primero de El capital de Marx. *Revista De Economía Crítica, 21*, 43–58.

Gartry, L. (2015, August 10). 'Cyborg Activist' Neil Harbison, with Antenna in Skull, Opens Up on Visit to Perth's Curtin University: Neil Harbisson, a Man with an Antenna Permanently Attached to His Skull and Who Identifies Himself as a 'Cyborg', Speaks of His Life and Beliefs on a Visit to Perth's Curtin University, Including the Difficulties He Faced in Getting the Implant. *ABC Premium News*. Retrieved from https://login.bucm.idm.oclc.org/login?url=https://www.proquest.com/wire-feeds/cyborg-activist-neil-harbisson-with-antenna-skull/docview/1702626265/se-2

Hume, D. (2005). *On Suicide* (Electronic Book ed.). Penguin Books.

Jensen, S. R., Nagel, S., Brey, P., Ditzel, T., Rodrigues, R., Broadhead, S., & Wright, D. (2018). *SIENNA D3. 1: State-of-the-Art Review: Human Enhancement*. SIENNA Project.

Levin, S. B. (2020). *Posthuman Bliss? The Failed Promise of Transhumanism*. Oxford University Press.

Levy, D. M. (2004). Machine Dreams: Economics Becomes a Cyborg Science: Philip Mirowski, Cambridge University Press, Cambridge, 2002. *Journal of Economic Behavior & Organization, 53*(3), 423–431. https://doi.org/10.1016/S0167-2681(03)00128-8

Linares, J. (2008). *Ética y mundo tecnológico*. Fondo de Cultura Económica.

Linares, J. (2018). De la naturaleza a la tecnoespecie: La proyección antropotécnica de la condición humana. *Contrastes: Revista Internacional de filosofía, 23*(2), 77–95.

Malmqvist, E. (2014). Reproductive Choice, Enhancement, and the Moral Continuum Argument. *Journal of Medicine and Philosophy, 39*(1), 41–54.

Marx, K. ([1932] 1974). *Cuadernos de Paris*. Ediciones Era.

Marx, K. ([1969] 1971). *Capítulo VI inédito: Resultado del proceso inmediato de producción*. Siglo XXI editores.

Marx, K. ([1932] 1980). *Manuscritos: economía y filosofía*. Alianza Editorial.

Marx, K. [1867] (2014). *El capital: Crítica de la economía política. Tomo I: El proceso de producción del capital*. Fondo de Cultura Económica.

Mirowski, P. (2002). *Machine Dreams Economics Becomes a Cyborg Science*. Cambridge University Press.

More, M., & Vita-More, N. (2013). Roots and Core Themes. In M. More & N. Vita-More (Eds.), *The Transhumanist Reader: Classical and Contemporary Essays on the Science, Technology, and Philosophy of the Human Future* (pp. 1–2). John Wiley & Sons.

Palacios, M. G. (2019). El metabolismo en Marx: apuntes desde la ontología del trabajo. *Éndoxa*, 43, 135–154.

Smith, A. ([1776] 2002). *An Inquiry into the Nature and Causes of the Wealth of Nations: Two Volumes in One*. University of Chicago Press.

Whitwam, R. (2023). *ExtremeTech.com—Ziff Davis: FDA Reportedly Rejected Elon Musk's Neuralink Brain Chip Trial over Safety Risks*. Newstex. Retrieved from https://login.bucm.idm.oclc.org/login?url=https://www.proquest.com/blogs-podcasts-websites/extremetech-com-ziff-davis-fda-reportedly/docview/2781348370/se-2

PART II

Neoclassical Contributions and Its Alternatives

CHAPTER 6

Energy Efficiency, Productivity and the Jevons Paradox

Estrella Trincado Aznar and José María Vindel

6.1 Introduction

In 1865, the English economist William Stanley Jevons published *The Coal Question*, posing a much-celebrated paradox on the relationship between technological change and well-being. As Jevons literally says: "It is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to a diminished consumption. The very contrary is the truth. As a rule, new modes of economy will lead to an increase of consumption according to a principle recognised in many parallel instances" (Jevons 1865, 140). Jevons cited the example of the Scottish iron industry, where energy efficiency implied a decrease of coal consumption per quantity of

E. Trincado Aznar (✉)
Department of Applied Economics, Structure and History, Complutense University of Madrid, Madrid, Spain
e-mail: etrincad@ucm.es

J. M. Vindel
Ministry of Labour and Social Economy, Madrid, Spain
e-mail: Jmaria.vindel@mites.gob.es

E. Trincado Aznar, F. López Castellano (eds.), *Science, Technology and Innovation in the History of Economic Thought*, Palgrave Studies in the History of Economic Thought,
https://doi.org/10.1007/978-3-031-40139-8_6

iron of more than two-thirds and led to a tenfold growth in total consumption, besides the indirect effect of encouraging other coal consuming sectors due to the availability of cheap iron (Trincado et al., 2021).

Jevons witnessed the introduction of the James Watt steam engine that boosted the efficiency of previous designs of the steam engine, such as Thomas Savery's or Thomas Newcomen's engines. Watt's steam engine was widely introduced in different industries, intended to obtain a greater thermodynamic efficiency, but it also led to an increase of British consumption of coal. Similarly, the Bessemer process, which reduced the consumption of coal for the creation of industrial quantities of steel, generated further increases in the efficiency of other processes and boosted the consumption of steel in a greater variety of industries (Rosenberg, 1989).

This "Jevons paradox" is part of a more general criticism of the author to classical economics. According to Jevons (1871), the value of commodities is determined, not by the cost of production, but by the marginal utility, (the last unit consumed). More precisely, the exchange ratio of two commodities is the reciprocal of the ratio of the final degrees of utility of the quantities of commodity available for consumption after completing the exchange. Utility is the final cause of value, but resources must be available and, in the final analysis, value is determined by the Jevons "catena": the cost of production determines supply, supply determines the final degree of utility and the final degree of utility determines value. Thus, when the cost of production declines due to resource efficiency, the marginal utility of commodities that use the given resource declines, increasing directly the consumption of those commodities and indirectly the consumption of other commodities with which they are exchanged. Then, scientific progress and resource efficiency is not a good path to the lesser use of resources: the declining cost of production will make producers use the resource more while consumers increase their consumption. We cannot leave technology alone without taking into account the economic behaviour of the agents. Actually, as coal is a non-renewable energy resource, it may be depleted. Demand grows exponentially, while supply is limited. Obviously, Jevons underestimated the relevance of coal substitutes such as hydroelectric power, petroleum or renewable resources (Clark & Foster, 2001). However, the Jevons paradox is perhaps the most widely known paradox in environmental economics (York, 2006).

In this chapter, the Jevons paradox is studied in the context of the debate on the limits to Growth. Jevons' line of thought led to new areas in economics that imply that economics cannot be fully split from other

sciences, in particular we will talk about the interdisciplinary area of econophysics. We will assess the current importance of the Jevons paradox at the macroeconomic and microeconomic levels, looking at the relationship between economic growth and energy efficiency. Finally, we will comment on the energy policies proposed to avoid the rebound effect, with some concluding remarks on the evolution of the concept.

6.2 The Debate on the Limits to Growth

With his paradox, Jevons was raising the question of the limits to growth. Overpopulation and prosperity would find its limits sooner than was commonly understood (as he showed in Fig. 6.1). But this idea was not at all strange to economic science. The concept of the stationary state had emerged long ago, in the period of the Scottish Enlightenment (Jonsson, 2013) and went into classical economics in a quite reductive version (Hollander, 1992). Actually, Malthus (1798) had given a much pessimistic vision of the limits to growth, which led the historian Thomas Carlyle to call economics the dismal science in *Chartism* (Carlyle, 1840) and in *Occasional Discourse on the Negro Question* (Carlyle, 1849). He contrasted this to the then-familiar phrase "gay science" used to refer to the art of troubadours or literature. At the same time, Carlyle argued in favour of reintroducing slavery in order to restore productivity in the West Indies. He considered that the individual freedom defended by economists was something unrealistic. Mill (1850) was the first to criticize Carlyle's vision. Inequality as assumed in slavery does not solve any problem; on the contrary, it raises justice dilemmas that lead to a general disillusion and rage at the system. However, Jevons was happy to come back to the original idea of a dismal science. And he also showed that inequality was not any solution for it.

According to Jevons, technological progress increases the rate at which the coal deposits of England deplete, and could not solve the stationary state problem (Alcott, 2005, 2008). Some engineers pointed out the increasing difficulty of obtaining coal and alerted about the possible exhaustion of resources; however, Jevons' idea implies an emancipation from engineers' arguments (Missemer, 2017, 29, 42–44). Jevons based on the calculations of the geologist Edward Hull (1861), who assessed the stocks of mineral available in the British and Irish subsoil. However, there are difficulties of calculating the recoverable reserves of a resource that is theoretically finite, something that is discussed in detail in the work by

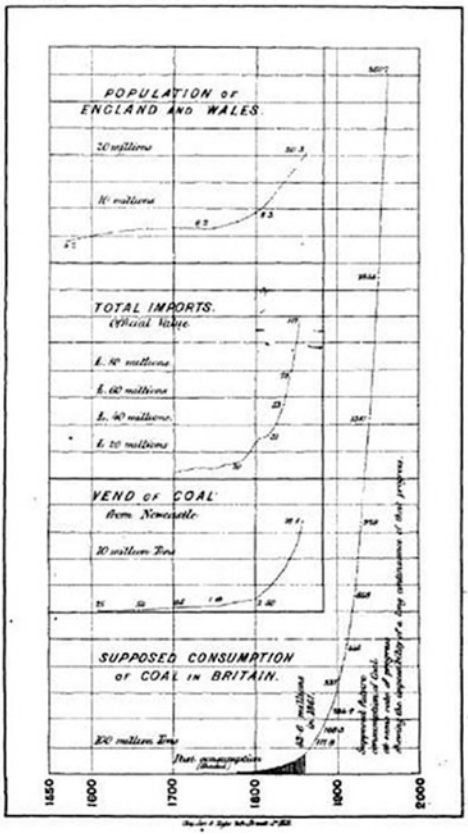

Fig. 6.1 Diagram depicted by Jevons to represent the rebound effect

Jevons' son, H.S. Jevons (1915). Nonetheless, according to Jevons, technical progress is the problem, not the solution (Veblen, 1904 stresses the opposite idea, being technological institutions the progressive and dynamic institutions based on idle curiosity and the instinct of workmanship). Besides, Jevons only finds partial solutions of political economy to the rebound effect problem: the substitution of coal for other resources, something about which Jevons was sceptical in his time. Taxes on coal may also be a solution, but they could lead to reprisals from other countries, which will go against free trade advantages and worsen the problem (Jevons, 1865, 361–362). Solutions, then, had to come in the time after,

when the problem became more pressing in the perception of the general public.

As shown in Missemer (2017), previous to Jevons, from Petty (1662) to Pierre Le Pesant de Boisguilbert (1695), Richard Cantillon (1755) or Quesnay (1767), the limits of growth and nature were found in the meanness of agricultural activity. Malthus, dealt with the natural laws due to agricultural production as related to demographic growth, stressing the problem of food dependence. However, demographic and agricultural resources are renewable; but Jevons was talking about non-renewable resources. Ricardo makes some allusion to fossil fuel (1817, 46–47, 67), and also McCulloch (1830) and Senior (1836) considered the importance of the role of coal in economics dynamics. Nevertheless, their energetic discourse was optimistic, as there was abundance of the resource within the period. Mill (1848, vol 1, 34–35 and vol 2, 257) began to talk about scarcity of mineral resources based on the law of decreasing marginal returns of agriculture, the same as Say (1828, 115–118) and Cournot (1838, 45–46, 1863, 135–136). For Ricardo, the stationary state is a condition in which capitalists have no tendency to increase or decrease output. It implies a falling rate of profit and that development variables remain unchanged. Technological advances can delay the coming of the stationary state, as they amplify the production possibilities function. However, they could temporarily lead to technological unemployment due to machines taking the place of workers (Ricardo, 1815, 1817). As the domestic value of commodities depends on 93% of the labour embodied or, more generally, on the cost of production, then lesser costs of production imply lesser use of resources. International trade, thanks to comparative advantage, allows countries to reduce the costs of production even further.

After Jevons, Marshall stressed the importance of mineral resources as they affected prices of the economy as a whole, and the fact that non-renewable resources can lead to an increasing curve of costs in the secular period. Harold Hotelling (1931) is considered the founder of non-renewable resources economics and, in particular, of economics of fossil energy (Missemer, 2017). But Hotelling simply trusts the solution to the substitution of resources and technical progress. From there, the possession of domestic coal has been considered one of the main drivers for industrialization (Simonin, 1867). Hotelling (1931) studies intergenerational allocation, but he does so as a known amount of resources owned by an individual who discounts future royalties. For some time, the Jevons paradox was left out from the economic orthodoxy because it raised

doubts on industrialization, science and technology when it deals with human behaviour.

Actually, the debate turned global with the Club of Rome of the 1960s and the publication of *The Limits to Growth* (Meadows et al., 1972). Kenneth Boulding (1966) and Nicholas Georgescu-Roegen (1971) pointed to a general contradiction of the economic process. This contradiction cannot be avoided through a better individual arbitrage between the present and the future using the rate of interest (Missemer, 2017). As Georgescu-Roegen explains, a nation does not discount, it works as if they were immortal. The economic process consists of a continual transformation of low entropy to high entropy, that is to say, materials in compact state used in the production and consumption process, and transformed into materials in a dissipated state—not exploitable. Besides, not all the energy from coal will create work: part of it is wasted and sends out heat into the environment. All processes, including recycling, consume energy, so they imply ever more dispersion and an increasing entropy, with a shortening of the number of years in which the current standards of living are sustainable (Martínez Alier & Roca, 2000). This gave renaissance to radical ecological economics and degrowth theories (Cosme et al., 2017). The increasing need for materials from the subsoil led to an incapacity to create an energetic surplus, as was implicit in the *produit net* of François Quesnay. Coal—or oil or gas—is inorganic energy and, when being decomposed, disperses along with the materials used in production and goes into the atmosphere as pollution (Gallego, 2022, 133).

For Georgescu-Roegen, economic activity is an extension and a complement of man's biological evolution and wherever there is evolution there is the work of the Entropy Law with its irrevocable qualitative change. Because of the very nature of exosomatic evolution—instruments that are integrated in ourselves as a continuation of biological processes—the social conflict will last under any regime as long as there is a human society. According to Georgescu-Roegen (1986), thermodynamics expresses our finitude and it is founded on four laws: first, total energy is constant; second, entropy steadily increases; third, the absolute zero of temperature cannot be reached; and fourth, and most important, thermodynamic equilibrium is a transitive condition. Matter, as energy, exists in two states, available and unavailable, and it dissipates into dust. Some authors claim that we can recycle all matter provided sufficient available energy is forthcoming, but according to Georgescu-Roegen, the time needed and the amount of work and matter exceed all imagination. It is a

regress without limit, and we do not have an infinite amount of energy or time. Both available energy and available matter are irrevocably degraded into unavailable states. There is no salvation even in a steady-state economy, as defended by Herman Daly (1973). Economics ignore the scarcity of natural resources because they think that anything is obtainable if one is prepared to invest the necessary capital and labour and equipment.

> The much stronger thesis that technological innovations can always do away with scarcity of any item (H. Barnett and C. Morse, 1963) has become the first article of economic faith of virtually all economists. (Georgescu-Roegen, 1986, 11)

These conception is affluent of the paramount conviction of the economic profession that economic growth is the gran objective (Harrod, 1965, 77). Robert Solow (1973, 1974) was the first master on growth to talk about these limits, although yet on mechanical grounds and based on the indifference of the market to pollution, so that we need to apply the "polluter pays" principle. Paul Samuelson finally came to speak of entropy in the last edition of Economics (Samuelson, 1980, 747) and asserted that "Science can temporarily turn the hourglass over." But Georgescu-Roegen states that thermodynamics is fundamental in science, as Arthur Eddington or Albert Einstein affirmed. Technology may be defined as an ensemble (a matrix) of feasible recipes such that any non-primary input of any recipe is the product of some other recipe. Georgescu-Roegen introduces another paradox: although it consists only of feasible recipes, a technology is not necessarily "viable." A viable technology must have the same qualities as those characterizing a living organism, which, in addition to performing certain specific activities, also maintains its material scaffold (its body) intact from one minute to the next. The best economic illustration is Karl Marx's simple reproduction, the stationary state. But a viable technology needs a continuous supply of environmental low entropy, converting environmental energy into energy and matter at our disposal for other activities. Only two inventions have represented this crucial technological advance (Promethean recipes): the invention of fire and that of the steam power. But this has speeded up the depletion of its very support, its specific fuel, so we are now in a technological crisis. And, Georgescu-Roegen says, solar energy is not the solution, as the Promethean recipe has not yet happened. First, due to the extremely weak radiation of solar energy reaching the soil and second because we need a disproportionate amount of

matter to harness solar energy in some appreciable amount (for new insights on the viability concept, see Vindel & Trincado, 2021).

6.3 Jevons and Econophysics

Jevons stressed in his works the relationship between nature and economics. This led to an original research programme not fully developed until the late twentieth century: the area of econophysics. In particular, Jevons also had a "sunspot" theory of business cycles further extended by H.L. Moore (Gallegati & Mignacca, 1994) In this case, Jevons sought a causal link between economic activity and meteorological conditions and in particular an influence of periodic solar activity on agriculture. Solar energy is part of a circular economy of nature typical of preindustrial societies. But Jevons found a correlation between the degree of sunspot activity and the price of corn. In his book *Investigations in Currency and Finance* (Jevons, 1878), he presents three essays: "The Solar Period and the Price of Corn" (1875) where he finds that the prices of the produce of agriculture have an eleven-year cycle (the sunspot cycle average length) (Jevons, 1909a [1875]). In a second essay "The Periodicity of Commercial Crisis and Its Physical Explanation" (1878) with "Postscript" (1882), Jevons claims that weather patterns have a strong relationship with business activity in basically agrarian societies such as India and Africa, which is to say, in arid and semiarid lands (Jevons, 1909b [1878]). The third essay entitled "Commercial Crisis and Sun-Spots Part I" (1878) and "Part II" (1879) proposes some policies to make the contraction of the business cycle smoother (Jevons, 1909c, 1909d [1878, 1979]). Jevons is connecting commercial crisis and cosmic phenomena (Edgeworth et al., 1909). The increase in the price of coal will lead to a competition disadvantage to Great Britain (Jevons, 1865, 24). If there is no exportation of coal, England could not import agricultural products and this will lead to famines and misery (Marshall, 1878). Jevons stresses the influence of the solar cycle on consumer spending and confidence. This random variable, as shown in Cass and Shell (1983) or Peart (1991) determines expectations.

William Stanley's son, H. Stanley Jevons, continued the work of his father on sunspots. Herbert S. Jevons (1915) criticizes legislation and labour unions for trying to keep up wages of miners while the cost of production of coal and its price was increasing, then worsening energy dependence. After publishing in 1909 in *The Contemporary Review* the article "Changes at the Sun's Heat as the Cause of Fluctuations of the Activity of

Trade and of Unemployment," he circulated it in the monograph entitled *The Sun's Heat and Trade Activity* (H.S. Jevons, 1910, 1933). H.S. Jevons admitted that the claim of his father that cycles occur every 10.45 years may not be consistent with astronomical data, although some literature in the 1930s consider that cycles of 11 or 12 years are true. "Summing up, we can say that from a statistical point of view there appears to be a clear correlation between the major cycles of non-agricultural business activity in the United States and the solar cycle of 11+ years" (Garcia-Mata & Shaffner, 1934, p. 26). Even nowadays, Gorbanev (2015) claims he has found correlation between the solar activity cycles (as measured by the number of sunspots on the sun surface) and the timing of recessions in different economies.

This line of research is the foundation of the interdisciplinary research field of econophysics, which apply theories and methods originally developed by physics in order to solve problems in economics. Econophysics was, from the very beginning, the application of the principles of physics to the study of financial markets, under the hypothesis that the economic world behaves like a collection of electrons or a group of water molecules that interact with each other. It included uncertainty or stochastic processes and nonlinear dynamics working with new tools of statistical physics and the recent breakthroughs in understanding chaotic systems (see Săvoiu & Simăn, 2013; Mantegna & Stanley, 2001; Vindel & Trincado, 2010). Econophysics, in this sense, is an interdisciplinary science, not a multidisciplinary one: it emerges out of elements of each separate discipline. However, transdisciplinarity suggests a deeper synthesis of approaches and ideas from the disciplines involved, and this is the term implied in Jevons and the ecological economists for what they are trying to develop. Within this line of research, entropy is a central concept. As we have previously seen, applying the Second Law of Thermodynamics, the replacement of lower entropy energy states with higher entropy ones (waste) provides the basis for an alternative view of stochastic price equilibria in economics (Rosser, 2016). In this sense, the seminal reference is Georgescu-Roegen (1971), who claims that economic process, instead of being a mechanical analogue as traditionally represented in mathematical economics, is an entropic process. Man struggles for low entropy, and economic scarcity is the reflection of the Entropy Law.

6.4 Current Importance of the Jevons Paradox

Within the contemporary economics, Kuznets curve predicted that more production at lower costs may increase global living standards while improving environment (Kurzweil, 2005; Kuznets, 1995). This is shown in Fig. 6.2.

However, the happy-ending of this well-being economics is darkened by the Jevons paradox. Cheap energy production could mean even in high per capita income countries higher levels of consumption of energy and a bigger hazard of climate change and environmental degradation. For this reason, energy economics has established a long-running debate on the nature, causes and consequences of the rebound effect (Greening et al., 2000; Bauer & Papp, 2009). Improved efficiency intends to reduce the amount of the resource needed for a given use, lowering its relative cost, but it can also increase the quantity demanded. Additionally, it improves real incomes and economic growth, and in so doing it further increases the demand for resources. All this implies counteracting (to some extent) the use diminution due to improved efficiency. When the effect of the increased demand outreaches the lesser cost, and the speed at which resources are used increases, we find the Jevons paradox.

Modern economists have re-examined the consumption rebound effect from improved energy efficiency (Herring, 1999; Berkhout et al., 2000). In the 1980s, a debate started on the ratio between the energy price and

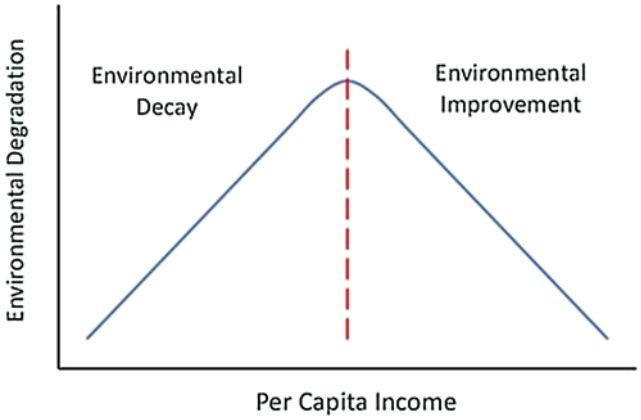

Fig. 6.2 The environmental Kuznets curve

energy efficiency (Henly et al., 1988; Jones, 1993; Khazzoom, 1980). Jevons deals with energy depletion concepts recently revisited by writers dealing with the peak oil problem. Capital costs of energy services are determinant of the variations in energy prices, so energy efficiency may be an endogenous variable with opportunity costs (Sorrell & Dimitropoulos, 2008; Mizobuchi, 2008; Vindel et al., 2021).

The law of demand predicts that, generally speaking, lesser costs (or price) of a good or service increase the quantity demanded. In microeconomic terms, the rebound effect is due first to the substitution effect. If the cost for travelling is lesser, people will travel more, making the demand for fuel increase. This direct rebound effect may offset the initial drop in the use of fuel due to increased efficiency. The Jevons paradox happens when there is a rebound effect greater than 100%, offsetting the initial efficiency gains (Clark & Foster, 2001). However, the size of the direct rebound effect depends on the price elasticity of the demand for the good (Chan & Gillingham, 2015). As shown in Fig. 6.3, the greater the demand elasticity, the greater the rebound effect. In a market under perfect competition and assuming that fuel is the sole input, if the price of fuel is constant but there are double efficiency rates, travelling would have halve the effective price (consumers can buy twice as much travel). However, the assumption of only one type of input is quite unrealistic (labour, machinery, etc. must be included), and there are other factors besides

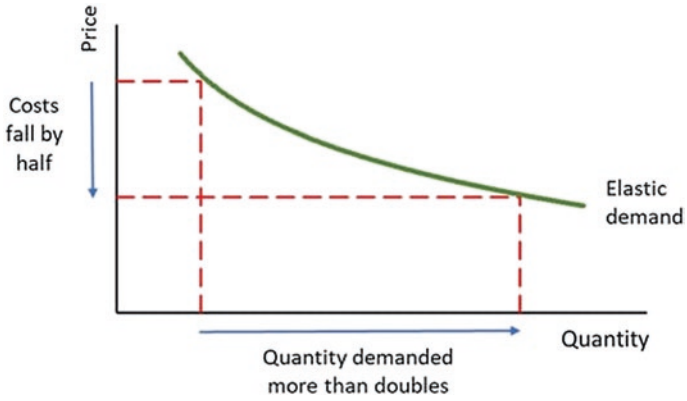

Fig. 6.3 The effect of the elasticity of the demand on the rebound effect

input cost that can affect price. These factors make the Jevons paradox less likely to occur, reducing the rebound effect.

Second, the rebound effect may be due to the income effect, as lower energy prices lead to higher disposable incomes. For example, the money saved on motor-fuel consumption may be spent on other goods or services that also have energy requirements. There are many types of indirect rebound effects, summarized in Sorrell (2009): re-spending and output effects, embodied energy effects or energy market and composition effects (Thomas & Azevedo, 2013). Microeconomic studies estimate empirically price elasticity or substitution and income effects derived from price changes (Velthuijsen, 1995; Koopmans, 1997; Koopmans & te Velde, 2001; Boom, 1998).

There are different methods for calculating the direct and the indirect rebound effect, such as risk and vulnerability rebound indicators or energy input–output coefficients (Berkhout et al., 2000; Freire-González, 2017), which calculate the rebound effect in a range from 0 to 30%. Such estimates are different across countries and across sectors: commercial, industry, residential and transport. Other studies determine a high global rebound effect in 2040 on the use of energy (70%) and related emissions (90%), with determinants such as induced supply and movement of labour among economic activities, and substitution elasticity between energy and other goods (Wei & Liu, 2017). Besides, limited evidence comes from developing countries, where the rebound effect is assumed to be higher.

The difference between direct or indirect effect is found in the channels through which these responses are achieved; (a) substitution of inputs, (b) increase in production and (c) macroeconomic growth. The direct rebound effect comes from the combination of the first two (a) and (b) (Gillingham et al., 2016). In this sense, Liu et al. (2019) carry out a study on the direct rebound effect in electricity for the Chinese industry since 1990. Their estimate holds that (a) it promotes 13.1% and (b) 23.9%, for a total of 37% direct rebound effect; attributing (a) to the response of light industry and (b) to heavy industry (higher energy consumption). This result goes hand in hand with Sorrell et al. (2009) and Rosenberg (1989): energy efficiency reduces energy costs, which encourages energy-intensive industries to consume more of the resource. These changes almost completely offset the resource consumption savings caused by the efficiency changes.

However, in mature markets such as markets for oil in developed countries, there is usually a small direct rebound effect, so that increased fuel

efficiency reduces resource use ceteris paribus (Gottron 2021). Hertwich shows different types of the rebound effect from an industrial ecology perspective (Hertwich, 2005). Additionally, the rebound effect has been extensively studied in the case of residential energy demand and transportation (Lin & Liu, 2015; Evans & Schäfer, 2013; Wang & Lu, 2014; Schleich et al., 2014; Font Vivanco et al., 2014; Linn, 2016; Chai et al., 2016; De Borger et al., 2016; Llorca & Jamasb, 2017).

The macroeconomic growth rebound effect is energy overspending, which is the difference between the optimal and the actual economic growth (Jin & Kim, 2019). Additionally, macroeconomic models simulate the effects on consumption behaviour of energy efficiency (Greene, 1992, Greening & Greene, 1997, Musters, 1995., Barker et al., 2009). Saunders (1992) argues that neoclassical growth theory broadly supports the Jevons paradox and that increased energy efficiency usually increases the consumption of energy by two means: first, the use of energy is made relatively cheaper, encouraging its consumption (the above-mentioned direct rebound effect, Greening et al., 2000). Second, real incomes and economic growth increase, which implies higher energy use for the whole economy. According to Saunders, at the microeconomic level of an individual market, although the rebound effect may happen, energy efficiency usually reduces energy consumption, causing the rebound effect to be less than 100%. Saunders argues that, considering both microeconomic and macroeconomic effects, energy efficiency improvements due to technological progress tend to increase total energy use (Binswanger, 2001; Zhang, 2019).

For Jorgenson and Fraumeni (1981), technical change happens at a fixed rate and direction, but more complex models suggest that technical change has different magnitude and sign between types of capital and sectors and in the course of time (Wing et al., 2007; Wing, 2008). In Jorgenson and Griliches (1967), contrary to usual assumptions, technical change has been energy-consuming, increasing energy intensity over time. There is a dynamic relationship between technological efficiency, consumption and the use of resources. The savings due to resource efficiency are eventually over-run by increases in consumption that draw to a net increase in the use of the resource (Freeman et al., 2016).

However, improved fuel efficiency can still be worthwhile although the Jevons paradox occurs: it leads to greater production and increased material quality of life (Ryan & Campbell, 2012). For example, the improved steam engine allowed cheaper transport and contributed to the

development of the Industrial Revolution. Even if there was not a reduction of the total amount of fuel used, there are other benefits associated such as the mitigation of price increases and disruptions and shortages in the global economy (Hirsch et al., 2006).

6.5 Economic Growth and Energy Efficiency

As previously commented, there are many studies that show strong correlations between production and energy consumption, but it is unclear the extent to which growth in the economic output can be taken as a cause of the increased energy consumption, or vice versa. A synergistic relationship between the two seems to underlie, each being the cause of the other within a positive feedback mechanism (Ayres & Warr, 2002). Neoclassical and "endogenous" growth theory considers that expansion in energy inputs does not play a major role in economic growth, due to the fact that energy accounts for a small share of total costs in relative terms (Barro & Sala-I-Martin, 1995; Denison, 1962; Gullickson & Harper, 1987; Jones, 2001). The increase in energy inputs results from the combination of increased labour and capital, improvement in the quality of inputs and in the total factor productivity, which frequently are referred to as "technical change." Ecological economists contest this view and argue that the main driver of economic growth over the last two centuries has increased availability of "high quality" energy inputs (Beaudreau, 1998, 2005; Hall et al., 1986). According to ecological economics, energy carriers are different both in their capacity to make useful work (embodied in the thermodynamic concept of "exergy") and in economic productivity—reflected by differences in price per kWh (Kaufmann, 1994)

Sorrell finds a synergistic relationship between energy consumption and economic growth (Sorrell, 2009). In Ruzzenenti and Basosi (2007), a circular feedback process is identified with increasing time lags: a rapid response (the direct rebound), a slow mechanism (the indirect rebound) and a restructuring process of the overall economic structure in the long-term (the general equilibrium effects). In Ayres and Warr (2002), the consumption of resources is considered as both a stimulus and a consequence of growth, stressing the existence of a positive feedback cycle between the consumer demand, industrial investment and lower unit costs and prices for consumers. In Cleveland and Ruth (1998) and Cleveland et al. (2000), the aggregate economic growth is shown to offset all efforts towards dematerialization.

Actually, there is little support in history for the claim that increases in income lead to declining energy consumption (Richmond & Kaufmann, 2006; Stern, 2004; Stern & Cleveland, 2004). Historical evolution of energy consumption according to different energy sources is displayed in Fig. 6.4.

According to the Kaya identity, there are four drivers for the emissions across different countries, and over time: GDP per capita, population, energy intensity (the energy per unit of GDP) and carbon intensity (CO_2 per unit of energy) over time. However, the increase in GDP was a stronger driving force than the increase in population, as shown in Fig. 6.5.

In Díaz and Puch (2019), economic activity alone (GDP growth) is not the variable that explains the increase in CO_2 emissions in Europe. What explains the increase is economic growth when energy intensity is high (Marrero, 2010; Barrera-Santana et al., 2021). Energy intensity is defined as the ratio of primary energy consumed over GDP (Wei, Zhou, Zhang,

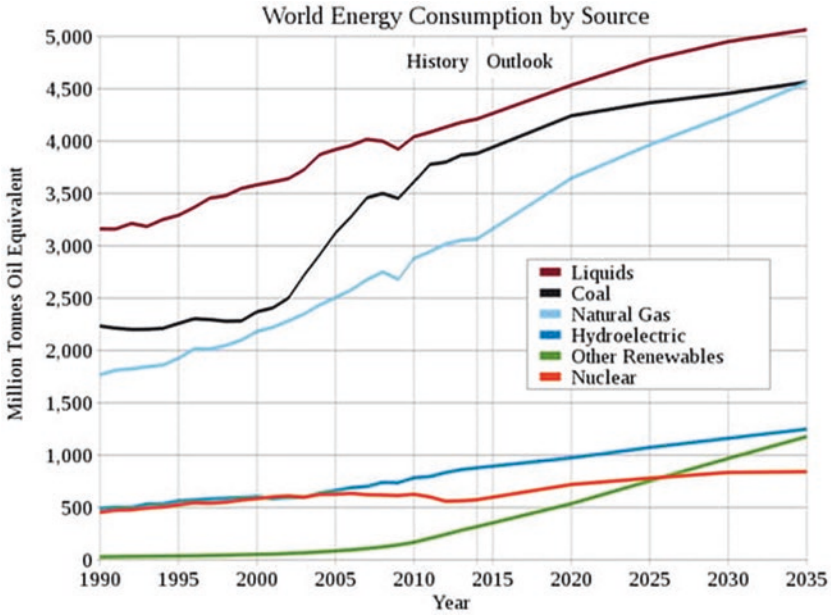

Fig. 6.4 World energy consumption outlook 2015 (https://commons.wikimedia.org/wiki/File:World_Energy_Consumption_Outlook_2015.svg, accessed on 8 July 2021)

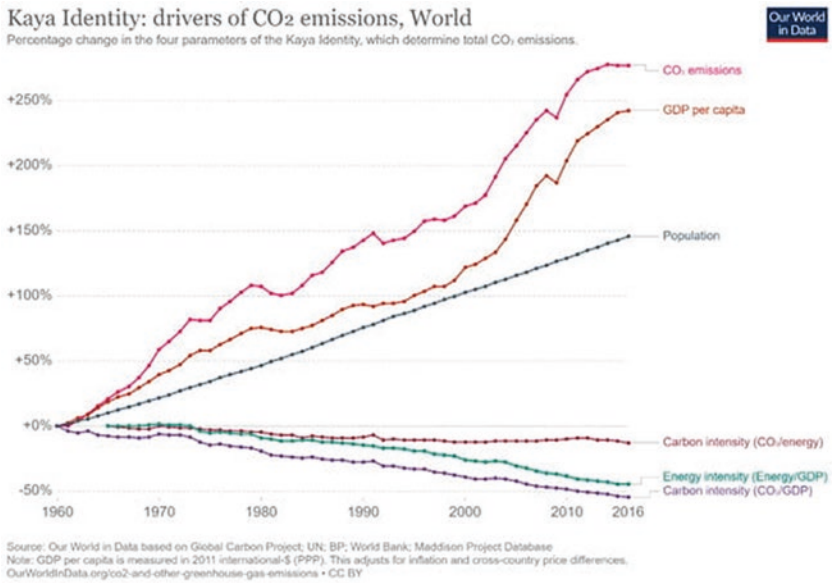

Fig. 6.5 Kaya Identity: Drivers of CO_2 emissions, world. Source: Maddison Project Database, version 2018 (Torrie et al., 2018)

2019). It is sometimes taken as an inverse of the energy efficiency, although, as predicted by Jevons, factors that influence energy intensity sometimes offset, or even augment, energy efficiency gains, such as GDP per capita, real prices or the composition of output (Torrie et al., 2018). Therefore, economic activity is important to understand the growth of CO_2 emissions in economies in which expansions throughout the economic cycle are sustained over energy-intensive sectors. Here, two representative country patterns have been found: the case of Germany, Belgium, France, Holland, Great Britain, Sweden and Switzerland, in which per capita CO_2 emissions and economic growth have moved in different directions over the last 40 years. In the literature, this phenomenon is known as decoupling. On the contrary, we have the case of Spain, Austria, Greece, Italy and Portugal, but also Denmark, Finland and Norway, where the synchrony in the movements of GDP per capita and CO_2 emissions is enormous. So, for them, growth is sustained by intensive energy sectors, and there is a trade-off between growth and energetic neutrality (Wei,

Liang et al., 2019). Certainly, the two groups of countries might not be at the same level of growth in the first place, so path dependence might influence the relationship of energy and CO_2 emissions.

6.6 Rebound Effect and Energy Policies

After Rifkin lectures all around Europe (Rifkin, 2000, 2002, 2011, 2019; De Graaf, 2021; Wolf et al., 2021), a Green New Deal with worldwide environmental policies has been demanded. But to counteract the rebound effect, consumption patterns must be accounted for (Bolt et al., 2018; Ehrhardt-Martinez & Laitner, 2008; Ehrhardt-Martinez & Laitner, 2010). A better feedback and analysis of energy bills, that is, a better understanding of the consumption of energy and the costs of actions taken at households, can lead to up to 10% savings in the consumption of electricity for heating in cold climates (Dorner, 2019). Short-term mechanisms that give the appropriate incentives to economic agents to avoid trade-off growth-emissions and rebound effects could be introduced. The increase in carbon taxes, with adequate counterweights (carbon dividends) for those who are in a weaker position to face them, or a regional convergence in energy intensities must be encouraged. In the short term, we cannot subtract growth from the most cyclical sectors, which pull the rest of the economy. This means that carbon taxes and subsidies on clean technologies must be cyclical—or countercyclical if we adopt a Schumpeterian approach.

Conservation policies that make the cost of use more expensive (such as trade barriers or green taxes, or even physical caps like quotas or rationing) are also proposed to control the rebound effect (Wright et al., 2000; Freire-González & Puig-Ventosa, 2015; Santarius et al., 2016). In this sense, efficiency gains need to go along conservation policies that maintain or increase the cost of use (Westergård, 2018). Higher fuel efficiency will not reduce, by itself, the rate of depletion of fossil fuels. For the falling of resource use, efficiency gains should go with other policies that limit the use of resource (Wackernagel & Rees, 1997).

Other research shows the relationship between consumption and resource use. For instance, Owen (2010) explains that the ICTs invested in transport have a rebound effect that increases traffic and, possibly, energy consumption. In Hilty et al. (2006), a direct correspondence is found between freight transport volumes and national material flow. So, sustainable energy policy could rely on government interventions that

reduce demand (Wright et al., 2000; Fischer-Kowalski et al., 2008; Amado & Sauer, 2012). Environmental economists point out that the use of fuel will unavoidably decrease if more efficiency is coupled with an intervention that maintains or increases the cost of fuel use (e.g. a fuel tax) (Laitner et al., 2003). Ecological economists, such as Mathis Wackernagel and William Rees, suggest that any cost savings from efficiency gains must be taxed away or removed from further economic circulation. They suggest that these savings are captured for reinvestment in natural capital rehabilitation (Westergård, 2018).

Other researchers comment on government energy efficiency policy as a counterbalance for the Jevons Paradox, such as Brookes (1990a, 1990b, 2000, 2004). More liberal policies of establishing higher emissions standards could be applied. The volume of tradable CO_2 emission rights is equivalent to 57% of the emissions, the rest being allocated free of charge to companies in sectors at risk of relocation due to carbon leakage. Therefore, an increase in the demand for emission rights, derived from a higher demand for electricity or industrial production associated with economic growth, translates into an increase in the price of electricity, whereas the reduction of prices due to an increase in supply also implies an increase in the volume of emissions. As the price of electricity is established within a marginalist market, an increase in the price of emission rights increases the price of electricity consumed. This also means that lower-cost technologies due to already amortized installations obtain windfall profits to which a correction tax could be applied. Besides, emission rights only affect the costs of generating electricity from fossil energy sources (coal or natural gas), not renewables.

6.7 Conclusions

Economists before Jevons assumed that a net product could emerge from the economic system and that the limits of growth should be found in the meanness of agricultural activity as related to population. If we solve the population problem, and preventive checks are introduced, a growth path could be attained and capital accumulation will be beneficent. Malthus theory dealt with renewable resources and, although talking about a dismal science, the theory was somewhat optimistic. Technological progress can postpone the stationary state. However, Jevons paradox, presented at the beginning of the second industrial revolution, talked about non-renewable resources and unavoidable limits to industrialization. It

emancipated economics from engineering while relating economics to physical phenomena—organic versus inorganic materials.

Jevons paradox was stressing a general problem on consumption and economic behaviour. The debate turned global with the Club of Rome of the 1968s and the publication of *The Limits to Growth*, when production and consumption processes were understood in terms of the energetic waste. Capitalism process becomes unsustainable due to the increasing need of inorganic materials from the subsoil that go into the atmosphere driving death and hell from the subsoil to earth in the surface. Matter becomes energetically unavailable. As Georgescu-Roegen says, what seems feasible, is not necessarily "viable" for living organisms, until a new Promethean recipe happens.

Jevons opened the area of econophysics, which was stressed by his son H. Stanley Jevons. This line of research seemed at first a simple summing up of some elements taken from each separate discipline, economics and physics. However, nowadays, a deeper transdisciplinary synthesis of econophysics has been made within ecological economics. Based at first on the second Law of Thermodynamics, it still remains to open itself to the questioning of consumerism and utilitarianism itself. To make the transition to climate neutrality irreversible, people and institutions must participate into the environmental turn. Hence, the importance of linking energy physics with economics and philosophy.

Jevons showed that energy efficiency may lead to an increase in consumption. The resource will be overused, although the last unit consumed will have decreasing levels of utility. Then, technological progress does not reduce the consumption of inputs; it shortens the relative cost of using a resource, which leads to increases in the quantity demanded and in real income, and accelerates economic growth, boosting once more the increase in the demand for resources. A direct and indirect rebound effect may happen, the first being the law of demand for which a decrease in price increases the quantity demanded, the second due to the fact that money saved on consumption may be spent on other goods and services with new energy requirements. Depending on the theoretical background used, very different correlations between economic output and energy consumption are considered. According to neoclassical and "endogenous" growth theory, to have more energy inputs play a relatively minor role in economic growth; according to ecological economists, the increased availability of energy inputs of "high quality" is the main driving force of economic growth over the last two centuries. However, these energy carriers

have different capacity to perform useful work and economic productivity. In general, to counteract the Jevons paradox, it seems necessary to gain a better understanding of the behaviour of consumers of energy and the costs of actions taken at households. Efficiency gains need to go with conservation policies that maintain the same (or higher) cost of use.

Energy efficiency policies try increasingly to counterbalance the Jevons paradox. Actually, climate change policies are now going beyond energy efficiency. In particular, they avoid carbon intensity to take into account other technological processes that may accelerate a transition to low carbon economies. Some of these policies are based on the interventionism paradigm; others are based on the liberal paradigm, such as the appeal to the cooperation of international and national institutions, the promotion of digital and knowledge-based economy or the establishment of higher emissions standards. As shown in this chapter, more self-regulatory policies should be implemented for aiming at the well-being of humanity in the long run. Then, we could make the most of the greater concern for the environment that people and institutions are assuming now.

References

Alcott, B. (2005). Jevons' Paradox. *Ecological Economics, 54*, 9–21.

Alcott, B. (2008). Historical Overview of the Jevons paradox in the Literature. In B. Alcott, J. M. Polimeni, K. Mayumi, & M. Giampietro (Eds.), *The Jevons Paradox and the Myth of Resource Efficiency Improvements* (pp. 7–78). Earthscan.

Amado, N. B., & Sauer, I. L. (2012). An Ecological Economic Interpretation of the Jevons Effect. *Ecological Complexity, 9*, 2–9.

Ayres, R. U., & Warr, B. (2002). *Two Paradigms of Production and Growth*. INSEAD.

Barker, T., Dagoumas, A., & Rubin, J. (2009). The Macroeconomic Rebound Effect and the World Economy. *Energy Efficiency, 2*, 411–427.

Barrera-Santana, J., Marrero, G. A., Puch, L. A., & Díaz, A. (2021). CO_2 Emissions and Energy Technologies in Western Europe. *Series.*

Barro, R. J., & Sala-I-Martin, X. (1995). *Economic Growth*. McGraw-Hill.

Bauer, D., & Papp, K. (2009). Book Review Perspectives: John Polimeni, Kozo Mayumi, Mario Giampietro, & Blake Alcott, the Jevons Paradox and the Myth of Resource Efficiency Improvements. *Sustainability: Science, Practice and Policy, 5*, 48–54.

Beaudreau, B. C. (1998). *Energy and Organisation: Group and Distribution Re-Examined*. Greenwood Press.

Beaudreau, B. C. (2005). Engineering and Economic Growth. *Structural Change and Economic Dynamics, 16*, 211–220.

Berkhout, P. H. G., Muskens, J. C. W., & Velthuijsen, J. (2000). Defining the Rebound Effect. *Energy Policy, 28*, 425–432.

Binswanger, M. (2001). Technological Progress and Sustainable Development: What About the Rebound Effect? *Ecological Economics, 36*, 119–132.

Bolt, J., Inklaar, R., de Jong, H., & van Zanden, J. L. (2018). *Rebasing 'Maddison': New Income Comparisons and the Shape of Long-Run Economic Development*; Groningen. Maddison Project Working Paper 10, University of Groningen.

Boom, J. T. (1998). *Market Performance and Environmental Policy: A Scenario Study for a Market Oriented Environmental Policy*. SEO Report No. 460, ECOF; Foundation for Economic Research.

Boulding, K. E. (1966). The Economics of the Coming Spaceship Earth. In H. Jarrett (Ed.), *Environmental Quality in a Growing Economy* (pp. 3–14). John Hopkins University Press.

Brookes, L. G. (1990a). Energy Efficiency and the Greenhouse Effect. *Energy & Environment, 14*, 318–333.

Brookes, L. G. (1990b). The Greenhouse Effect: The Fallacies in the Energy Efficiency Solution. *Energy Policy, 18*, 199–201.

Brookes, L. G. (2000). Energy Efficiency Fallacies Revisited. *Energy Policy, 28*, 355–366.

Brookes, L. G. (2004). Energy Efficiency Fallacies—A Postscript. *Energy Policy, 32*, 945–947.

Cantillon, R. (1755/1997) *Essai sur la nature du commerce en général*. INED.

Carlyle, T. (1840). *Chartism*. Goldsmiths'-Kress Library of Economic Literature, No. 31770. J. Fraser.

Carlyle, T. (1849). Occasional Discourse on the Negro Question. *Fraser's Magazine for Town and Country, X*, 670–679.

Cass, D., & Shell, K. (1983). Do Sunspots Matter? *Journal of Political Economy, 91*, 193–228.

Chai, J., Yang, Y., Wang, S., & Lai, K. K. (2016). Fuel Efficiency and Emission in China's Road Transport Sector: Induced Effect and Rebound Effect. *Technological Forecasting and Social Change, 112*, 188–197.

Chan, N. W., & Gillingham, K. (2015). The Microeconomic Theory of the Rebound Effect and Its Welfare Implications. *Journal of the Association of Environmental and Resource Economists, 2*, 133–159.

Clark, B., & Foster, J. B. (2001). William Stanley Jevons and the Coal Question: An Introduction to Jevons's "Of the Economy of Fuel". *Organization and Environment, 14*, 93–98.

Cleveland, C. J., Kaufmann, R. K., & Stern, D. I. (2000). Aggregation and the Role of Energy in the Economy. *Ecological Economics, 32*, 301–317.

Cleveland, C. J., & Ruth, M. (1998). Indicators of Dematerialization and the Materials Intensity of Use. *Journal of Industrial Ecology, 2*, 15–50.

Cosme, I., Santos, R., & O'Neill, D. W. (2017). Assessing the Degrowth Discourse: A Review and Analysis of Academic Degrowth Policy Proposals. *Journal of Cleaner Production, 149*, 321–334.

Cournot, A. A. (1838/1980). Recherches sur les principes mathématiques de la théorie des richesses. In G. Jorland (Ed.), *Oeuvres complètes* (vol. VIII). Vrin & CNRS.

Cournot, A. A. (1863/1981). *Principles de la théorie des richesses*. In G. Jorland (Ed.), *Oeuvres complètes* (vol. IX). Vrin & CNRS.

Daly, H. E. (1973). *Toward a Steady-State Economy*. W.H. Freeman.

de Boisguilbert, P. (1695). Le Detail De La France, La Cause De La Diminution De Ses Biens, & La Facilité Du Remede: En Fournissant En Un Mois, Tout L'argent Dont Le Roi a Besoin, & Enrichissant Tout Le Monde. In J. Hecth (Ed.), *Pierre de Boisguilbert ou la naissance de l'économie politique* (pp. 581–662). INED.

De Borger, B., Mulalic, I., & Rouwendal, J. (2016). Measuring the Rebound Effect with Micro Data. *Journal of Environmental Economics and Management, 79*, 1–17.

De Graaf, J. (2021). *The Promise of the Green New Deal*. Retrieved July 8, 2021, from https://weall.org/the-promise-of-the-green-new-deal-by-john-de-graaf

Denison, E. F. (1962). *Sources of Economic Growth in United States and the Alternatives before Us*. Committee for Economic Development.

Díaz, A., & Puch, L. A. (2019). Investment, Technological Progress and Energy Efficiency. *Journal of Macroeconomics, 19*.

Dorner, Z. A. (2019). Behavioral Rebound Effect. *Journal of Environmental Economics and Management, 98*.

Edgeworth, F. Y., Stanley Jevons, W., Foxwell, H. S., & Stanley Jevons, H. (1909). Investigations in Currency and Finance. *The Economic Journal, 19*(74), 253. https://doi.org/10.2307/2221442

Ehrhardt-Martinez, K., & Laitner, J. A. (2008). *The Size of the U.S. Energy Efficiency Market: Generating a More Complete Picture*. American Council for a More Energy-Efficient Economy.

Ehrhardt-Martinez, K., & Laitner, J. A. (2010). Rebound, Technology and People: Mitigating the Rebound Effect with Energy-Resource Management and People-Centered Initiatives. In *Proceedings of the 2010 ACEEE Summer Study on Energy Efficiency in Buildings*, Pacific Grove, CA, 15–20 August.

Evans, A., & Schäfer, A. (2013). The Rebound Effect in the Aviation Sector. *Energy Economics, 36*, 158–165.

Fischer-Kowalski, M., Gaube, V., & Rainer, G. (2008). Mefaspace: A Model Predicting Freight Transport from Materials Flows, and Transport Activity in Europe. *Journal of Industrial Ecology, 10*, 15–35.

Font Vivanco, D., Freire-González, J., Kemp, R., & van der Voet, E. (2014). The Remarkable Environmental Rebound Effect of Electric Cars: A Microeconomic Approach. *Environmental Science & Technology, 48*, 12063–12072.

Freeman, R., Yearworth, M., & Preist, C. (2016). Revisiting Jevons' Paradox with System Dynamics: Systemic Causes and Potential Cures. *Journal of Industrial Ecology, 20*, 341–353.

Freire-González, J. (2017). A New Way to Estimate the Direct and Indirect Rebound Effect and Other Rebound Indicators. *Energy, 128*, 394–402.

Freire-González, J., & Puig-Ventosa, I. (2015). Energy Efficiency Policies and the Jevons Paradox. *International Journal of Energy Economics and Policy, 1*, 69–79.

Gallegati, M., & Mignacca, D. (1994). Jevons, Sunspot Theory and Economic Fluctuations. *History of Economic Ideas, 2*, 23–40.

Gallego, D. (2022). *Los Caminos Del Progreso: una Historia del Desarrollo Económico*. Granada.

Garcia-Mata, C., & Shaffner, F.-I. (1934). Solar and Economic Relationships: A Preliminary Report. *Quarterly Journal of Economics, IX*, 545–588.

Georgescu-Roegen, N. (1971). *The Entropy Law and the Economic Process*. Harvard University.

Georgescu-Roegen, N. (1986). The Entropy Law and the Economic Process in Retrospect. *Eastern Economic Journal, 12*(1), 3–25.

Gillingham, K., Rapson, D., & Wagner, G. (2016). The Rebound Effect and Energy Efficiency Policy. *Review of Environmental Economics and Policy, 10*(1), 68–88. https://doi.org/10.1093/reep/rev017

Gorbanev, M. (2015). Can Solar Activity Influence the Occurrence of Economic Recessions? *MPRA Paper* 65502, University Library of Munich.

Gottron, F. (2021). Energy Efficiency and the Rebound Effect: Does Increasing Efficiency Decrease Demand? (PDF). *National Council for Science and the Environment*. Retrieved May 15, 2021, from http://www.policyarchive.org/handle/10207/bitstreams/3492.pdf

Greene, D. L. (1992). Vehicle Use and Fuel Economy: How Big Is the "Rebound" Effect? *The Energy Journal, 13*, 117–143.

Greening, L., Greene, D. L., & Difiglio, C. (2000). Energy Efficiency and Consumption—The Rebound Effect—A Survey. *Energy Policy, 28*, 389–401.

Greening, L. A., & Greene, D. L. (1997). *Where Are We Going Wrong? Modeling the Effects of Energy Technology Gains*. Draft Report September 24, Berkeley National Laboratory, Berkeley, CA.

Gullickson, W., & Harper, M. J. (1987). Multi Factor Productivity in US Manufacturing 1949–1983. *Monthly Labor Review, 110*, 18–28.

Hall, C. A. S., Cleveland, C. J., & Kaufmann, R. K. (1986). *Energy and Resource Quality: The Ecology of the Economic Process*. Wiley Interscience.

Harrod, S. R. (1965). *Reforming the World's Money*. St Martin's Press.

Henly, J., Ruderman, H., & Levine, M. D. (1988). Energy Saving Resulting from the Adoption of More Efficient Appliances: A Follow-up. *The Energy Journal, 9*, 163–170.

Herring, H. (1999). Does Energy Efficiency Save Energy? The Debate and Its Consequences. *Applied Energy, 63*, 209.

Hertwich, E. G. (2005). Consumption and the Rebound Effect: An Industrial Ecology Perspective. *Journal of Industrial Ecology, 9*, 85–98.

Hilty, L. M., Arnfalk, P., Erdmann, L., Goodman, J., Lehmann, M., & Wäger Patrick, A. (2006). The Relevance of Information and Communication Technologies for Environmental Sustainability—A Prospective Simulation Study. *Environmental Modelling and Software, 21*, 1618–1629.

Hirsch, R. L., Bezdek, R., & Wendling, R. (2006). Peaking of World Oil Production and Its Mitigation. *AICHE Journal, 52*, 2.

Hollander, S. (1992). *Classical Economics* (2nd ed.). University of Toronto Press.

Hotelling, H. (1931). The Economics of Exhaustible Resources. *Journal of Political Economy, 39*(March–April), 137–175.

Hull, D. (1861). *The Coal-Fields of Great Britain: Their History, Structure, and Resources; With Notices of the Coal-Fields of Other Parts of the World*. Edward Stanford.

Jevons, H. S. (1910). *The Sun's Heat and Trade Activity*. F. S. King and Son.

Jevons, H. S. (1915). *The British Coal Trade*. Kegan Paul, Trench and Trübner.

Jevons, H. S. (1933). The Causes of Fluctuations of Industrial Activity and the Price-Level. *Journal of the Royal Statistical Society, 96*, 545–605.

Jevons, W. S. (1865). *The Coal Question* (2nd ed.). Macmillan and Company.

Jevons, W. S. (1871). *The Theory of Political Economy*. Macmillan and Company.

Jevons, W. S. (1878). Commercial Crises and Sun-Spots. *Nature, 19*, 33–37.

Jevons, W. S. (1909a). Chapter VI, The Solar Period and the Price of Corn (1875). In *Investigations in Currency and Finance* (pp. 194–205). Macmillan.

Jevons, W. S. (1909b). Chapter VII, The Periodicity of Commercial Crises and Its Physical Explanation (1878), with Postscript (1882). In *Investigations in Currency and Finance* (pp. 206–220). Macmillan.

Jevons, W. S. (1909c). Chapter VII Commercial Crises and Sunspots Part I (1878). In *Investigations in Currency and Finance* (pp. 221–234). Macmillan.

Jevons, W. S. (1909d). Chapter VII Commercial Crises and Sunspots Part II (1879). In *Investigations in Currency and Finance* (pp. 235–243). Macmillan.

Jin, T., & Kim, J. A. (2019). New Approach for Assessing the Macroeconomic Growth Energy Rebound Effect. *Applied Energy, 239*, 192–200.

Jones, C. J. (2001). *Introduction to Economic Growth*. W.W. Norton.

Jones, C. T. (1993). Another Look at U.S. Passenger Vehicle Use and the Rebound Effect from Improved Fuel Efficiency. *The Energy Journal, 14*, 99–110.

Jonsson, F. A. (2013). *Enlightenment's Frontier: The Scottish Highlands and the Origins of Environmentalism. The Lewis Walpole Series in Eighteenth-Century Culture and History*. Yale University Press.

Jorgenson, D., & Fraumeni, B. (1981). Relative Prices and Technical Change. In E. R. Berndt & B. C. Field (Eds.), *Modeling and Measuring Natural Resource Substitution*. MIT Press.

Jorgenson, D. W., & Griliches, Z. (1967). The Explanation of Productivity Change. *The Review of Economic Studies, 34*, 249–283.

Kaufmann, R. K. (1994). The Relation Between Marginal Product and Price in Us Energy Markets—Implications for Climate Change Policy. *Energy Economics, 16*, 145.

Khazzoom, J. D. (1980). Economic Implications of Mandated Efficiency Standards for Household Appliances. *The Energy Journal, 1*, 21–40.

Koopmans, C. (1997). NEMO: CPB's New Energy Model. *CPB Report, 2*, 34–37.

Koopmans, C. C., & te Velde, D. W. (2001). Bridging the Energy Efficiency Gap: Using Bottom-Up Information in a Top-Down Energy Demand Model. *Energy Economics, 23*, 57–75.

Kurzweil, R. (2005). *The Singularity Is Near: When Humans Transcend Biology*. Penguin.

Kuznets, S. (1995). Economic Growth and Income Inequality. *The American Economic Review, 45*, 1–28.

Laitner, J. A., De Canio, S. J., & Peters, I. (2003). Incorporating Behavioural, Social, and Organizational Phenomena in the Assessment of Climate Change Mitigation Options. Society, Behaviour, and Climate Change Mitigation. *Advances in Global Change Research, 8*, 1–64.

Lin, B., & Liu, H. (2015). A Study on the Energy Rebound Effect of China's Residential Building Energy Efficiency. *Energy and Buildings, 86*, 608–618.

Linn, J. (2016). The Rebound Effect for Passenger Vehicles. *The Energy Journal, 37*, 257–288.

Liu, H., Du, K., & Li, J. (2019). An Improved Approach to Estimate Direct Rebound Effect by Incorporating Energy Efficiency: A Revisit of China's Industrial Energy Demand. *Energy Economics, 80*, 720–730. https://doi.org/10.1016/j.eneco.2019.02.012

Llorca, M., & Jamasb, T. (2017). Energy Efficiency and Rebound Effect in European Road Freight Transport. *Transportation Research Part A, 101*, 98–110.

Malthus, T. R. (1798). *An Essay on the Principle of Population, as it Affects the Future Improvement of Society with Remarks on the Speculations of Mr. Godwin, M. Condorcet, and Other Writers*. J. Johnson.

Mantegna, R. N., & Stanley, H. E. (2001). *An Introduction to Econophysics: Correlations and Complexity in Finance*. Wydawnictwo Naukowe PWN.

Marrero, G. A. (2010). Greenhouse Gases Emissions, Growth and the Energy Mix in Europe. *Energy Economics, 32*, 1356–1363.
Marshall, J. (1878). The Coal Question. In T. E. Thorpe (Ed.), *Coal: Its History and Uses* (pp. 292–319). Macmillan.
Martínez Alier, J., & Roca, J. (2000). *Economía ecológica y política ambiental.* Fondo de Cultura Económica.
McCulloch, J. R. (1830). *Observations on the Duty of Sea-borne Coal; and on the Peculiar Duties and Charges on Coal.* Manning and Co.
Meadows, D. H., & Club of Rome's Project on the Predicament of Mankind. (1972). *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind*. Universe, A Potomac Associates Book.
Mill, J. S. (1848). *Principles of Political Economy.* Little & Brown.
Mill, J. S. (1850). The Negro Question. *Fraser's Magazine for Town and Country, XLI*, 29.
Missemer, A. (2017). *Les Économistes et la fin des énergies fossiles (1865–1931)* (p. 225). Classiques Garnier, Series: Bibliothèque de l'économiste.
Mizobuchi, K. (2008). An Empirical Study on the Rebound Effect Considering Capital Costs. *Energy Economics, 30*, 2486–2516.
Musters, A. P. A. (1995). *The Energy Economy Environment Interaction and the Rebound Effect*. Netherlands Energy Research Foundation.
Owen, D. (2010). Annals of Environmentalism the Efficiency Dilemma What's the Best Way to Use Less Energy? *The New Yorker, 78*, 78.
Peart, S. J. (1991). Sunspots and Expectations: W. S. Jevons's Theory of Economic Fluctuations. *Journal of the History of Economic Thought, 13*, 243–265.
Petty, W. (1662). A Treatise of Taxes and Contributions. In C. H. Hull (Ed.), *The Economic Writings of Sir William Petty* (pp. 1–97). Augustus M Kelley.
Quesnay, F. (1767/2005). Maximes generals du gouvernement économique d'un royaume agricole. In C. Théré, L. Charles, & J. C. Perrot (Eds.), *François Quesnay. Oeuvres économques completes et autres textes* (pp. 565–596). INED.
Ricardo, D. (1815). *Essay on Profits.* London.
Ricardo, D. (1817/1911). *The Principles of Political Economy and Taxation.* Dent & Dutton.
Richmond, A. K., & Kaufmann, R. K. (2006). Is There a Turning Point in the Relationship Between Income and Energy Use and/or Carbon Emissions? *Ecological Economics, 56*, 176–189.
Rifkin, J. (2000). *The Age of Access: The New Culture of Hypercapitalism, Where All of Life Is a Paid-for Experience*. Putnam Publishing Group.
Rifkin, J. (2002). *The Hydrogen Economy: The Creation of the Worldwide Energy Web and the Redistribution of Power on Earth.* Jeremy P. Tarcher.
Rifkin, J. (2011). *The Third Industrial Revolution: How Lateral Power Is Transforming Energy, the Economy and the World.* Palgrave Macmillan.

Rifkin, J. (2019). *The Green New Deal: Why the Fossil Fuel Civilization Will Collapse by 2028, and the Bold Economic Plan to Save Life on Earth*. St. Martin's Press.

Rosenberg, N. (1989). *Energy Efficient Technologies: Past, Present and Future Perspectives. How Far Can the World Get on Energy Efficiency Alone?* ORNL.

Rosser, J. B. (2016). Entropy and Econophysics. *The European Physical Journal Special Topics, 225*(17–18), 3091–3104. https://doi.org/10.1140/epjst/e2016-60166

Ruzzenenti, F., & Basosi, R. (2007). Energy Growth, Complexity and Efficiency. In J. Palm (Ed.), *Energy Efficiency*. Sciyo.

Ryan, L., & Campbell, N. (2012). Spreading the Net: The Multiple Benefits of Energy Efficiency Improvements. *IEA Energy Paper*, 27–49.

Samuelson, P. A. (1980). *Economics*. 11a. ed. New York: McGraw-Hill Book Company.

Santarius, T., Walnum, H. J., & Aall, C. (Eds.). (2016). *Rethinking Climate and Energy Policies: New Perspectives on the Rebound Phenomenon; Cham*. Springer.

Saunders, H. (1992). ·The Khazzoom-Brookes Postulate and Neoclassical· Growth. *The Energy Journal, 13*, 131–148.

Săvoiu, G., & Simăn, I. (2013). Chapter 1—History and Role of Econophysics in Scientific Research. In G. Săvoiu (Ed.), *Econophysics* (pp. 3–16). Academic Press.

Say, J.-B. (1828). *Cours complet d'économie politique pratique* (p. 2). Rapilly.

Schleich, J., Mills, B., & Dütschke, E. A. (2014). Brighter Future? Quantifying the Rebound Effect in Energy Efficient Lighting·. *Energy Policy, 72*, 35–42.

Senior, N. W. (1836/1965). *An Outline of the Science of Political Economy*. Augustus M. Kelley.

Simonin, L. (1867). *La vie souterraine ou les mines et les mineurs*. Hachette.

Solow, R. (1973). Is the End of the World at Hand? *Challenge*, *16*, 39–50.

Solow, R. (1974). The Economics of Resources or the Resources of Economics. *American Economic Review, 64*, 1–14.

Sorrell, S. (2009). Jevons Paradox Revisited: The Evidence for Backfire from Improved Energy Efficiency. *Energy Policy, 37*, 1456.

Sorrell, S., & Dimitropoulos, J. (2008). The Rebound Effect: +623.Microeconomic Definitions, Limitations and Extensions. *Ecological Economics, 65*, 636.

Sorrell, S., Dimitropoulos, J., & Sommerville, M. (2009). Empirical Estimates of the Direct Rebound Effect: A Review. *Energy Policy, 37*(4), 1356–1371. https://doi.org/10.1016/j.enpol.2008.11.026

Stern, D. I. (2004). The Rise and Fall of the Environmental Kuznets Curve. *World Development, 32*, 1419.

Stern, D. I., & Cleveland, C. J. (2004). *Energy and Economic Growth*. Rensselaer Polytechnic Institute Troy.

Thomas, B. A., & Azevedo, I. L. (2013). ·Estimating Direct and Indirect Rebound Effects for U.S. Households with Input-Output Analysis Part 1: Theoretical Framework. *Ecological Economics, 86*, 199–210.

Torrie, R. D., Stone, C., & Layzell, D. B. (2018). ·Reconciling Energy Efficiency and Energy Intensity Metrics: An Integrated Decomposition Analysis. *Energy Efficiency, 11*, 1–18.

Trincado, E., Sánchez-Bayón, A., & Vindel, J. M. (2021). The European Union Green Deal: Clean Energy Wellbeing Opportunities and the Risk of the Jevons Paradox. *Energies, 14*, 4148. https://doi.org/10.3390/en14144148

Veblen, T. (1904). *The Theory of Business Enterprise*. Martino Fine Books.

Velthuijsen, J. W. (1995). *Determinants of Investments in Energy Conservation*. Ph.D. Thesis, University of Groningen, Groningen, The Netherlands.

Vindel, J. M., & Trincado, E. (2010). The Timing of Information Transmission in Financial Markets. *Physica A: Statistical Mechanics and its Applications, 389*(24), 5749–5758. https://doi.org/10.1016/j.physa.2010.08.048

Vindel, J. M., & Trincado, E. (2021). Viability Assessment of Algal Wastewater Treatment Projects Under Outdoor Conditions Based on Algal Productivity and Nutrient Removal Rate. *Renewable and Sustainable Energy Reviews, 150*, 111435. https://doi.org/10.1016/j.rser.2021.111435

Vindel, J. M., Trincado, E., & Sánchez-Bayón, A. (2021). European Union Green Deal and the Opportunity Cost of Wastewater Treatment Projects. *Energies, 14*, 1994.

Wackernagel, M., & Rees, W. E. (1997). Perceptual and Structural Barriers to Investing in Natural Capital: Economics from an Ecological Footprint Perspective. *Ecological Economics, 20*, 3.

Wang, Z., & Lu, M. (2014). An Empirical Study of Direct Rebound Effect for Road Freight Transport in China. *Applied Energy, 133*, 274–281.

Wei, T., & Liu, Y. (2017). Estimation of Global Rebound Effect Caused by Energy Efficiency Improvement. *Energy Economics, 66*, 27–34.

Wei, T., Zhou, J., & Zhang, H. (2019). Rebound Effect of Energy Intensity Reduction on Energy Consumption. *Resources, Conservation and Recycling, 144*, 233–239.

Wei, Y.-M., Liang, Q.-M., Wu, G., & Liao, H. (2019). *Energy Economics: Understanding Energy Security in China*. Emerald Publishing Limited.

Westergård, R. (2018). *One Planet Is Enough: Tackling Climate Change and Environmental Threats Through Technology*. Springer.

Wing, I., Sue, E., & R.S. (2007). The Implications of the Historical Decline in Us Energy Intensity for Long-Run CO_2 Emission Projections. *Energy Policy, 35*, 5267.

Wing, S. I. (2008). Explaining the Declining Energy Intensity of the U.S. Economy. *Resource and Energy Economics, 30*, 21.

Wolf, S., Teitge, J., Mielke, J., Schütze, F., & Jaeger, C. (2021). The European Green Deal—More than Climate Neutrality. *The International Economy, 56*, 99–107.

Wright, A. J., Formby, J. R., & Holmes, S. J. (2000). *A Review of the Energy Efficiency and Other Benefits of Advanced Utility Metering*. EA Technology.

York, R. (2006). Ecological Paradoxes: William Stanley Jevons and the Paperless Office. *Human Ecology Review, 13*, 143–147.

Zhang, Y. (2019). Energy Rebound Effect Analysis Based on Technological Progress. *Conference Series: Earth and Environmental Science, 300*.

CHAPTER 7

Max Weber: Science, Technology and Vocation

Alfredo Macías Vázquez

7.1 Introduction

In 1917, Weber (2004) was invited to give a lecture at the University of Munich. Weber's intention was to respond to a question of interest to the young students: what can make science attractive as a vocation (*Beruf*). By then, science had long ceased to be a way of knowing the divine. Research no longer had anything to do with the passionate dedication to solving a mystery, which required assuming that the universe had been created by

A. M. Vázquez (✉)
University of León, León, Spain
e-mail: amacv@unileon.es

E. Trincado Aznar, F. López Castellano (eds.), *Science, Technology and Innovation in the History of Economic Thought*, Palgrave Studies in the History of Economic Thought,
https://doi.org/10.1007/978-3-031-40139-8_7

God[1] and that knowing nature meant knowing God better. However, at the beginning of the twentieth century, science was at the service of the rationalization process that dominated Western modernity, giving rise to specialization in autonomous disciplines in a totally disenchanted and soulless world.

Weber's lecture probably disappointed his young audience, who was critical of scientific specialization and the utilitarian subordination of science and the work of academics to capitalist development. Weber admitted that the rationalization process, which was intimately related to scientific progress, had caused a separation between science and life, which hindered the possibility of addressing scientific work in a unitary and humanistic sense. But, unlike the students, Weber thought that the rationalization process should not be avoided, because it had a meaning that went beyond the increasing instrumental rationality resulting from it. For the famous lecturer, scientific work continued to be meaningful and was still capable of nurturing a vocation. The problem was that the question about its meaning should not be formulated in relation to the general context of life and the value judgments of the world. Weber considered that, in reality, the values present in science formed a subsystem that was in competition with other alternative subsystems. In his view, science not only derived from some specific set of value judgments, but it was a normative criterion in itself (Crease, 2019). To use a contemporary example, during the recent global pandemic, there were scientists who committed themselves to developing a vaccine that would stop the expansion of the disease. But there were also other individuals who worked toward the same goal by, for instance, taking care of older people who were confined in their homes or making homemade masks with the available materials.

In order to understand Weber, it is important to recognize the originality of his thought, particularly the way in which he synthesized and combined historical and anthropological factors in his analysis of the

[1] Since the eighteenth century, natural theology, also known as rational theology or clerical naturalism, had been very much in vogue as a reaction to the scientific revolution. It provided a method for finding evidence of God's existence without resorting to supernatural revelation, and therefore differed from revealed theology, which had been prevalent before, and was based on the holy scriptures and on religious experiences. In general, clerical naturalism tried to prove God's existence through the study of nature. God, according to this school, manifested himself through the works of his creation. In that sense, the universe could only be the work of a supreme being. Scientists like Newton or Boyle, or Malthus himself, belonged to that school of thought.

determinants of the development of the different socioeconomic systems. In the same way as nineteenth-century political economy did, Weber naturalized capitalism and used an ontological principle to explain human behavior: the pursuit of self-interest through the use of reason[2] was, in his view, the universal motivation explaining individual actions and, as a result, social evolution. However, he did not imply that this ontological principle could, by itself, explain the historical specificity of Western capitalism (Ingham, 2008). In fact, Weber went so far as to claim that the principle manifested itself more clearly in certain Asian societies, where intensely lucrative forms of commercial capitalism had been developed. On the contrary, the Western singularity was better explained by its capacity to regulate those greedy impulses and to integrate formal rationality in the calculation of profit, which was systematically reinvested in the firms created as autonomous entities, separate from the families and the State. In other words, by restraining their immediate pecuniary instinct, people could achieve continuous and sustained profitability over time.

This historical outcome was reached through ethical consensus. While Marx considered that primitive capital accumulation had a violent origin, Weber (2002) believed that the internalization of these norms of economic behavior could only be achieved through a shared ethics. More specifically, the Protestant ethic, particularly its Calvinist version, served this historical function. In other words, it was a cultural and religious form which crystalized the new economic system. The paradox lies in that Calvinist asceticism, in its eagerness to separate itself from the world, unintentionally ended up giving rise to the economic system that has historically caused the largest transformation and exerted the largest control over the world. From that moment onwards, human life was considered successful so far as rational calculation was applied, professional specialization increased, scrupulous and tireless work generalized, and hedonistic enjoyment of profit given up. In parallel, this implied the end of the brilliant and charismatic authority, and the subordination of the individuals to bureaucratic organization. Thus, what started as an ethical choice ended

[2] Similarly to Vico and Comte, Weber thought that rationalization was a basic feature of humankind since its origins, which was used to dominate nature. For instance, if there was a persistent drought, people prayed to the divinity, asking for rain. But during the scientific revolution, things started to change and did so substantially. Traditional practices were marginalized and rational calculation began to govern most social activities in an inflexible manner.

up being imposed as an obligatory fate, an objective and automatic way of life, where the individuals found themselves trapped in an iron cage.

How can one live in a world like that? The problem was, basically, that the Puritan work ethic implied a constant accumulation of wealth, which could lead to the corruption of the individual, always suspected of falling back into hedonistic behavior. The only solution was to further incentivize the ascetic, methodical behavior, which in turn exhausted the individual's energy, and their ability to draw enthusiasm from new prophecies. In other words, the question that really worried Weber was how to live in a progressively disenchanted world, where humanity was trapped in a mechanistic structure, unable to renovate itself, immersed in cold, listless specialization. In *Science as a vocation*, Weber's intention (2004) was precisely to define a specialization that escaped this tragic fate. He wondered how one could passionately give oneself to science in a world dominated by social automatisms and bureaucratic coldness, where advances in knowledge were absolutely temporary, incapable of surviving scientific progress and of generating charisma. He also asked himself how to surrender to such passion without falling into minority elitism, aristocratism, the defense of ultimate and supreme values (Nietzsche, 2013). In addition, he raised the question about how to devote oneself to the quest for scientific truth beyond all technological mediations, and about what type of mental and psychic structure could nurture the scholar's vocation in a merciless environment. We will start this chapter by analyzing Weber's response to these questions and will continue by assessing the feasibility of his proposition in the contemporary context of the technoscientific revolution. Finally, we will critically discuss Weber's postulates in relation to Marx's approach.

7.2 Science and Values

How can we describe a scientific personality when the most passionate motivations to undertake scientific research are gone, when all researchers are aware that their personal contribution will be overthrown by subsequent scientific progress. These are undoubtedly complex questions. In fact, in academic environments, it is not uncommon that after overcoming the obstacles associated with professional promotion, the teaching and researching staff lack the incentive to continue researching and feeling passionate about their work. Ascetic behavior, based on order and discipline, certainly fits in well with the methodical life required for scientific

activity. Faced, however, with the disappearance of charismatic authority in a disenchanted world, Weber wonders which psychic sublime could replace it, thus making it possible for the individual to devote themselves to science. For Weber, underneath the mechanistic structure, a minimum degree of freedom should be preserved in order to allow for passion to germinate and facilitate the giving of one's life to science, without everything being reduced to the rational consideration of the different options.

Lives devoted to science, however passionately, cannot be conceived in isolation, nor can they respond to universal or general impositions emanating from a charismatic authority. Such dedication is only possible within small scientific communities, built on pluralistic values and voluntary bonds between their members. This way of bonding is completely different from one based on a monotheistic conception of value as promoted by strong and charismatic authorities. In this sense, an academic should be humble and admit that the values that support their passion for research must not be imposed on anyone else, rather than disregard those who do not share their own values. Weber states that every scientific community needs to be based on aspirations and values that enable their members to be passionate about their research activity in a non-narcissistic way. He considers that this is the only way to prevent the iron cage from being definitely and fully imposed as the only possible source of obedience and discipline. An ascetic, exacting, methodical, non-narcissistic passion, based on total surrender to the cause, is thus necessary.

In this sense, it is important to clarify that, in his advocation for value neutrality and a value-free science (*Wertfreiheit*), Weber did not expect scholars to avoid any adherence to values. By supporting the independence of science with respect to values, Weber meant to oppose historicism, Marxism and utilitarianism. However, as underlined by Parsons (1965), Weber argued that every academic community stands on its own subsystem of values, namely, those that are typically associated with science: clarity, coherence, conceptual generality and empirical precision. According to Weber, science must be value-free in the sense that it does not need to sacrifice its own subsystem of values to other, conflicting values belonging to another social or cultural subsystem. On the other hand, *Wertfreiheit* does not require the researcher to take a stance in a wider cultural sense, nor does it imply that their values need to be linked to a specific culture, as advocated by historicism.

Obviously, Weber was not naïf. He was perfectly aware that science is guided by society's set of values. But, in his opinion, this fact is not

incompatible with science's fundamental independence. In fact, he developed a methodological setting that sought to guarantee it (Weber, 2011). In reality, Weber was trying to solve another problem, the one caused by the spiritual exhaustion of capitalism in an increasingly disenchanted world. In this historical context, the academic, as a human being, needs to create a vocational bond with science in consonance with the values of the scientific community. Only this way will it be possible to respond to the double challenge posed by capitalist rationalization, bureaucratization and socialization. As mentioned before, it is necessary to preserve a certain degree of freedom with respect to the growing mechanistic and bureaucratic framework that dominates academic life. In addition, it is important to acknowledge that science is not an individual activity but increasingly organized from a social point of view, as modern society is.[3]

In this sense, it is important to keep in mind the historical circumstances in which the debate on science and values gained prominence. First of all, we must consider that the debate was conditioned by the vicissitudes in the development of the principal sciences at the end of the nineteenth century. During that period, scientific activity was indeed so intense that it shook the whole social structure. The map of academic disciplines changed dramatically: some sciences expanded and colonized other disciplines, as was the case with Mathematics; others separated from the common root and became independent, as it happened with Sociology and Psychology; others, such as Chemistry or Physics, were reinvented and consolidated on new theoretical bases. The method dispute (*Methodenstreit*) was the background against which this process took place. Within the context of this controversy, the methodological distinction between natural and social sciences took shape, and the concept of "value" had a place in that distinction. In contrast with previous definitions, that concept was now understood as linked to historical and cultural meaning, thus leaving the narrow economic realm. In parallel, the process of secularization experienced by Western societies was fed by scientific progress and the consolidation of new disciplines. The disenchantment of the world and the decline of religious spirituality made it necessary to find a new meaning for life, which was eventually identified with the idea of progress. This idea naturally implied an assessment, a judgment concerning social improvement, a reference to values. The foundation and the content of progress

[3] It is clear that Weber's reflections greatly influenced subsequent discussions on the philosophy of science (Kuhn, 2012).

were provided by the scientific and technological advances of that period, which generated a climate of intellectual excitement, especially reflected in the development of positivism.

However, positivism decisively contributed as well to creating an atmosphere of suspicion, distance and opposition between spirit and nature, between feeling and reason. Authors as relevant as Weber or Pareto (founding fathers of Sociology who nevertheless considered themselves as economists rather than sociologists) conceived the interference of values in scientific research as a threat to the progress of knowledge (thus, the need for *Wertfreiheit*). This dichotomous conception led to the objectivization of social phenomena and transformed their study into actual scientific elaborations (Weber, 2011; Pareto, 1978). Yet, Weber, much like Menger (2019), did not fully share this extreme naturalistic monism. Both authors realized that it is impossible to separate the social from the natural without granting humanity a certain ontological privilege. For instance, in his *Principles*, Menger clearly advocated that the decision to define a knowledge of social things as science should be based on values, that is, that values should be at the root of the constituent principles of that science. From Weber's perspective, sciences were highly responsible for the world's disenchantment, the death of spirit, the imposition of the iron cage. Values are the only irreducible reality allowing us to harbor some hope. They have come to occupy the place that archaic religions occupied in the past; they represent a return to ancient polytheism. The ancient pagan gods were crushed by Christian monotheism, which over time, as we already know, derived into an ethical consensus that activated the development of Western capitalism (Weber, 2002). But, in reality, those gods remained alive as incandescent embers of a poorly extinguished fire. As Nietzsche announced (2008), ancient gods always come back. Or, as Heidegger claimed, only a god can save us (Sheehan, 1981). Weber believed that, despite having been exiled by Christianity, the pagan gods have always been there somehow. In Greece, they took the objective form of personified myths and sculptures (Eliade, 2020). In our disenchanted and rationalized world, they cannot return in those concrete forms, but in the abstract form of values, as objective superhuman structures embodied in us, as demons pulling the strings of our lives and our passions.

Therefore, in Weber's view, the disenchantment is not complete. Values are necessarily present in the debate on the statute of science, which cannot be reduced to knowable facts. Accordingly, sciences cannot be considered pure theory, immaculate knowledge. In reality, as the modern philosophy of sciences acknowledges, sciences are but another institutional subsystem

and research communities are steeped in values (Kuhn, 2012). But this is not the problem. The background issue is that these conceptions continue to approach the relationship between facts and values from a dichotomous point of view. Values are considered mere "guests" at the "party" of scientific progress. They may be accepted at the "party", but should they get "intoxicated" to the point of believing they are more important than they actually are, they will be thrown out the back door. As a matter of fact, that was what Weber did (2011). He recognized the existence of values and acknowledged the fact that the work of scholars is conditioned by certain goals. Then, he developed a methodology that enabled the development of pure science. This procedure was fully integrated in contemporary scientific methodology: to make value judgments explicit, to get rid of them immediately afterward. It is so much taken for granted that we are not even capable of tracing back its origin. However, is this methodological approach enough? Doesn't history and the evolution of science show us that the dichotomous scheme is insufficient (not to say mistaken) when it comes to analyzing the relationship between sciences and values?

7.3 The Technoscientific Revolution

Science discovered an uncomfortable truth and called into question the religious explanation of the origin of the world, from which the ethics that guided the practical behavior of human beings emanated up to that point. The development of the empirical sciences decisively fostered the disenchantment of the world and configured a modernity that detached itself from all religious interpretations and produced a new image of the universe, while describing the previous one as irrational. This way, nature came to be explained by casual laws, after the removal of all purpose-oriented connotations from the concept of "causality", which led to the retreat of ethics from the sphere of ultimate and sublime values toward that of personal privacy (Weber, 1993). To a large extent, this bifurcation set the basis for the dichotomous scheme described at the end of the previous section. On the one hand, rationality and scientific objectivity were applied to the conceptual knowledge of empirical facts, while, on the other, ethics were subordinated to subjective evaluations, which do not depend on reason. In other words, the process of rationalization that characterizes Western modernity dealt a heavy blow not only to religion, but to all critical theories that connected the being with the ought-to-be (Lambruschini, 2021). This context became the ideal brooding ground

for the proliferation of a plural living practice, where different valuation subsystems (economic, politic, aesthetic, scientific, religious, etc.) appeared separately, while a mechanistic and automatic framework (in fact, a renovated ethical irrationalism) bound them together. This framework was a paradoxical (and non-intentional) outcome of the theoretical rationalization of every aspect of social life carried out by science. The more complex modernity became, the more those trends were exacerbated, often reaching a tragical dimension.

This disenchanted modernity was therefore built upon an absolute lack of meaning at a global level and led to a devastating ethical irrationalism that constantly showed how powerless the systems elaborated by philosophers and the particular assessments made by atomized individuals were. Modern societies were fragmented and became entrenched in unsolvable normative conflicts. In reality, postmodernism is but the zenith of this process, the outbreak of an endless Hobbesian war in the normative sphere. While the world became progressively disenchanted, the establishment of universal criteria to guide the practical life of people proved unfeasible unless the value subsystem of some individuals was sacrificed, in other words, unless the particular values of a specific group were imposed on the rest. This way, personal privacy became subject to the pressure exerted from the various spheres in which human life is developed, each of them driven by different and often antagonistic value subsystems (among them, the scientific subsystem) vying to govern the practical behavior of individuals. Weber understood this social dynamic as an ontological fact, as a given, and disregarded the elaboration of a critical theory (which the Frankfurt School would later on undertake, based on similar categories). Weber opted for an absolute polytheism of values (manageable, in principle, within a tolerant democratic culture), which, as mentioned before, was a disenchanted version of the ancient pagan gods (Schluchter, 1985). In modernity, however, values emerge as impersonal powers, abstract forms, worldviews, which do not naturally emanate from the community itself, but among which the individual is compelled to choose, apparently on their own free will, as if choosing among competing products in the market but actually knowing that choosing a certain set of values implies opposing those of their rivals.

The main difference between modernity and traditional societies, or archaic religiosity, is that the individual choice of values involves responsibility for its practical implications, as well as for the individual's own destiny. In this sense, the modern individual can see how the ethics of

conviction and the ethics of responsibility are irrevocably combined. Nevertheless, to the eyes of the modern individual, the eligible set of values appears as something objective, as a given, and they tend to adopt those values unthinkingly. Therefore, science provides conceptual tools that help individuals live an autonomous and rational life, following their own beliefs and taking responsibility for their practical consequences (Weber, 2004). More specifically, scientific practice enables them to rise above their instinctive existence and know beforehand the rational motivations and practical implications of their actions, which is associated with a greater degree of freedom (Mommsen, 1965). But during the process of curricular specialization and the subsequent deepening of empirical research, the methodical practice of the scholar is increasingly devoid of any transcendental meaning, until it becomes a simple activity dominated by scientific technology. Thus, the problem does not lie exclusively in the need to liberate science from the values of other institutional subsystems (*Wertfreiheit*), but in the fact that scientific activity no longer has any transcendental implications. Weber repeatedly warned of the danger of future societies being exclusively dominated by technology (Freund, 1966). Philosophy, which used to link advances in knowledge to existential aspirations, is definitely defeated, whereas scientific practice, having more instrumental and ephemeral purposes, is triumphantly progressing. Ultimately, the technoscientific revolution is but the unavoidable outcome of the exacerbation of instrumental rationality in all spheres of social and academic life.

In other words, despite Weber's intention to develop a science based on vocation, as an unassailable stronghold where a certain degree of freedom will be preserved in the face of the relentless expansion of the iron cage, scientific practice has actually surrendered to disenchantment. Even if, as will now be analyzed, the discourses associated with the new technoscientific revolution tend to highlight the prominence of innovation, creativity and entrepreneurship, while they encourage young people to specialize in the study of certain disciplines, the rationalization process is in fact advancing inexorably and bringing academic activity under the automatic mechanism of the iron cage. Weber (2004) was certainly pessimistic with regard to the possibility of giving meaning to science. However, he proposed an ascetic and self-restrictive conception of scientific vocation as a lesser evil. From Weber's point of view, the activity of a scientist may progress even if they forgo pursuing an aim. Obviously, accepting this possibility involves admitting the existence of a forward movement, an objective progress,

which transcends the individual. Scholars accept with resignation the fact that their contribution may later on be surpassed by the work of their colleagues, given that the general movement toward progress manifests itself with overwhelming objectivity, as an autonomous social force that outweighs them. Unlike many of his contemporaries, Weber did not intend to avoid rationalization, he tried to find a pragmatic meaning for the scientist's life within this process. Similarly to Tolstoy, he believed that science cannot tell us how we should live. But he did not expect science to respond to this fundamental question, which would in fact be impossible due to the persistent conflict between value subsystems that cannot be rationally explained. Under these circumstances, the individual can only choose between one set of values and another, and the academic must give them up all in their rationalized professional activity. In Weber's view, the scientist is neither a prophet nor a political leader.

Considering these limitations, it was foreseeable that technology would become autonomous from science. In other words, it was foreseeable that the traditional foundations of the theory of knowledge would be questioned by reality itself, for those foundations were based on the idea that technology was but applied science, that is, a mere outcome of scientific knowledge. During the last century, we have witnessed the gradual separation of the dynamics of science from those of technology. In principle, the technoscientific revolution has given greater prominence to conception (design, engineering, etc.) than to execution in production processes, which should apparently rekindle Weber's hopes. However, it is important to avoid drawing any ideological conclusions. In reality, the ethics of responsibility cannot be combined with the ethics of conviction anymore, insofar as the possibilities of proposing and disposing in the phase of intellectual conception are absolutely separate. For instance, how can a scientist's sensible behavior matter when technological dynamics have a life of their own, when conception is fully subsumed into the mechanical and automatic execution of the production process? From the prevalence of conception work, it is impossible to infer any kind of emancipation of immaterial labor from production itself, not even a relative reconciliation between intellectual and manual work (Macías Vázquez, 2017). In fact, it is quite the opposite. Since the first industrial revolution, the general knowledge accumulated by society has turned against the particular knowledge of the immediate producers through the mechanization process associated with large-scale industrialization. With the new technoscientific revolution, this process has made a qualitative leap forward with the

subsumption of immediate scientific work into the mechanistic framework of capitalist modernity. More recently, a similar process has taken place among artists and other professionals, such as publicists and designers, who do immaterial labor. Numerous professionals, including doctors, lawyers and teachers, who until now had enjoyed a special vocational status, are now directly subjected to the logic of rationalization and to the iron cage.

Suárez-Villa (2012) analyzed in detail the mechanical rationalization of scientific work. In fact, the most important thing in research is not anymore to discover the truth but to meet the sacrosanct criteria of economic profitability. But no matter how much capitalist programming of research is implemented, the process is never simple, for it is not easy to maintain a creative drive when the main objective is economic profitability. Creating is not the same as tightening a screw. Creativity has a fragile and intangible nature. It is particularly resistant to standardization or quantification, despite the continuous efforts to bureaucratize it (Graeber, 2015). For these reasons, stimulating the productivity of a scientific researcher is more complex than increasing that of an industrial worker (the industry being a field in which various production organization methods, for instance, those inspired by Taylorism, have been relatively successful). On the other hand, despite the attempt to depict scientists as individuals who work alone in their laboratories, the reproduction of scientific creativity is in fact supported by networks and relationships within the social context, where scientists interact with various actors (Tarde, 1969). The social context is also essential as a provider of ideas to the researchers, as well as to increase their capacity to imagine, to think differently, to undertake experiments and to understand the risk and the uncertainty that belong in the creative process. However, the logic of rationalization also operates at that level, in a way that reinforces alienated behaviors in relation to what is possible to imagine, the variety of ways of thinking that are allowed, the type of experiments that can be conducted or the way that the risk and uncertainty associated with those experiments are addressed.

The transformation of talent into economic value is almost always a humanly degrading experience. But even when it is not, it is in clear disagreement with the creative effort or the creative practice. Thus, by conditioning the imagination, economic valorization may become the main source of alienation for researchers. In order to fight the possible negative effects of this type of conditioning on the productivity of scientific work, the technoscientific revolution is in urgent need to develop an ideology, to build a propaganda apparatus around the valorization of scientific

creativity, in order to spread the idea that the economic logic becomes more democratic in the new capitalist landscape (Florida, 2002). In this sense, it repeatedly reproduces the narrative on entrepreneurship and innovation (Schumpeter, 2021). The purpose is to persuade us that we all have opportunities to succeed and to participate in the gestation of this new society of knowledge and innovation as long as we have new ideas that can be applied to production (Hanlon, 2014). However, the harsh reality is that only large corporations have the resources required for it and are progressively appropriating social creativity in a private and parasitical way. In this sense, we are facing the transformation of profit into rent (Vercellone, 2008), which fundamentally calls into question the ethical sense of business activity as envisaged by Weber (2002). In order to achieve their goals, large technocapitalist corporations, such as Apple, Microsoft or Google, to mention only a few relevant examples, must steer the research process and activity in a particular direction, furthering their instrumental rationalization. For that purpose, certain procedures are specifically configured, including the design of experiments, the test trials, the interpretation of results, the development of new phases in the activity or the combination with other experiments. Even if it has a damaging effect on the overall vision and on the social interactions that drive the research, the different phases of the creative activity are increasingly fragmented and systematized as part of the process of rationalizing and structuring it. This way, scientific work processes are standardized, controlled and made measurable, as if on a Taylorist assembly line in the automobile industry.

Secondly, the creative process needs to be disconnected from its original context and alienated from the real flesh-and-blood people who carry it out. Given the difficulty to identify the exact contribution of each individual to the results of the research, their commercialization may unfold as a process completely detached from the new ideas, processes, formulas, methods or services. Nowadays, in many activities, the object created has been completely deprived of authorship to the benefit of the large technocapitalist corporations. Thus, an objectifying fetishism is crudely imposed on this field (Marx, 1990), even as reputational rites (prizes, promotions, etc.) are presented as the most attractive incentive for researchers. In parallel, an attempt is made to introduce fetishist mechanisms in order to conceal this process of objectification. For instance, an illusion of control over the results of the research on the part of the scholars involved in it is generated. For this reason, autonomous initiatives based on multidisciplinary research teams are often established, so that the teams can organize

themselves and strengthen their creative power. In addition, intrinsic values, such as altruism and self-esteem, tend to be emphasized (through the possibility of gaining prestige and acknowledgment) over extrinsic values, which are associated with more traditional tools such as salary rises, promotions or stock options. This way, scientific communities are usually a long way off from Weber's ideals, bonded by corporative narratives, offered intrinsic incentives presented as corporative values. Ultimately, the purpose is to achieve corporative alienation and appropriation in a way that is more acceptable to academics, while it strips them of any capacity to make a value choice.

Finally, a permanent state of urgency is imposed on all aspects related to time and speed in research activity. On the one hand, an obsessive concern for providing a rapid response to unexpected events is settled in the corporative sphere. This has to do with short-term financial pressures and the competition between technocapitalist corporations as they struggle to develop new globalized innovations. In this sense, failures such as that of Nokia are frequently explained as lack of reflexes or slowness in responding to the strategies of its immediate competitors. To create this obsessive environment, a layer of dynamic agents is superimposed on that of the researchers and their assistants for the purpose of stimulating and controlling their innovation capacity and their rate of performance. On the other hand, as a result of the need to compress the time of scientific activity, sequential and modular research programs are established, so that different lines of research may be developed simultaneously within the same field, and the time phases of the different projects may be connected according to their provisory results.

In summary, as pointed out by Vincent (2020), scientific work suffers during the process of capitalist rationalization, through which it is transformed into a tool for unlimited accumulation of value, cut off from any vocational motivation. But it is true that something changes as conception work acquires a more relevant role within the context of the current technoscientific revolution. The economic valorization of this type of work takes on a more processual nature, given the need to reconcile production processes which, from a technical-material point of view, are very heterogeneous. Some specific aspects of human intellectual activity, which are basic to rationalize the evolution of very complex production systems, are nevertheless left aside in this process. In reality, one of the main problems in the way capitalism operates during the technoscientific revolution is that it requires people to know what they are doing, but only up to a

certain point. For the sake of capitalist profitability, the ability to connect different pieces of knowledge always ends up being limited. However, a production system based on conception work should give more space to reflexivity, which ultimately involves stepping back from the abstract, impersonal and automatic logic of capitalist rationalization. From the point of view of this logic, it does not matter where we are heading to, what matters is accumulating value. All knowledge and all communication that do not progress in that direction are radically marginalized, even if reflexivity within the system is thus notably reduced. Obviously, the dangers underlying these issues are enormous, especially when the technoscientific revolution is speeding up.

7.4 Critical Discussion

In his analysis of Western capitalism, Weber showed the limits of a naturalistic explanation of its historical origins. He argued that despite the existence of a profit-pursuing motivation in the individual, cultural forms are actually capable of curbing and regulate those pecuniary and hedonistic instincts, enabling sustained profitability. In his argument, facts and values are the undisputable protagonists of ontological dualism. Later on, Weber explained, the world becomes disenchanted, while capitalism operates at "cruising speed" or, so to speak, "on autopilot". Ethical values no longer have a driving role, they cease to activate the economic mechanisms of Western capitalism. Under these circumstances, the world becomes a place governed by social automatisms, where values remain hidden, "resisting" in small communities (scientific ones, among others) that need vocation, conviction and responsibility to preserve their methodical life and cultivate their creativity and coherence.

Although, to a large extent, Weber developed his theory on the origins of Western capitalism to counteract the influence of Marx's thinking, in reality, both authors reached similar conclusions. Capitalist modernity is characterized by the strength of its social automatisms, of its automatic (non-coercive) social relationships, but Marx and Weber disagree on the historical and categorial nature of the process (Artous, 2006). For Weber, hope lies in vocation, in individual responsibility, in values, in the return of the pagan gods from the archaic world. In this sense, our era is still deeply Weberian: values represent the unassailable sanctuary of the individual, which resists undamaged by the avatars of an objectively devastating world. Weiis (2015) analyzed how values have played a historically

fundamental role in regulating the tension that exists in any capitalist society between, on the one hand, the individual's freedom to buy and sell goods (including the labor force) according to their own capacities and preferences and, on the other, the non-agency derived from the individual's dependence on automatic social relationships, the particularities of the commercial exchange, and the lack of technoscientific control over the general production process. Although in an increasingly ideological sense, values reconcile freedom with necessity (some examples include the defense of public education, science or the public healthcare system, or the fight for the right to housing or quality public transport).[4]

Marx and Weber could develop more scientific visions of capitalism precisely because they went beyond the naturalization of phenomenological forms that was typical of the historical school of economics and political economy. But there is a substantial difference between the two. Weber followed Kant when he argued that the passage from sensitive to scientific knowledge is made through a priori conceptual structures. Marx, on the contrary, broke away from the philosophy of his time by suggesting that the different ways of thinking are a product of the evolution of the material conditions. In this sense, Sohn-Rethel's approach (2010) is relevant, for he found that scientific thought is an abstract reflection of the split between manual and intellectual work taking place in capitalism as a result of the actual subsumption of labor into capital (which, as analyzed before, has been exacerbated by the technoscientific revolution). From this point of view, thought and science do not emerge autonomously in society. For Weber, on the other hand, science is a process separate from materiality, it is a legal interpretation. Thus, the causal determinism found in a scientific explanation is all the rationality that is possible. In fact, Weber practiced

[4] However, in the current period, which is characterized by a crisis of values as social relationships (Postone, 1993), values are no longer able to mediate between freedom and non-agency for the whole of society, and their vindication is presently limited to the ideology of the progressive middle classes. As a result, new forms of normativity, such as pragmatism, duty or virtue, have irrupted and are conquering an ever-widening territory. While pragmatism drains the collectivity of normative content and serves the competitive individualism of the neoliberal period, duty replaces values among the population seeking protection in community forms with stronger bonds (including the family, the neighborhood or ethnic or religious associations), and virtue does the same among the population having enough resources to cover their basic needs (in the form of civil movements, volunteerism or environmental associations). In brief, the new forms of normativity reflect the evolution of capitalism, and the gradual acceptance of the increasing loss of individual freedom and the exacerbated absence of agency in the contemporary world.

empirical sociology. He was satisfied with explaining what happens, as it happens. For him, cause–effect relationships are a reconstruction that does not question the contingency of individual behavior.

From Marx's perspective, the individual in capitalism is not free because a formal objectivity is imposed on their daily life which forces them to behave in a specific way (White, 2013). In other words, they are compelled to produce and relate socially in a way that perpetuates precisely the cognitive structures that their conscience is presented with. In this material context, the transformational capacity of the intersubjectivity of community forms is—beyond the reflective capacity of, for instance, scientific communities—purely ideological. Weber regarded concepts as mere tools, separate from reality. To determine the processes of causality in scientific activity, it is only necessary to empirically understand what is being done, which is assumed to be an ontological social behavior. Understanding the bond between interiority and the world, between ethos and reality is all the rational capacity we can develop to rebuild real connections in the world through causal interpretation. In this sense, the outcome of an action can only be traced back to individual responsibility. For Weber (2004), the dimension of individual responsibility cannot be dissolved in a context of common normativity and objective ethical values.

Marx's position was very different, although he apparently reached the same conclusions. For Marx, historical evolution has generated a course of action that is presented as natural and necessary, although, deep down, it is not. In contrast with Weber, Marx considered that the logic of capitalism is historically specific, and this is a fundamental difference. The meaning behind action is not false consciousness and is not prevailed over by changing mentalities or beliefs or by reinforcing individual responsibility as the only way to break out of the "iron cage" (even if provisionally, as Weber is content enough to accept). In capitalism, action gives meaning to a logic that makes forms present themselves as they do (White, 2013). In Weber's view, the fact that the objective forms of reality and thought are imposed on the individual does not relieve them from their responsibility in relation to their actions (Vincent, 1992). As we can see, Weber's was a nominalist and voluntarist conception of science and action. For Marx, they are not projections of will, but the outcome of objective conditions. According to him, this is the main thing we should know. The purpose of knowing is not to hold the free individual responsible for their actions, but to liberate them from the above-mentioned formal logic imposed on their lives.

Using the technoscientific revolution as reference, we have analyzed how combining the ethics of conviction and the ethics of responsibility becomes unfeasible as scientific work is subsumed into the logic of capitalism. Scientific activity, despite it being performed by community-based structures with a well-rooted value system, gets caught up in a logic that engulfs it and becomes an easy prey to this fetishistic society. The paradox lies in that, the more it incurs in a voluntarist attitude, the more it is overcome by that logic. As technology becomes autonomous from science, the dangers increase, a distrust of all expert systems is developed, and the perception that we live in a society of risk is generalized (Beck, 1992). Weber provides an illustrated solution, based on intersubjectivity, powerless in the face of unstoppable objectivation, increasingly fed by the individuals' own actions. It is not a question of responsibility, because reaching an ethical intersubjective consensus will not modify the general dynamic. Ultimately, the purpose of knowing is not to hold the free individual responsible for their actions, but to liberate them from the objective forms that condition their behavior.

References

Artous, A. (2006). *Le fétichisme chez Marx. Le Marxisme comme théorie critique*. Syllepse.

Beck, U. (1992). *Risk Society: Towards a New Modernity*. Sage.

Crease, R. (2019). *The Workshop and the World: What Ten Thinkers Can Teach Us About Science*. W.W. Norton & Company.

Eliade, M. (2020). *Myth and Reality*. Harper & Row.

Florida, R. (2002). *The Rise of the Creative Class*. Basic Books.

Freund, J. (1966). *Sociologie de Max Weber*. Presses Universitaires de France.

Graeber, D. (2015). *The Utopia of Rules: On Technology, Stupidity, and the Secret Joys of Bureaucracy*. Melville House.

Hanlon, G. (2014). The Entrepreneurial Function and the Capture of Value: Using Kirzner to Understand Contemporary Capitalism. *Ephemera. Theory & Politics in Organization, 14*(2).

Ingham, G. (2008). *Capitalism*. Polity Press.

Kuhn, T. (2012). *The Structure of Scientific Revolutions* (Introduction by Ian Hacking). University of Chicago Press.

Lambruschini, P. (2021). *Max Weber. Las antinomias entre lo racional y lo irracional*. Prometeo Libros.

Macías Vázquez, A. (2017). *El colapso del capitalismo tecnológico*. Escolar y Mayo.

Marx, K. (1990). *Capital: A Critique of Political Economy* (Vol. 1). Penguin Books.

Menger, C. (2019). *Principles of Economics*. Mises Institute.
Mommsen, W. (1965). La sociologie politique de Max Weber et sa philosophie de l'histoire universelle. *Revue Internationale des Sciences Sociales, XVII*(1).
Nietzsche, F. (2008). *Thus spoke Zarathustra*. Oxford University Press.
Nietzsche, F. (2013). *On the Genealogy of Morals*. Penguin Classics.
Pareto, V. (1978). *Oeuvres complètes: Tome 5, Les systèmes socialistes (Travaux de droit, d'économie, de sociologie et de sciences politiques)*. Librairie Droz.
Parsons, T. (1965). Evaluation et objectivité dans le domaine des sciences sociales: une interprétation des travaux de Max Weber. *Revue Internationale des Sciences Sociales, XVII*(1).
Postone, M. (1993). *Time, Labor and Social Domination: A Reinterpretation of Marx's Critical Theory*. Cambridge University Press.
Schluchter, W. (1985). *The Rise of Western Rationalism: Max Weber's Developmental History*. University of California Press.
Schumpeter, J. A. (2021). *The Theory of Economic Development*. Routledge.
Sheehan, T. (Ed.). (1981). *Heidegger. The Man and the Thinker*. Transaction Publishers.
Sohn-Rethel, A. (2010). *La pensée-marchandise*. Éditions du Croquant.
Suárez-Villa, L. (2012). *Technocapitalism. A Critical Perspective on Technological Innovation and Corporatism*. Temple University Press.
Tarde, G. (1969). *On Communication and Social Influence* (Edited and with an Introduction by Terry N. Clark). University of Chicago Press.
Vercellone, C. (2008). The New Articulation of Wages, Rent and Profit in Cognitive Capitalism. In *The Art of Rent*. Queen Mary University School of Business and Management.
Vincent, J. M. (1992). Max Weber et la Constellation du Matérialisme Historique. *Actuel Marx, 1*(11).
Vincent, J. M. (2020). *Fétichisme et société*. Critiques Editions.
Weber, M. (1993). *The Sociology of Religion* (Introduction by Talcott Parsons). Beacon Press.
Weber, M. (2002). *The Protestant Ethic and the Spirit of Capitalism*. Penguin Classics.
Weber, M. (2004). *The Vocation Lectures: "Science as a Cocation"; "Politics as a Vocation"*. Hackett Publishing.
Weber, M. (2011). *Methodology of Social Sciences*. Routledge.
Weiis, H. (2015). Capitalist Normativity: Value and Values. *Anthropological Theory, 15*(2).
White, H. (2013). Materiality, Form, and Context: Marx contra Latour. *Victorian Studies, 55*(4).

CHAPTER 8

The Age of Innovation: More Schumpeter than Keynes

Manuel Santos Redondo

Today, some sixty years after their deaths, Schumpeter's star probably outshines Keynes's.
—Robert Solow, *2007*

In 1983, on the centenary anniversary of both John Maynard Keynes (1883–1946) and Joseph A. Schumpeter (1883–1950), *Forbes* ran this topic as cover story with a long article from Austrian American management expert Peter Drucker (1909–2005):

> The centenary of Keynes' birth is being celebrated with a host of books, articles, conferences and speeches. If the centenary of Schumpeter's birth were noticed at all, it would be in a small doctoral seminar. And yet it is becoming increasingly clear that it is Schumpeter who will shape the think-

M. Santos Redondo (✉)
Complutense University of Madrid, Madrid, Spain
e-mail: msantosr@ucm.es

E. Trincado Aznar, F. López Castellano (eds.), *Science, Technology and Innovation in the History of Economic Thought*, Palgrave Studies in the History of Economic Thought,
https://doi.org/10.1007/978-3-031-40139-8_8

> ing and inform the questions on economic theory and economic policy for the rest of this century. (Drucker, 1983)

Drucker and Forbes' opinion didn't come out of the blue. And they were right, according to scholar citations (Diamond Jr., 2009; Dalton & Gaeto, 2022). Times were changing in economic theory, in politics, and in international competitiveness. But one could think that, after victories of Thatcher in 1979 and Reagan in 1980, it would be the "age of Hayek," or Friedman, or neoliberalism, in economics. But it was Schumpeterian innovation and "creative destruction" that was going to be at the very center of the scene.

Keynes and Keynesianism had been enthroned by brilliant young economists all over the world, and in Harvard after 1937 (Tobin, 1988). The quarter century after World War II was certainly "the age of Keynes," both in economic theory and policy. During the Great Depression, or at least in the first years, most economists believed that the crisis will be over without large government intervention, as the crisis of 1920–1921 disappeared and gave way to the roaring twenties. Even Roosevelt's New Deal was attacked as socialist. But with the "Keynesian revolution," it was the opposite. Lesson from the sufferings of the Depression were clear, both to Keynesianism and to Chicago monetarists. Keynesian stabilization policy was good for the public, the politicians, and the corporations. Those "liquidationists" were in retreat, even with their softened position.

Before explaining what was happening in the 1980s and the rise of Schumpeter's and his "creative destruction" to the superior fame of economists, let us start from the beginning: the life of Joseph Schumpeter and his work on innovation. We will review his biography in the intellectually most productive years, until the outbreak of the Great War. Then we will discuss the evolution of his ideas on innovation, entrepreneurship, and "creative destruction."

Then we will review what happened in the 1980s to make the last quarter of twentieth century the "Era of Schumpeter." The rivalry may be, initially, with Keynesianism, being in the same side than Hayek and the Austrian School. In Macroeconomics and in political and academic influence, Friedman and the Chicago School were very much the winners against Keynesianism, together with Hayek. The fall of the Berlin Wall and the collapse of the Soviet Union reinforced the tendency. But together with this battle of ideas, American industry faced competition from Japan and East Asia, thought technological innovation. And in the 1980s,

innovation economics in several schools, some coherent, some loose, became the main issue for economist and for economic policy. Their aim was to provide an innovation policy, to build an innovation system, with an important role for the government which can be considered entrepreneur.

8.1 Joseph A. Schumpeter (1883–1950)

Josep Alois Schumpeter was born on 1883 in Triesch, near Iglau, in Moravia, in the Austro-Hungarian empire (now Třešť and Jihlava, in Czechia), the son of Josef Alois Kael Schumpeter and Johanna Grüner. Iglau had some 27,000 inhabitants and the presence of the Army. Triesch was 14 km south, a small town of about 5000 inhabitants. The Schumpeters were a prominent family in Triesch, owning and managing for generations a large textile factory complex. Both his grandfather and great grandfather had been mayors of the town. Johanna's father and grandfather were doctors at Iglau. Both families were ethnic Germans, while most of Moravians were Czech. In 1887, when Josef was a three-year-old, and his mother 25, the father died in a hunting accident. The same year Johanna's father died, and in a year, her mother. The young widow decided to move with her child to Graz, an attractive city 180 km south of Vienna and well connected by train. There Schumpeter attended a good German-speaking primary school. When he was 10, Johanna met and married Sigmund von Kéler, retired lieutenant field marshal of the Austro-Hungarian army. They settled in the capital, and with his stepfather's connections, Josef joined the main elite high school of the Austro-Hungarian empire, the Theresianum, known in England as "Austria's Eaton" (Hülsmann, 2007, pp 35–38). It was a boarding school, with some students like Schumpeter going home every night. Subjects included law, economics, history, languages, and also fencing and horse riding. The students were trained to administrate the empire. Many of them were aristocrats. All his life, Schumpeter would imitate these manners. But don't get confused: he was always a hard-working guy. (See general biographies of Schumpeter: Allen, 1991; Swedberg, 1991; McCraw, 2010).

In 1901, he left the Theresianum with very good grades and immediately began studying political economy at the University of Vienna, which at the time was only possible as part of a law degree. His teachers were Friedrich von Wieser (1851–1926) and Eugen von Philippovich (1858–1917). Since 1904, he attended the seminar of Eugen

Böhm-Bawerk (1851–1914). Böhm-Bawerk had been minister of finance on various occasions and was the leading figure of the "abstract" political economy, as opposed to German Historical school, led by Gustav Schmoller (1838–1917). Schumpeter met there relevant scholars and politicians: Rudolf Hilferding (1877–1941) Austro-German economist, socialist scholar, and finance minister of Germany; Ludwig von Mises (1881–1973): Felix Somary (1881–1956), Austrian–Swiss bank manager; and Otto Bauer (1881–1938), and Emil Lederer (1882–1939), both socialists.

In February 1906, he received his doctorate in Law. In the summer, he attended Schmoller's seminar in Berlin and met every important economist both in Austria and Germany. Events and achievements were coming really fast for young Josef. He spent a year at the London School of Economics and at the Universities of Oxford and Cambridge. There he met Gladys Ricarde Seaver, the daughter of an officer of the Church of England. They married in November 1907, being 24 and 36. The couple departed for El Cairo, where Schumpeter worked for an Italian Law firm which defended resident foreigners before the "Mixed Court." There he was also involved in practical finances and business and found time to write a book for his *habilitation* for teaching: *The Nature and Essence of Economic Theory* (Schumpeter, 1908/2017). His name appeared as "Joseph," with the English spelling. Schumpeter took side with the "abstract" or "theoretical" school of political economy, led by Böhm-Bawerk and Wieser, his teachers and mentors in Vienna. After the "Methodenstreit" or "method dispute" between Carl Menger and Schmoller in 1883, Historical School reigned in Germany, and theoretical economy was called "Austrian." But Schumpeter, instead of keeping the bitter tone of the dispute, tried to reconcile both sides (with no success at all). The book is an exercise on pure economics, but prepares the scene for entrepreneur and change:

> My presentation is based on the fundamental differentiation between "statics" and "dynamics" of the economy, a point that cannot be stressed enough. The methods of pure economics today are just good enough for the former. "Dynamics" is totally different from "statics," in their methods and in content. … We withdraw entrepreneurial profit from our static system. (Schumpeter, 1908/2017)

The couple went back to Austria–Hungary, and young Schumpeter got a position at Czernowitz University (now Chernivtsi, Ukraine), capital of the historic region of Bukovina, 1000 km east of Vienna. It was a multicultural city with Ukrainians, Romanians, Jews, Germans, and Poles. Apart from shocking students and colleagues with his showmanship, he wrote there his most important contribution to economics: *The Theory of Economic development* (1911), claiming the central role that economic change introduced by entrepreneurs has in economic growth:

> By "development," therefore, we shall understand only such changes in economic life as are not forced upon it from without but arise by its own initiative, from within. … the carrying out of new combinations … covers the following five cases: (1) The introduction of a new good. (2) The introduction of a new method of production. (3) The opening of a new market. (4) The conquest of a new source of supply of raw materials or half-manufactured goods. (5) The carrying out of the new organization of any industry. (Quoted from the English edition, 1934)

Schumpeter would work on these ideas throughout his life, in the revised editions of this book, and in other works (Brouwer, 2002; Śledzik, 2013; Becker & Knudsen 2002). In the more stylized version of his most popular book, *Capitalism, Socialism, and Democracy* (Schumpeter, 1942):

> [This] process of industrial mutation … incessantly revolutionizes the economic structure *from within*, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism.

In his 1911 book, the center is the entrepreneur, described as a kind of superior man, at least for this function, that through intuition more than economic calculation achieved something out of the established economic activity. At that time, the aspiration to Nietzschean *Übermensch* or "above-human" was part of the cultural climate of Austria and Germany, and very likely came to Schumpeter through Werner Sombart (Santarelli & Pesciarelli, 1990; Reinert & Reinert, 2006). In more economic terms, innovation came from young, small firms, outsiders, "start-ups" in modern words. In Schumpeter's later revised version, innovation came mainly from large corporations (Scherer, 1992; Samuelson, 2009).

In October 1911, Schumpeter was appointed full professor at Graz University by the ministry, a much more relevant position than Czernowitz.

He got it with the strong mentoring of Wieser and Böhm-Bawerk, and against the will of most of the faculty, which favored German Historical School and opposed any "abstract" economist. At 28, he was the youngest full professor in the field of political economy in Austria–Hungary.

In 1913, Schumpeter's publications and prestige gained him an invitation from Columbia University to spend a year in New York. It was quite an honor, and remarkable for his youth. Gladys stayed in London. They will never live together again. He was granted an honorary degree by Columbia, being 29. And spend seven months, traveling, lecturing, meeting every economist, and leaving a strong impression. When he returned to Graz, in April 1914, his career as economics professor was outstanding.

But during the next years, everything was going to change, starting with the outbreak of the Great War. Schumpeter was 31; unlike Mises, 32, and teenager Hayek, he avoided being conscripted, alleging being the only professor of Political Economy at Graz. It was a complex situation for Austria–Hungary, an even more for an Anglophile Schumpeter, fearing both military defeat and domination by Germany. After the war, Austria–Hungary, with 51 million people and many different ethnic groups, was dissolved, and led way to small German-speaking Austria, with 6.5 million, and several new independent states. The name was "Republic of German Austria," with plans for eventual unification with Germany that Schumpeter publicly opposed. Paradoxically, conservative Schumpeter entered politics thanks to his socialist contacts from Böhm-Bawerk's seminar in Vienna, Rudolf Hilferding, Emil Lederer, and Otto Bauer. He joined Germany's "Socialization Commission," a board of experts for the coal industry, which recommended quasi-nationalizing the industry, with his sign. And in March 1919, he was appointed minister of Finance, as independent, in the Government of Karl Renner, a coalition of Social Democrats and Christian Socialists, with Otto Bauer as a strong man. He was forced to resign in October, after facing hostility from everyone due to his lack of political skills and for publicly opposing unification with Germany. And, last but not least, the task was quite difficult. In the words of fellow-Austrian Peter F. Drucker:

> …as minister of finance in the newly formed Austrian republic … he, totally unsuccessful, tried to stop inflation before it got out of hand. … his measures were not acceptable in the short term—the very measures that, two years later, a non-economist, a politician and professor of moral theology

> [Ignaz Seipel] did apply to stop the inflation, but only after it had all but destroyed Austria's economy and middle class. (Drucker, 1983)

His life as a professor in Graz was not enough for him after this political experience. He then focused on business. In 1921, he got a bank license, something customary for former Finance ministers. Instead of selling it, he became involved, as president of the Biedermann joint-stock bank. Banks were crucial in Schumpeter's ideas on entrepreneurs; as he put in the revised version of his 1911 book: "Talent in economic life 'rides to success on its debts'." Talent or not, the Vienna stock market crisis of 1924 ended this venture, and he was forced to resign (Peneder & Resch, 2021).

Deciding to resume his academic career, he got a position in Bonn University, one of the top ones in Germany, and he took German citizenship. In Bonn, his course on economic theory was a great event. He revised his book on innovation and entrepreneurs, and produced a second German edition in 1926, and a third in 1931. The English translation would appear in 1934, when he was already established at Harvard.

Let us stop in his personal life at this moment. At the end of his political and business adventures, he fell in love with and married Anna ("Annie") Reisinger, the daughter of the porter of his mother's building in Vienna, 20 years younger than him. They married, without clarifying the situation with first wife Gladys, in November 1925, as soon as Schumpeter got the position in Bonn. In the summer of 1926, tragedy struck: In June, Johana, his mother, died. And in August, Annie, his young wife, died in childbirth, being 23 years old. The baby died some hours later. Schumpeter never got out of chronic depression after this; we now know reading from his diaries.

In 1927–1928, he came to Harvard for a year as Visiting Professor, and repeated his visit in the winter of 1930. This time he returned to Europe by way of Japan, where he had many followers, and his lectures there were a success. In 1932, he moved to Harvard permanently. In 1939, he published his monumental two-volume work on *Business Cycles*. The book was a total failure. In 1942, he published his most successful book, *Capitalism, Socialism, and Democracy*. In these books, and in several articles, innovation and "creative destruction" were at the center, but individual entrepreneur was diluted. As Samuelson (2009) recalls:

> …when first in September 1935 I entered his Harvard Yard graduate classroom, Schumpeter was still stressing youthful innovators. He then seemed

> to doubt that a General Electric or a Bell System Laboratory could succeed in staying at the frontier of technical and know-how discovery. But later, contemporary economic history converted him to the view that the great oligopolies of the *Fortune 500* corporations deserved most credit for progress in mid-twentieth-century total factor productivity. (Samuelson, 2009, pp. 76–77)

So, the theory of entrepreneur and innovation that Schumpeter explains in 1911 evolves in his subsequent works, from individual entrepreneur to the *function* of the entrepreneur, which can be performed by those embedded in another economic role (capitalist, manager) and even by groups, corporations, or countries.

8.2 The Age of Schumpeter

But the world had different concerns in the 1930s and the 1940s. Schumpeter's "creative destruction" was not at its best during depression. In the 1930s, the Great Depression reduced corporations' investment in R&D to bare bones. In the 1940s, research was state funded and oriented to war. Bartz and Winkler (2016) compare the ideas of Schumpeter, about the economic crisis being motivated by "creative destruction" and so they must go on without large government intervention, with the alternative view, that they center in Friedman, that crisis is caused by distortions of the financial system and this hampers entrepreneurial activity and, hence, the process of creative destruction. They look at German small and medium enterprises during the 2009 financial crisis, and the conclusion is clear: creative entrepreneurship benefits from stability.

Economist and politicians in the Western world were designing a post-war order trying to avoid the terrible mistakes of the 1930s. Keynesianism was enthroned. American corporations were at the edge of technology and innovation, and they didn't fear competition. Instead of past isolation, now American public opinion, corporations, and politicians were ready to lead the Western world. Many socialist parties were winning elections; and if the Conservatives took over, they didn't challenge the idea of government responsibility for alleviating mass economic distress. Hayek and Friedman and the like would work patiently in the battle of ideas, through the Mont Pelerin Society and other groups, trying to turn the tide.

So in the last years of Schumpeter's life, all the fame was for Keynes and Keynesianism. He was a respected economist, quite far from the prevalent

trend in politics and economics. Most brilliant Schumpeter's students left him for Keynesian ideas. The rivalry had a clear winner. What happened in the following decades to bring "the age of Schumpeter"? (Giersch, 1984).

8.2.1 Technological Progress (Solow). New-Growth Theory. Evolutionary Economics

Schumpeter was in favor of modern mathematical economics since his earlier works. He was among the founders of the Econometric Society in 1930. But most of his work was in prose. In the words of Frederic M. Scherer, Schumpeter's ideas about innovation by small and large enterprises

> were mere fragments, lacking both conceptual precision and empirical support … Economists sought to clarify and extend the Schumpeterian conjectures. Their research proceeded along three main lines: theory building, case studies, and statistical analysis. (Scherer, 1992, p 763)

And thus, Schumpeter's ideas, now without Nietzschean tones and referred to innovation by firms of different sizes, were developed in the field of "industrial organization."

In the different field of economic growth, Robert Solow (1957) measured its different components. Schumpeterian distinction of static equilibrium (or growth through accumulation) and dynamic growth through innovation turned, in modern economic language, "segregating shifts of the aggregate production function from movements along it." The increase in Total Factor Productivity (TFP) measured the economic progress. Most of this increase came from technological progress, dubbed "residual" by Solow. It was still seen as an exogenous factor, in the "exogenous growth model"; but brought it at the center or economists' work. In the 1980s, and the 1990s, technological change was internalized by the "endogenous" or "new growth theory" (Hospers, 2005). And, in a way, less tied to neoclassical economics, modern "evolutionary economic" (Nelson & Winter, 1982; Castellacci, 2007). All of them take inspiration from the works of Schumpeter:

> The influence of Joseph Schumpeter is so pervasive in our work that it requires particular mention here. Indeed, the term 'neo-Schumpeterian' would be as appropriate a designation for our entire approach as 'evolution-

> ary'. … evolutionary ideas provide a workable approach to the problem of elaborating and formalizing the Schumpeterian view of capitalism as an engine of progressive change. (Nelson & Winter, 1982)

As evolutionary economics went on, the link with Schumpeter's own work became more an inspiration than formal similarities. But we can conclude with Faberger:

> …although there are important differences between Schumpeter's work and some of the more recent contributions, there nevertheless remains a strong common core. (Fagerberg, 2003)

Those in the more orthodox neoclassical field also praise Schumpeter. Like Scherer, Solow criticizes the lack of conceptual precision and modern measurements, but praise his insight:

> Schumpeter could claim to have been the progenitor of a torrent of modern research that analyzes the dynamics of profit-driven innovation and innovation-driven economic growth. (Solow, 2007)

Schumpeter and Keynes focused on different problems. Unemployment was seen by Schumpeter as *technological* unemployment (Boianovsky & Trautwein, 2010). Not the best tool to deal with the Great Depression. Only after those terrible times, can we understand Solow's final judgment (similar to Hayek, 1994):

> It is possible to see Keynesian and Schumpeterian ideas as complementary. Keynes is about short-run economic fluctuations brought about by erratic variations in the willingness of investors and governments to spend; Schumpeter is about the long-run trajectory driven by the erratic march of technological progress. This complementarity only became clear later, after both men had died, when economic growth became an explicit objective of public policy and topic of systematic analysis. (Solow, 2007)

The main difference between Schumpeter's "vision" and explanation of the "creative destruction" that occurred in the past, and today's innovation economics, is that of time and velocity of changes. In 1942, Schumpeter writes about "creative destruction":

> …we are dealing with a process whose every element takes considerable time in revealing its true features and ultimate effects … we must judge its performance over time, as it unfolds through decades or centuries. (Schumpeter, 1942)

But innovation in our time takes years or months to be relevant.

8.2.2 Schumpeter and Neoliberalism: The Mont Pelerin Society

Schumpeter, although sometimes paradoxical, was quite conservative in politics (Hayek, 1994; Muller, 1997). He was in favor of aristocratic society, but with social mobility (at least in the long term) based on aptitude; and identify this with capitalism. But this society is doomed, because with the routinization of innovation by corporations, there will be no room for such a large reward for entrepreneurial aptitude. For young Schumpeter, the crucial function of entrepreneurs, which are exceptional individuals, is linked to elites, and more particularly to social mobility and the justification of differences (Schumpeter, 1950). But in *Capitalism, Socialism and Democracy* (1942), Schumpeter is pessimistic about capitalism, or at least about the society he likes. He seems to think, like Berle and Means (1932) and Keynes (1926), that the march of history is in favor of corporations and some form of socialism. This was part of the professional *milieu* in the United States in the 1930s, in a comparable way with the "over-human" in Austria and Germany at the beginning of the century.

Schumpeter calls this tendency "The March into Socialism" (1942, 1950). But what he calls socialism seems to be the "mixed economy" that most of the Western countries had after 1950 (Fagerberg, 2003, pp. 133–134). The same idea that Hayek had in mind in the dedication of *The Road for Serfdom* in 1944: "To the socialist of all parties." In Schumpeter's essay "Capitalism in the Postwar World" (1943/2017), he considers that this mixed economy "is capitalism in the oxygen tent—kept alive by artificial devices and paralyzed in all those functions that produced the success of the past." For Hayek, Friedman, and most of Mont Pelerin members after 1947, mixed economy was an undesirable system worth fighting against. In the words of Hayek: "I'm trying to move opinion in a certain direction … I'm hoping that I can just divert it moderately. But Schumpeter's attitude was one of complete despair and disillusionment over the power of reason" (Hayek, 1994).

Let us examine the relation between Schumpeter and the "Austrian" school and Ordoliberalim. Basically, they both were on the same side, against government intervention, during the Great Depression (Klausinger, 1995). And Schumpeter was acquainted with Walter Eucken, and they had mutual respect (Dathe & Hedtke, 2018). But Schumpeter was not very relevant for modern "Austrian" school of economics in America, with Hayek and Mises, after the war. He was not present in the first meeting of the Mont Pelerin Society, in 1947. We know Walter Eucken was not happy with Schumpeter's acceptance of the end of capitalism and the arriving of "socialism." Likely neither Eucken nor Hayek considered Schumpeter a candidate, because of his plain affirmation that capitalism was doomed.

In his 1950 address to the American Economic Association, published as "The March into Socialism," Schumpeter includes a paragraph mentioning the Mont Pelerin Society, without naming it, as an example of pro-capitalist ideas being out of date:

> I believe that there is a mountain in Switzerland on which congresses of economists have been held which have expressed disapproval of all or most of these things. But these anathemata have not even provoked attack.

In the 1958 meeting of the Mont Pelerin Society in Princeton University, held for the first time in the United States, Albert Hunold, a Swiss businessman, founder and then secretary of the Society, used this remark to point out the progress of the pro-market group, and to mock Schumpeter: "Was Schumpeter right in his prophecies, and would he have said the same if he had been invited to join the group meeting above the Lake of Geneva? If we look at the world today … it would be easy … to appreciate the enormous change, both in the intellectual field and in policy-making, which has since taken place in the Western world, especially in Germany" (Hunold, 1958). Many considered this as being inelegant toward Schumpeter and was one step more in the tensions between Hayek and Hunold, that would eventually lead to the preeminence of the Chicago School in the Mont Pelerin Society.

Together with Friedman, Hayek was going to be leader of the anti-Keynesian. His authority was based on his academic credentials, but also in his soft manners and incredible job in keeping together, in the Mont Pelerin society, a group of pro-market economists with quite diverse ideas. His intellectual work after *The Road to serfdom* (1944) was focus on politics, much more than his monetary texts on the 1930s and his work

explaining the market as a decentralized mechanism which translate both information and incentives to the agents, which got into mainstream economics. He got the Nobel Prize in 1974, and became, with Friedman, the most visible face of neoliberalism.

The common enemy that galvanized the pro-market intellectuals was John K. Galbraith (1908–2006), economist and politician, a good writer, but with less academic credentials than those in Mont Pelerin. He considered Schumpeter a "sophisticated conservative" and claimed that corporations were now responsible for innovation, quite in line with Schumpeter (Audretsch, 2015). Galbraith's TV show "The age of uncertainty" in 1973 was going to spark the successful counterattack from Friedman in a similar format, but opposite in ideology, with TV series "Free to choose" (1980) (Burgin, 2013). The battle of economic ideas became popular as well as academic.

In this battle of ideas, not strictly academic, we must turn to the new "Austrian" school of economics. Those economists mainly working in the United States are more diverse and less academic than one generation before. Most of them choose political and popular influence instead of academic. The one more related with Schumpeter is Israel Kirzner (born in 1930), whose work put the emphasis in the role of the entrepreneur (Kirzner, 1999; Boettke et al., 2016). But there are clear differences with Schumpeter's ideas. Kirszner's entrepreneur is an equilibrating agent. Schumpeter's innovator is clearly a disruptor. The new "Austrian" ideas about entrepreneurship are better understood following Brunner and Meckling (1977): the relevant model of man, for economists, is the "Resourceful, Evaluating, Maximizing Man" (REMM), which includes an entrepreneurial component: "Resourcefulness emerges whenever man is confronted with new and unfamiliar opportunities, or when man searches for ways to modify the constraints and opportunities."

8.2.3 Supply-Side Economics (and Rhetoric): Libertarian right

Schumpeter was also a hero for supply-side economics, or "Reaganomics" or in right-wing American populism. It is a version loosely based on Schumpeter; putting emphasis more on becoming rich than in technological innovation. This is more relevant as political rhetoric than economic theory or policy. As Schumpeter is not very precise, his name and ideas can be used for this purpose. Pack (1987) examines the 1981 best seller book of George Gilder (b. 1919), *Wealth and Poverty*, which advocate for

supply-side economics and traditional morality, and was quite influential in the Reagan times:

> For, in apparent innocence from a close reading of Schumpeter's work, it is as if Gilder has taken most every reason why Schumpeter says that capitalism cannot survive, and turned them around to show why capitalism can and must survive. (Pack, 1987)

This connection with supply-side economics and Austrian School of Economics has some importance in the academic field of economics, but much more in politics and mass media. Most Austrian scholars choose to write out of academic journals (Boettke et al., 2016):

> Many young scholars in the 21st century first encountered the Austrian school of economics not in a classroom lecture or an assigned reading by an economics professor, but through Google … For better or worse, the future of Austrian economics was monogamously wedded to political libertarianism. (Boettke et al., 2016)

At this level of rhetoric or popular ideas on capitalism, we can put writer Ayn Rand, the pen name of Alice O'Connor (1905–1982), author of the novel *Atlas Shrugged*, published in 1957. The novel is a dystopia in which productive businessmen are burdened with taxes and regulation, and they rebel and build a new capitalist society. Literary reviews were negative, but it became a best seller and has maintained its popularity. It has been praised by modern Austrian economists and the libertarian right in United States (Boettke, 2005).

But there is one part of this "entrepreneurship rhetoric" that has a role in implementing an active policy to promote entrepreneurship. This may be linked to innovation, as was the case with Japan's MITI. But in western countries, most of the times, these policies are related with fighting unemployment, and entrepreneurship is loosely defined, or defined as self-employment. The results of these policies are not clear in terms of job generation, even less in promoting innovation:

> We debate the motivation for and effectiveness of public policies to encourage individuals to become entrepreneurs. … mostly generate one-employee businesses with low-growth intentions and a lack of interest in innovating. (Acs et al., 2016)

8.2.4 American Business in the 1980s: More Finance than Tech. Japan's "Miracle"

The change in the interest of the economist may be in part due to an endogenous intellectual shift, but another part is a change in economic problems. The oil crisis was a shock for western economies. But it affected even more the American economy and society, confronted with the fact that Japan and Germany, which were far more dependent on oil than USA, were leading technological innovation and menacing American competitiveness. In 1989, Mitsubishi bought the majority stake of the company owning the Rockefeller Center of New York, and Sony bought Columbia pictures. This shocked American society, made front pages in the news and was present in popular culture, too.

Years before, in 1980, in an academic article, Robert H Hayes (b. 1936) and William J. Abernathy (1933–1983) explained what was happening and blamed no less than the American system of management:

> During the past several years, American business has experienced a marked deterioration of competitive vigor … in many high-technology as well as mature industries America has lost its leadership position. … By its very nature, innovative design is, as Joseph Schumpeter observed a long time ago, initially destructive of capital—whether in the form of labor skills, management systems, technological processes, or capital equipment. … Conditioned by a market-driven strategy and held closely to account by a "results now" ROI-oriented [Return on Investment] control system, American managers have increasingly refused to take the chance on innovative product-market development. (Hayes & Abernathy, 1980)

Almost half a century after the publication, Robert Hayes reflected about the article and its huge impact:

> Until the late 1970s, the United States tended to regard itself as the exemplar of modern management. … In the 1970s, a series of shocks—including oil crises, high inflation, and the substantial inroads of imported products in major markets such as textiles, toys, and steel—began to shake America's complacency. Since those industries tended to be low-tech or environmentally unattractive or both, foreign companies' success in those markets was generally not seen as evidence of a serious decline in overall U.S. … In the 1980s … it became clear that inroads made by foreign companies into an increasing array of critical, higher technology industries—including

> automobiles, machine tools, and consumer electronics—constituted a serious threat to domestic industries. (Hayes, 2007)

Japan's achievements, with impressive economic growth and competitiveness through technological and organizational innovation, are the other side of the decline of American industry, so conspicuous after the oil crisis. Japan prospered during the years of the long postwar boom (1954–1970), and economic growth continued until the 1990s. In some respects, Japan's strategy has been distinctly Schumpeterian, with both the state and some companies being the disruptive innovator—the part of destruction happening mainly in America. In the late 1940s, there was an intense debate over Japanese development strategy: with low labor costs, low-technology industries were an obvious choice. Instead, MITI, which advocated emphasis on high-technology industries. Japanese growth is a case of government intervention in the process of technological innovation, with at least temporary industrial leadership by the state (Scherer, 1992; Ebner, 2009). Schumpeter's ideas on innovation, in its later version, in which the entrepreneurial *function* may correspond to *groups* and to the government, seem to fit here. The innovation system relies on the coordination between public and private sectors. Schumpeter had many followers in Japan, since his time in Bonn, his visit to Japan in 1931; his third wife, Elizabeth Boody, was an expert on Japanese economy. Altogether, it is not a surprise that Japan's "miracle" is considered Schumpeterian.

8.3 Conclusion

Schumpeter considered technological and organizational innovation the main force of economic progress. Writing in 1911, being 28 years old, he made his main contribution to economics, and completed and revised these ideas throughout his life. Innovation and "Creative destruction" are crucial to economic growth and the rise in the standard of living. He kept the essential of this idea, but emphasis changed from individual entrepreneurs to big business or even states. In his time, unemployment and Depression were at the center of the stage. For this problem, he was in the conservative, "liquidationist" side that was run over both by Keynesian revolution and by the Chicago school. But his insights on technological and organizational innovation were fruitful. Technological and organizational innovation soon proved the key for economic growth and

competitiveness in modern economy. And plenty of economists, both working within the neoclassical framework or trying to substitute it, got inspired by Schumpeter's work and developed it in several ways. Because of his work on innovation and "creative destruction," and because this is the main feature of the world in which we live, it is not an exaggeration to say that the last quarter of the twentieth century was the age of Schumpeter.

References

Acs, Z., Åstebro, T., Audretsch, D., & Robinson, D. T. (2016). Public Policy to Promote Entrepreneurship: A Call to Arms. *Small Business Economics, 47*, 35–51.

Allen, R. L. (1991). *Opening Doors: Life and Work of Joseph Schumpeter*. Routledge.

Audretsch, D. B. (2015). Joseph Schumpeter and John Kenneth Galbraith: Two Sides of the Same Coin? *Journal of Evolutionary Economics, 25*, 197–214.

Bartz, W., & Winkler, A. (2016). Flexible or Fragile? The Growth Performance of Small and Young Businesses During the Global Financial Crisis — Evidence from Germany. *Journal of Business Venturing, 31*(2), 196–215.

Becker, Markus C., & Knudsen, Thorbjørn (2002). Schumpeter 1911: Farsighted visions on economic development. *American Journal of Economics and Sociology, 61*(2), 387–403.

Berle, A. A., & Means, G. C. (1932/1991). *The Modern Corporation and Private Property*. Transaction Publishers.

Boettke, P. J. (2005). Teaching Economics Through Ayn Rand: How the Economy is Like a Novel and How the Novel Can Teach us About Economics. *The Journal of Ayn Rand Studies*, 445–465.

Boettke, P. J., Coyne, C. J., & Newman, P. (2016). The History of a Tradition: Austrian Economics from 1871 to 2016. In *Including a Symposium on Austrian Economics in the Postwar Era*. Emerald Group Publishing Limited.

Boianovsky, M., & Trautwein, H. M. (2010). Schumpeter on Unemployment. *Journal of Evolutionary Economics, 20*, 233–263.

Brouwer, M. T. (2002). Weber, Schumpeter and Knight on Entrepreneurship and Economic Development. *Journal of Evolutionary Economics, 12*, 83–105.

Brunner, K., & Meckling, W. H. (1977). The Perception of Man and the Conception of Government. *Journal of Money, Credit and Banking, 9*(1), 70–85.

Burgin, A. (2013). Age of Certainty: Galbraith, Friedman, and the Public Life of Economic Ideas. *History of Political Economy, 45*(suppl_1), 191–219.

Castellacci, F. (2007). Evolutionary and New Growth Theories. Are they Converging? *Journal of Economic Surveys, 21*(3), 585–627.

Dalton, J. T., & Gaeto, L. R. (2022). Schumpeter vs. Keynes Redux:"Still not dead". *Southern Economic Journal, 89*(2), 569–592.

Dathe, R., & Hedtke, U. (2018). Habent sua fata professores. Joseph A. Schumpeter an Walter Eucken. *Ordo, 2018*(69), 1–34.
Diamond, A. M., Jr. (2009). Schumpeter vs. Keynes: "In the long run not all of us are dead". *Journal of the History of Economic Thought, 31*(4), 531–541.
Drucker, P. F. (1983). Schumpeter and Keynes. *Forbes*, May 23. Published Without Naming the Author. Reprinted in: Drucker, P. F. (2020). Chapter 12. Modern Prophets: Schumpeter or Keynes? In *Peter F. Drucker on Globalization* (pp. 87–99). Harvard University Press.
Ebner, A. (2009). Entrepreneurial State: The Schumpeterian Theory of Industrial Policy and the East Asian "Miracle". In *Schumpeterian Perspectives on Innovation, Competition and Growth* (pp. 369–390). Springer.
Fagerberg, J. (2003). Schumpeter and the Revival of Evolutionary Economics: An Appraisal of the Literature. *Journal of Evolutionary Economics, 13*, 125–159.
Giersch, H. (1984). The Age of Schumpeter. *The American Economic Review, 74*(2), 103–109.
Gilder, George F. (1981). *Wealth and Poverty*. Basic Books.
Hayek, F. A. 1994. *Hayek on Hayek: An Autobiographical Dialogue* (Ed. S. Kresge & L. Wenar). Routledge.
Hayes, R. H. (2007). 'Managing Our Way…' A Retrospective. *Harvard Business Review, 85*(7–8).
Hayes, R. H., & Abernathy, W. J. (1980). Managing Our Way to Economic Decline. *Harvard Business Review, 58*(4).
Hospers, G.-J. (2005). Joseph Schumpeter and His Legacy in Innovation Studies. *Knowledge, Technology & Policy, 18*(3), 20–37.
Hülsmann, J. G. (2007). *Mises: The Last Knight of Liberalism*. Ludwig von Mises Institute.
Hunold, A. (1958). *The Story of the Mont Pelerin Society*. Address to the 9th meeting of the Mont Pelerin Society in Princeton, NJ, September 8. Foundation for Economic Education (FEE). Retrieved April 26, 2021, from https://fee.org/media/5012/the-story-of-mont-pelerin.pdf
Keynes, J. M. (1926/2016). The End of Laissez-faire. Reprinted in *Essays in Persuasion* [1931]. Springer.
Kirzner, I. M. (1999). Creativity and/or Alertness: A Reconsideration of the Schumpeterian Entrepreneur. *The Review of Austrian Economics, 11*(1-2), 5–17.
Klausinger, H. (1995). Schumpeter and Hayek: Two Views of the Great Depression Re-examined. *History of Economic Ideas*, 93–127.
McCraw, T. K. (2010). *Prophet of Innovation. Joseph Schumpeter and Creative Destruction*. Harvard University Press.
Muller, J. Z. (Ed.) (1997). *Conservatism: An Anthology of Social and Political Thought from David Hume to the Present*. Princeton: Princeton University Press. Includes: Schumpeter, Joseph A. "Aptitude and Social Mobility" ["Die

sozialen Klassen im ethnisch homogen Milieu", 1927], with an introduction by editor Jerry Z. Muller, pp. 222–232.

Nelson, R. R., & Winter, S. G. (1982). *An Evolutionary Theory of Economic Change*. Harvard University Press.

Pack, S. J. (1987). Schumpeter Plus Optimism Equals Gilder (Ceteris Paribus). *History of Political Economy, 19*(3), 469–480.

Peneder, M., & Resch, A. (2021). *Schumpeter's Venture Money*. Oxford University Press.

Reinert, H., & Reinert, E. S. (2006). Creative Destruction in Economics: Nietzsche, Sombart, Schumpeter. In J. Backhaus & W. Drechsler (Eds.), *Friedrich Nietzsche (1844–1900) Economy and Society* (pp. 55–85). Springer Science & Business Media.

Samuelson, P. (2009). Advances in Total Factor Productivity and Entrepreneurial Innovation (Chapter 4). In *Entrepreneurship, Growth and Public Policy* (pp. 71–89). Cambridge University Press.

Santarelli, E., & Pesciarelli, E. (1990). The Emergence of a Vision: The Development of Schumpeter's Theory of Entrepreneurship. *History of Political Economy, 22*(4), 677–696.

Scherer, F. M. (1992). Schumpeter and Plausible Capitalism. *Journal of Economic Literature, 30*(3), 1416–1433.

Schumpeter, J. A. (1908/2017). *The Nature and Essence of Economic Theory* [*Das Wesen und der Hauptinhalt der theoretischen Nationalökonomie*]. Routledge (Transaction Publishers, 2010).

Schumpeter, J. A. (1942/1976). *Capitalism, Socialism, And Democracy*. Allen & Unwin.

Schumpeter, J. A. (1943/2017). Capitalism in the Postwar World. Reprinted in *Essays: On Entrepreneurs, Innovations, Business Cycles and the Evolution of Capitalism*. Clemence, Richard V. (Ed.) [1951]. Routledge.

Schumpeter, J. A. (1950). The March Into Socialism. *The American Economic Review, 40*(2), 446–456.

Śledzik, K. (2013). Schumpeter's View on Innovation and Entrepreneurship. In *Management Trends in Theory and Practice* (Ed.) S. Hittmar, Faculty of Management Science and Informatics. University of Zilina & Institute of Management by University of Zilina.

Solow, R. M. (1957). Technical Change and the Aggregate Production Function. *The Review of Economics and Statistics*, 312–320.

Solow. R. M. (2007). Review of Thomas K. McCraw, Prophet of Innovation: Joseph Schumpeter and Creative Destruction. *The New Republic*, May 21.

Swedberg, R. (1991). *Joseph A. Schumpeter. His Life and Work*. Polity Press.

Tobin, J. (1988). A Revolution Remembered. *Challenge, 31*(4), 35–41.

CHAPTER 9

The Crisis of the Neoclassical Framework and the Schumpeterian Echo in the Current Paradigm of the Economic Analysis of Technological Change

Antonio García Sánchez, Luis Palma Martos, and Ignacio Martínez Fernández

9.1 Introduction

When raising the need to review the attention that economic analysis has paid to issues related to innovation and technological change, it is necessary to address it with a double objective; on the one hand, the degree of exogeneity that has been attributed to the consideration of technological change (especially in the neoclassical approach), which would avoid the need to explain it from the economic model and would justify its merely tangential consideration; and on the other, to present how the

A. García Sánchez (✉) • L. Palma Martos • I. Martínez Fernández
University of Seville, Seville, Spain
e-mail: acichez@us.es; lpalma@us.es; imfernandez@us.es

E. Trincado Aznar, F. López Castellano (eds.), *Science, Technology and Innovation in the History of Economic Thought*, Palgrave Studies in the History of Economic Thought,
https://doi.org/10.1007/978-3-031-40139-8_9

consideration of this variable has evolved in terms of effects on the competitiveness of companies, productive sectors and economic systems, as well as on the potential for growth and economic development of countries and regions.

This reflection must start with Adam Smith, both because of the consensus that considers him the father of economic science, and because of Marx's vision that it is after the industrial revolution that the conscious application of knowledge on a large scale to productive activity occurs, thus generating important changes in economic activity and in the growth rates of the territories. In the words of Motta and Moreno (2020), classical economists were the first to consider the economic impact of technological change, with increases in productivity being the main effect and the division of labour being the facilitating element. This economist vision of technological change associated with gains in productivity and/or generation of new products forms the central axis of the works of Rosenberg (1982, 1994) and Stoneman (1983), the latter especially concerned with the process and the effects of the diffusion or generalization of technological change to the economy.

Despite being a matter dealt with from Classical Economics, economic thought relegated the analysis of technological change's exogenous element to the system in determining the supply functions, either from the micro or macroeconomic perspective. It was not until the second half of the twentieth century that Solow (1956, 1957) and Abramovitz (1956) "stumbled" upon the impact of technological change while estimating the sources of growth and found that more than half of the measured growth was due to different elements from the accumulation of capital and the human factor, that economic analysis turned once again to technological change, the element ("residue") to which this unexplained growth was attributed.

After this introduction, the rest of the work will be dedicated to analysing the four main paths from which economic analysis has approached the study of technological change (Antonelli, 2008). In Sect. 9.2, the approach based on the classical legacies of Adam Smith and Karl Marx will be addressed, focusing on the analysis of the determinants of the size of the "residue" and its regional and national differences, giving an important role to knowledge and its accumulation in capital goods, as well as the main criticisms of the neoclassical model. Section 9.3 refers to the approach based on the Schumpeterian legacy, which highlights the role of competitive processes, which condition the creation of knowledge, technology

and innovations and determine the possibilities of growth and income redistribution. Section 9.4 focuses the attention on the evolutionary models and the systemic approach to innovation and knowledge (evolutionary approach and biological suggestions based on the Marshallian legacy in terms of Antonelli (2008). Finally, in Sect. 9.5, some reflections on cultural elements, creativity and innovation, which fit within what Antonelli (2008) called the Arrowian legacy are presented, since it pays special attention to the role of knowledge. We finish with the conclusions section, which to a large extent will highlight the existence of a kind of "cross fertilization" in the most recent approaches.

9.2 The Early Analysis of Innovation in Classical Economics and the Path to the Criticism of the Neoclassical Growth Theory

9.2.1 The Early Analysis of Innovation in Classical Economics

The radical changes brought to society during the Industrial Revolution and the birth of Political Economy as a discipline in the last third of the eighteenth century implied not only the transfer of resources and population from the activities in agriculture to industry but also radical changes related to the concepts of production, distribution and factors of production itself. It is in this aspect where another of the fundamental changes for the interpretation of production growth will take place, when the impact of innovation, which was already established as a catalyst for improving productivity in agricultural activities throughout the British agrarian transition, also leaked into the economic analysis of the Classical School.

Adam Smith in his *Wealth of Nations*, by highlighting the importance of philosophers or men of speculation, was incipiently recognizing the importance of what today we would call R&D activities, while pointing out the effects of mechanization on specialization and the division of labour in terms of productivity gains and the flow of constant improvements, finding in Book I a discussion of what today is identified as the sources and consequences of technical advance (Nelson & Winter, 1982). In this way, he would identify the two central elements to consider technical progress as an economic activity: (1) it is carried out to obtain advantage; (2) requires prior mobilization/investment of resources.

For Thomas Malthus and David Ricardo, although it is true that both are interested in the impact of technical change, this is interpreted as an exogenous factor and indirectly through the substitutability between machinery and the work factor that derives from technological improvement. Along these same lines, Ricardo ([1817] 2001; *On Machinery*) analysed the effects of the incorporation of capital goods (mechanization) on growth and income distribution, raised the possibility of asymmetric effects derived from the introduction of machinery in the production process, its orientation towards saving scarce production factors and the potential conflict between labour and capital (machinery), in what today we could call technological unemployment. John Stuart Mill, following Ricardo's thesis relative to the tendency of the economies to the stationary state, would incorporate the technical change in his analysis, but in this case, as a source of temporary disturbance of the path of growth.

It will be necessary to wait until Karl Marx and "Capital" to find an interpretation of technical progress as continuous and evolving, which returns to the essence of Smith's approach. For Marx, the progressive mechanization of production is a fundamental tendency of the system to achieve improvements in labour productivity, necessary for the self-expansion of the system (Shaikh, 1978), being explained by the pressure of competition in the market and not by private ownership of production and capital (Elster, 1992). This was a novel and fact to the activity that emerged from the industrial revolution, the conscious application of science to productive activities as a mechanism to respond to problems and needs of said activity (Rosenberg, 1974, 1976). As a result, the division of labour is constantly affected in a process of constant evolution and adaptation to the evolution of mechanization requirements, which makes technological change, its cyclical components and its effects on unemployment (industrial reserve army) in a component of the cumulative, evolutionary and dynamic process of development of the forces of production (Neffa, 2000; Ricoy, 2003).

However, the immediately subsequent evolution of economic thought relegated the analysis of technological change to an element exogenous to the economic system, in the determination of supply functions, either from the micro or macroeconomic perspective. It was not until the second half of the twentieth century that Solow (1956) and Abramovitz (1956) "stumbled" upon the residual when estimating the sources of growth and found that more than half of the measured growth was due to different elements. After the accumulation of capital and the human factor,

economic analysis turned to look again at technological change, the element ("residue") to which this unexplained growth was attributed.

From then on, this approach focused on issues such as introducing technological change into an aggregate production function, how to measure capital and its different components more efficiently, and even refining the Solow and Abramovitz result to reduce the weight of the "residual," by expanding the range of explanatory variables, such as human capital (Mankiw et al., 1992). In any case, in a review of growth estimates for different countries and periods, by including the effects of human capital and R&D capital, Kyriakou (2002) finds that the "residual" effect of technological change was above 35%, with differences associated with geographical and temporal elements and with between 10% and 15% resulting from investment in R&D. From Kaldor's (1957) approach, a Technical Progress Function would have to be estimated, which would help to explain the relationship between the growth rates of per capita production and per capita capital, which implies the existence of two sources of economic growth: capital accumulation and technological progress, although there are limits to the capacity for capital accumulation and therefore to the rate of technical progress and the possibilities of economic growth.

The "Cambridge Controversies" initiated an intense debate over the foundations of Economic Growth Theory by confronting the capital theory of the economists attached to the neoclassical-Keynesian synthesis with its critics (Cohen & Harcourt, 2003) in a discussion focused on endogeneity problems to measure capital, the implications of using a dynamic or static framework and the heterogeneous or homogeneous nature of capital. Nevertheless, the criticism to the neoclassical growth paradigm will keep being central for decades until a new wave of criticism was elevated, its usefulness started to fade decades later due to its inadequacy to explain the lack of convergence for the modern economy

9.2.2 Criticisms During the "Cambridge Controversies"

The criticisms that unleash the debate by Joan Robinson are oriented towards the social implications of the relationships between the components of the economic mechanisms in the accumulation process, highlighting the fact that the productivity of capital and the efficiency of investment only have sense when they impact the objective living conditions of the population. In other words, the interest is not only in the

"technical" part of the economic categories but also in their social counterparts.

In her 1953 paper, Joan Robinson connected the measurement problems of neoclassical capital theory with the methodological problem underlying the conception of dynamic analysis as a series of static equilibrium. The problem of endogeneity derives from the very dual nature of capital, as reflected in Pasinetti and Scazzieri (1990, p. 144):

> "Capital" can be conceived of in two fundamentally different ways: (i) … as a "free" fund of resources, which can be switched from one use to another, without any significant difficulty: this is what may be called the "financial" conception of capital; (ii) … as a set of productive factors that are embodied in the production process as it is carried out in a particular productive establischment: this is what can be called the "technical" conception of capital.

The generalization in the use of the financial conception of capital would thus provoke scenarios of "reswitching" of capital techniques and "reverse capital deepening" due to Wicksell effects,[1] both phenomena undermining the static equilibrium framework.

In Lazzarini (2011, pp. 39–52) "reswitching" will appear as the possibility that a production technique initially considered more capital-intensive, chosen for a given interest rate, is in turn also chosen for another range of interest rates. This would break the monotonous relationship between interest rates and factor intensity in production techniques. The "reverse capital deepening" would represent the possibility of a direct relationship between interest rates and the demand for capital, based on the heterogeneity of capital goods,[2] the central element of Lazzarini's analysis. These inconsistencies in the neoclassical theory of capital would lay the foundations for the criticism of Garegnani (1970) coming to question the validity of the marginalist theory to explain income distribution.

[1] In Joan Robinson (1953), we can find the exposition of Wicksell effects divided in Price Wicksell Effects, defined as changes in relative prices corresponding to a change in income distribution (with fixed technology); and Real Wicksell Effects, as changes in relative prices corresponding to a change in income distribution also with technical changes.

[2] This idea was early presented by Hayek in Investment that raises the demand for capital (1937), under the assumption that each kind of the heterogeneous capital goods present their own interest rates.

9.2.3 Criticisms Over Convergence

In his review of the empirical studies on convergence, De Long (1988) would open the door to various factors that would explain the lack of convergence in the levels of well-being of the different economies, especially since 1870. Among these factors, the most notable are the characteristics of the political system, cultural factors such as religion and, finally, the technological assimilation capacity of countries. This last factor would facilitate the inclusion of knowledge and technology in the theoretical framework of growth theory.

Mankiw et al. (1992) suggest the usefulness of studying the accumulation of knowledge as an element that would make it possible to close the unexplained gap of the exogenous technological component of growth. According to these authors, although it is true that the relationship between the savings rate and population growth proposed by the Solow model (1956) makes it possible to predict the trend of economic growth, the magnitudes of said growth could not be adequately predicted. These findings, together with those of Barro and Sala-i-Martin (1992), will lead to the development of the concept of "conditional convergence," emphasizing that the neoclassical model of growth "did not imply that all countries would reach the same level of income growth per capita income. Instead, what it implies is that countries would reach their respective steady states. Therefore, when looking for convergence in a cross-country study, it is necessary to control for differences in the steady states of different countries" (Islam, 1995, p. 1131).

9.3 Economic Growth Driven by Innovation and Technological Change

Faced with the neoclassical model based on comparative statics, the Schumpeterian conception of the economy is dynamic, and innovation plays a central role in the economic process and in the generation of growth, and the distribution of income. From this perspective, any point of equilibrium that might appear would be unstable and dynamic; being this instability and dynamism determined by innovation. In this sense, the Schumpeterian approach is a critique of the neoclassical orthodox vision based on equilibrium and comparative statics.

It is necessary to highlight the relevance of innovation and its endogenous character (at least when talking about the process of "creative

accumulation," although the initial approach was exogenous in the process of "creative destruction") to the economic system, the result of the performance of the entrepreneur, the crucial agent, who can detect the opportunities associated with an invention or a new application of existing knowledge before others. In this sense, recognizing the important distinction between invention and innovation is paramount, inventions being a kind of "raw material" for the innovative entrepreneur, and the dependence on institutional elements, especially market structures. This distinction is in line with the vision of Rae (1834), for whom the generation of wealth depends on the emergence of new investment opportunities (reinvestment and capital accumulation) derived from the invention; note the similarity to the role of the Schumpeterian innovative entrepreneur in identifying and materializing such (re)investment opportunities. In other words, for Rae (1834), innovation is the key element in economic development, while capital accumulation is a consequence and not a cause of innovation; also note the similarity between this idea and the evolution of the model of creative destruction to that of creative accumulation in the Schumpeterian vision.

However, as Rosenberg (1976) highlighted, two crucial elements were left out of the Schumpeterian analysis: on the one hand, the limitations on the supply of knowledge (inventions), which generally operates as a restriction of technological supply in society in which employers must play their role; on the other, the important continuous and incremental nature of innovation as opposed to the vision of discontinuous innovation, both in the process of creative destruction and in that of creative accumulation. In other words, Schumpeter does not consider those minor innovations that do not immediately generate new products or productive sectors, but that do generate an accumulation of innovation and absorption capacity on the part of the companies and that will be decisive for a better future performance of the system of innovation (Freeman, 1974, 1982).

Heertje (2006, pp. 75–112) proposes to analyse the Schumpeterian model of innovation in terms of a disruption with respect to the stationary state. This analysis starts from a situation of stagnation, in terms of productivity and business benefits. At this point the Schumpeterian entrepreneur comes into play "discovering" a new way of combining technology and the resources at his disposal, thus generating profits and economic growth.

This phase of creative explosion is characterized by a first comer's type structure, so that innovation would generate initial benefits, diluting these

as innovation spills over to other companies and industry. Once the initial momentum was lost, stagnation would return.

Thus, the innovation model could be identified with the technological gap model proposed by Posner (1961) and later developed by Hufbauer (1966), in which competitive advantages in international trade are due to a time lag in the innovation process, between the different countries. So the country that innovates first enjoys a privileged position in trade until its new technology trickles down to other countries.

Vernon (1979) analyses it in terms of the company's economy when considering its product life cycle. Also starting from an advantage based on the technological difference, Vernon disaggregates the growth phase into birth, maturity and standardization. Distinguishing these by the growth rate of profits and sales, and the relative importance of production factors.

It is vitally important to understand how Schumpeter focuses the innovation process, and therefore growth, on the offer, thus distancing himself from the idea that new products and processes arise from a previously unidentified demand.

9.3.1 Schumpeter: From Exogenous to Endogenous Innovation

When studying the concept of innovation in Schumpeter's work, some precision is needed because, throughout his life, this concept will be modified to such an extent that we can speak of two different models, model I exposed in *The Theory of Economic Development* (Schumpeter, 1912); and model II presented in *Capitalism, Socialism and Democracy* (Schumpeter, 1942).

Model I, represented in Fig. 9.1, starts from a conception of innovation exogenous to companies and existing market structures (that is for the whole system). In such conditions, a select group of entrepreneurs[3] capable of appreciating the potential of these exogenous innovations assume the risk of incorporating them into production. Thus, the market's mechanisms would come into operation, so that those entrepreneurs succeeding in incorporating innovations would generate a situation of temporary monopoly based on technology and thus will obtain extraordinary benefits.

The dynamics of this model I has certain similarities with Marxist interpretation of innovation. Since, for Marx, an innovation would mean a

[3] Who would play the entrepreneur's role in its full sense.

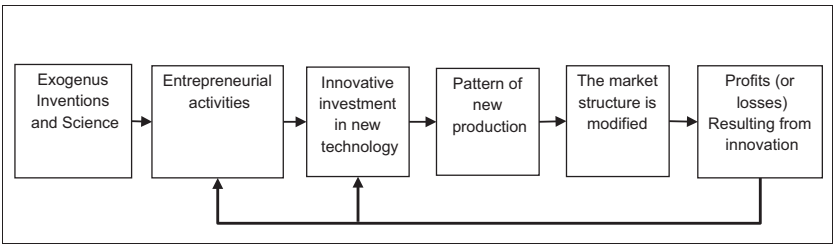

Fig. 9.1 Schematic representation of Schumpeter's Model I. (Source: Palma Martos, 1989, p. 101)

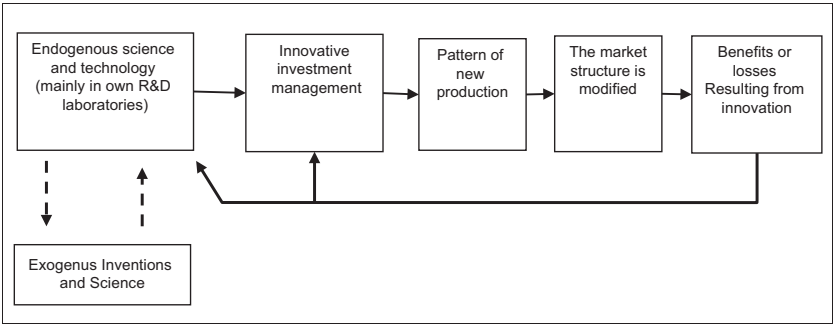

Fig. 9.2 Schematic representation of Schumpeter's model II. (Source: Palma Martos, 1989, p. 103)

temporary deviation from the stationary state, for Schumpeter it would represent a deviation, also temporary, in the market structure from perfect competition to monopoly.

Three decades later, the model II (summarized in Fig. 9.2) would incorporate the technology as an endogenous element of production. This change, in appearance contradictory in Schumpeter's vision, can be easily attributed to the author's own experience regarding the role of large companies in the innovative process. Since the birth of large companies as a differentiated economic actor during the last decades of the nineteenth century, the business class began to internalize the need to innovate as a growth engine. In this way, just as the Second Industrial Revolution and the new forms of work organization brought about the creation of human

resources departments in companies, the need for innovation prompted the creation of R&D departments.

As shown in Fig. 9.2, it will be the companies' R&D departments that can give applicability to the scientific–technical discoveries that are produced exogenously. The dynamics of the process once these innovations are incorporated will not be very different from that presented in model I, although now the temporary monopoly arising from the innovation may tend to be extended over time given the positive feedback occurring between the results of the successful innovations and increased investments in R&D. The essential difference between Schumpeter's models I and II lies in the incorporation of endogenous scientific and technical activities carried out by large companies.

9.3.2 Schmookler and the Demand-Induced Innovation

Faced with the Schumpeterian vision of innovation as a process mainly arising from supply, Jakob Schmookler was the great promoter of the demand-pull hypothesis. In this approach, consumers, through changes in their demand functions, would generate a market signal about the products that could best satisfy their needs. The entrepreneurs would initially take a reactive role since the initial effects of the motivation behind a change in demand are, however, not specific. Schmookler's approach is summarized in Fig. 9.3.

However, only those entrepreneurs capable of correctly identifying these changes as a demand for specific goods that best meet consumers' needs will reap extraordinary benefits. Thus, Schmookler would suggest that *demand tends to generate its own supply* (Schmookler, 1965).

This vision certainly has suggestive elements about the role of demand through the market as an attraction mechanism for business decisions. As can be seen in Fig. 9.3, the success different companies face to the new demand will be determined by competition between their production techniques. Schmookler would identify the incentive for the search and application of an invention in a competitive industry through two elements: (1) the correlation between the elasticity of demand and alternative supply in the absence of innovation; and (2) the volume of demand. Furthermore, he opens the door to a specific analysis of research and development activities as a differential branch of business behaviour, a function that would later be included in the development of the Theory of Endogenous Growth.

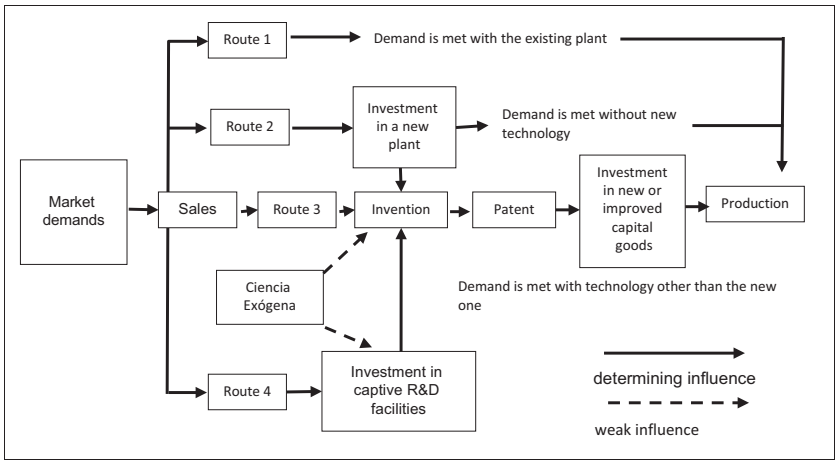

Fig. 9.3 A schematic summary of Schmookler's model. (Source: Palma Martos, 1989, p. 98)

9.4 Growth, Technology and Innovation in the Current Approach

In the process of "cross fertilization" developed through the coexistence and debate between the different approaches, we can point out that the main characteristics of the current approach (those prevailing after debate) are related with the systemic approach of innovation and with the endogenous consideration of the generation of knowledge and its application to innovation. Thus, one of the effects of the diffusion of technological change (Stoneman, 1983) to the innovation system (Freeman, 1974, 1982, 1995) as a whole would be improvements in productivity that would translate into economic growth above the expected from factors accumulation. Thus, an endogenous character to growth arises, allowing more refined estimates of growth components or determinants, including the effect of the accumulation of human capital (Romer, 1994; Sala-i-Martin et al., 2004) and R&D capital (Kyriakou, 2002; Romer, 1994); nevertheless, the main share of growth is explained by innovation and technological change, and investment in R&D, even discounting the effect of the accumulation of human capital and capital in R&D (Kyriakou, 2002). However, from the distinction based on the radical or incremental nature of innovation or technological advances (Freeman & Pérez, 1988),

the growth associated with productivity can be understood as a result of incremental changes (whose cumulative effect is captured by estimates of the effects of technical progress in the long term), while radicals can also generate a reconfiguration of the economic system, which is not differentially identified by such estimates.

Considering that innovation has a systemic nature, which may differ across countries and regions, means moving away from the orthodox neoclassical approach to deep into the heterodox analysis of historicism (both the German and British schools) and institutionalism (Archibugi & Michie, 1998; Lundvall, 1992). Additionally, understanding that there is an important endogenous component in the generation of knowledge, innovation and growth, means moving away from orthodox neoclassical growth models à la Solow (Solow, 1956, 1967, 1994), which maintain the exogenous vision of technological change, analysed on an aggregate scale, and address growth as a phenomenon of discontinuous change between equilibrium, in which the role of innovation and technological change is to explain the ("residual") part of growth, estimated from the aggregate production function, that cannot be explained by the change in the accumulation of capital and labour factors. Thus we are moving from an exogenous consideration of innovation and technological change to an endogenous perception, already pointed out by Schumpeter (1942) when he defined the model of creative accumulation in what it has come to be called (Freeman et al., 1982) the Type 2 model, to differentiate it from creative destruction (Type 1 model).This endogenous approach allows us to address issues abandoned by neoclassical analysis, including the effects of competitive rivalry and market structures, the complexity of technological change and its disruptive and destabilizing effects, the complex interactions between sources and factors of growth, and the role played by institutions in the performance of economic activities (Nelson, 1997). Furthermore, it provides answers to the criticisms made to the logical consistency of neoclassical models, discussed above when addressing the so-called *Cambridge Controversy*.

9.4.1 The Theory of Endogenous Growth and Knowledge Generation

The New Theory of Growth or Theory of Endogenous Growth emerged last century in the late 1980s and the early 1990s, to respond to the limitations of the Neoclassical Growth theory. That research were focused on to

incorporate into neoclassical models mechanisms to overcome the limitations pointed out by heterodox approaches, especially to incorporate technological change as an endogenous element to the economic process (Aghion & Howitt, 1990; Grossman & Helpman, 1991; Romer, 1990). Thus, the economic literature referring to these models as "endogenous growth models." In general, these models respond to the criticisms pointed out by Nelson (1997) regarding the partial appropriability of technological knowledge, the incentive effects derived from non-competitive market structures, the positive returns of R&D expenses and the Side effects on old technologies (obsolescence and loss of competitiveness of technologies, companies, sectors and economies). However, they do not address issues related to innovation trajectories and uncertainty in that process (Nelson, 1997).

Cortright (2001) characterizes the Endogenous Growth Theory by two main elements: (a) his vision of technological progress as an indirect effect of economic activity; and (b) the existence of increasing returns in knowledge and technology that drive the growth process. This view of the role of technology and knowledge is rupturist with Solow's (1956, 1967) neoclassical growth model, where the potential growth of an economy was determined by the saving rate or the per capita stock of capital; leaving technology as an exogenous variable to explain the divergence of the growth rate between countries with similar savings rates. But it also supposes a break with the vision initially pointed out by Adam Smith, for whom technological change was the result of the division of labour in the process of firms seeking for individual benefit, which through the phenomenon of accumulation and reinvestment of capital constituted the key factor in the increase in productivity observed during the Industrial Revolution (Smith, 1776, p. 112).

The new interpretation of the implications from the human capital framework was consolidated around two "types" of the endogenous growth models, based on whether the accumulation process of human capital is driven by a process of learning by doing or by direct investment in the "creation of new knowledge."

- *Learning models.* In Romer (1986, 1990, 1994) can be found a production function AK with spillovers of knowledge in production. The model can be written as: $Y = AK^{\alpha}L^{1-\alpha}\kappa^{\eta}$; where κ are the spill-over effects of capital investment; and η measures the sensitivity of the economy to these spill-over effects.

Lucas (1988) presents a similar model, but in this case, it is the per capita capital ratio of the economy that would be the origin of the spillovers of knowledge in the economy, instead of being the level of the stock of capital.

- *Increases in the stock of knowledge.* The key idea behind this generation of endogenous growth models lies in defining a growth path for knowledge and technological level, in analogy with the accumulation of physical capital. Romer (1990) presents a model of three sectors where labour is distributed between the production of technological knowledge and the production of consumer goods; differentiating the production of the R&D sector as a production factor additional to the classical production factors.
  Benhabib and Perli (1994) present a variant of the Lucas-Uzawa model under the same premise of knowledge accumulation, but understanding human capital as a complementary factor to the labour factor, which increases its productivity; and focused on the time invested to increase human capital.

9.4.2 Nelson and Winter: The Evolutionary Approach to Innovation

When we jointly consider the systemic nature of innovation and the endogeneity of technological change, going beyond endogenous growth models is needed. The relationships between patterns of technological change and growth patterns must be addressed in the context of interactions between agents with different capacities for innovation and absorption–imitation. That is, by analysing the interrelationships and competition processes, essentially asymmetrical, between components of a markedly heterogeneous group. As response, Nelson and Winter (1982) propose an evolutionary approach in which companies make not only productive decisions, but also technological ones. Firms search for knowledge and existing production techniques, or they generate them within the company, and make decisions about technology incorporation based on expectations (subject to error and uncertainty) about the rate of return between different technologies. As a result, an evolutionary process of selection arises, both on production techniques and on companies, whose survival and pre-eminence (face both, to existing competitors as well as to potential incumbents) depend on the efficient selection of technology under

conditions of uncertainty. It is this evolutionary character with a dynamic and stochastic component that gives this approach its name.

Among the advantages of evolutionary models, their ability to explain both time series and the microeconomic aspect of technical change stands out. In this sense, both the differences between companies and the imbalance in the system appear as essential aspects of economic growth commanded by technical change. The relevance or inertial effect of historical elements (path dependence) in the body of knowledge and practices constituting the existing technological and knowledge stock, as well as in the processes of mastery (knowledge capitalization) and progress (increase in the stock of knowledge) and its application to economic activity, become the critical factors of technological change and thus determinants to this evolutionary process (Nelson & Winter, 1982).

9.4.3 Freeman and the Systemic Approach of Innovation

Despite the important contribution, evolutionary models do not sufficiently address the issues inherent to the legal and institutional framework and the historical context in which evolutionary processes take place, under different conditions in different temporal and geographical contexts. The possibility (in terms of capacity and probability) of introducing an innovation in the market is mediated by many conditions that do not depend only on firms and that are closely related to the levels of development of the country or region in which they operate, establishing an indissoluble relationship between the micro and macro aspects in innovation processes (Natera, 2022): the availability of qualified workers (which in turn depends on the quality, extension and intensity of the educational system), access to the necessary inputs (linked to the degree of openness of the economy), administrative and bureaucratic limitations (related to the institutional maturity) and the existence of a sufficiently large market for products (which is related both to country's income levels and distribution of income and wealth, as well as to competitiveness and access to international markets).

This set of interactions, relationships and interdependencies generated a new approach (Edquist, 1997, 2001, 2004; Freeman, 1974, 1987, 1995, 2002; Lundvall, 1992; Nelson, 1993) that analysed the innovation process from a systemic and holistic perspective, structured by three key elements (Pérez, 1996; Soete et al., 2010): (1) the existence of agents, institutions and organizations, public and private, that interact with each

other with different frequency and with different objectives (the system); (2) the identification, use, generation and dissemination of knowledge, its applications and technological and organizational (innovation) improvements; and (3) contextualization in a specific geographical (national, regional or local) area (subsequently extended to sectorial approach by Malerba, 2005, 2008), which also includes an evolutionary and dynamic component.

In this sense, the current concept of Innovation System, referring both to geographical or sectoral approaches, is the result of a complex process of "cross fertilization" between contributions, whose origin is usually established in the ideas of List (1841) on the existence of a National System of Political Economy (Lundvall, 1992; Erbes & Suárez, 2020, Suárez & Erbes, 2021), in which there are also elements of the historical schools (German and British), the institutionalism, the Marxist vision of the relationship between technological change and economic systems, the Marshallian perception of the institutional context as a determining factor of economic activity, the Schumpeterian analysis of the innovative process as a determinant of economic development, and the crucial role of interactions in the process of creating and diffusing knowledge and technology, giving rise to a prolix approach in literature in which Freeman, Lundvall, Nelson and Edquist occupy a central place.[4]

When addressing the relationship between National Innovation Systems and development, we must be aware that, although the approach was not born as a theory of development, it offers tools to understand both, development processes (impacts of economic growth on the standard of living of the society to which the system refers) and the differences between systems (countries, regions, or sectors) and its determinants. Compared with the aforementioned limitations of the orthodox approaches to growth (whether exogenous or endogenous), the systemic approach has the advantage of considering the role of capacities (technological or innovative, absorptive, and social) and other dimensions, such as market structures and institutions, to understand development as an improvement in the level and living conditions of society in the Myrdalian sense (Johnson

[4] For an interesting and recent synthesis of the process of generating the concept of Innovation System and the development of the powerful methodological tool it provides for economic analysis and policy design, including a differential analysis from the perspectives of central economies and peripheral countries (especially those in Latin America), see Erbes and Suárez (2020).

et al., 2003). At the same time, this entails considering innovation as a multidimensional problem and context dependent, so that different dominant drivers of innovation may coexist according to different contexts (Hong et al., 2012).

When considering technological capabilities, the systemic approach to innovation refers to three elements (innovative, absorptive and social capacities), that complement and interact with each other and with the other components of the system as market structures, institutions, and other non-market elements (Lall, 1992). Thus, technological and *innovative capacities* refer to the potential of companies (Bell & Pavitt, 1995; Patel & Pavitt, 1997) and of countries (Archibugi et al., 2009; Castellacci, 2011; Fagerberg & Verspagen, 2007) or sectors (Malerba, 2005, 2008) to generate new knowledge or new applications of existing knowledge, which are transformed into innovations and technological change; *Absorptive capacities* are associated with the potential to incorporate to the production process innovations, knowledge and their applications, even if they have been generated outside the system; *Social capacities* have to do with cultural factors, the social consideration of entrepreneurs and innovators, risk aversion, entrepreneurial spirit, etc. (Kim, 1997; Lall, 1992). In other words, every country, region or sector will evolve following a certain trajectory as a consequence of the combination and interaction of economic, technological and sociopolitical aspects that will generate different patterns of innovation and development profiles (Castellacci & Natera, 2016; Natera, 2016; Dutrénit et al., 2019, 2011).

The generation of capacities is closely related to the patterns and volumes of investment in human and physical capital and the technological and innovative effort, and can be understood as the capacity of firms (micro) and of the whole set of economic agents (macro) to develop an effective use of knowledge (scientific, technological and of general purpose) for its application in the productive process and transform it into innovations, in a process in which investment strategies play an important role (Bell & Pavitt, 1995; Lall, 1992; Patel & Pavitt, 1997).

Jointly with this potential, the systemic approach has certain limitations, mainly derived from the scarce attention paid to sociopolitical factors (power relations, trust in institutions and their efficiency…), generally addressed as a conditioning factor, sometimes even exogenous (Natera, 2022), but with a lower degree of importance than technoeconomic factors (Pérez, 1983). As a result, a limit arises in the capacity of systemic approach to analyse and formulate recommendations to enhance the

so-called social capacities that determine the system adaptative capacity to changes in knowledge patterns and converge towards higher levels of development (Abramovitz, 1986), or to identify what type of institutions favour the functioning of the system of innovation and enhance the results of the other capacities (Cozzens & Sutz, 2014; Von Tunzelmann, 2003).

9.5 Conclusions

The importance and effects of technological change on the economic system, including its endogenous character, were early perceived by economists of the classical-Marxist approach. In general terms, they focused on their effects on productivity and labour specialization and the effects of capital accumulation.

However, in the marginalist-neoclassical approach, the attention paid to this topic was scarce and it was not reconsidered until the estimates on the determinants of growth in the mid-twentieth century found that two thirds could not be explained by growth factors and were attributed to a "residual" factor, which was identified with technological change.

The response inside the neoclassical approach focused on incorporating technological change as an (exogenous) source of growth, along with capital accumulation, and refining the elements of the aggregate growth function to include, among other variables, the accumulation of human capital and technological capital (R&D). The main controversy within this neoclassical approach was related to the distinction between financial capital and technical-productive capital and the incorporated nature of technology in the replacement of technical-productive capital and the effects of the interest rate on the choice of heterogeneous techniques with different capital intensity. Despite this, the residual component was still around 35% of growth.

Outside of the orthodox neoclassical approach, the Schumpeterian vision stood out in the first place, proposing a dynamic vision of the economy based on the central role of innovation and the entrepreneur. This supposes a supply side approach and a pioneering consideration of the endogenous nature of innovation and technological change (which constitutes an essential source of change and instability, generating dynamism) and moves away from neoclassical analysis based on comparative statics and the search for equilibrium. In this way it is possible to explain growth and competitiveness (both in micro and macroeconomic perspective) on the basis of innovation. This is compatible with the interpretation of the

origin of competitive advantages as result of innovation, as well as with explaining growth and development differentials on as a consequence of technological gaps.

The current approach is the result of the interaction between different researches lines developed in the last decades of the twentieth century. Based on endogenous growth models, innovation and technical change were integrated into the functioning of economic activity highlighting their ability to generate increasing returns (due to improvements in knowledge and technology) that drive the process of growth. On the other hand, evolutionary models seek to take into account the existing relationships between growth patterns and technological change patterns, which are developed in a context of interactions between agents, with different capacities for innovation and absorption–imitation, who make both productive and technological decisions. To do this, they pay attention to the asymmetries in the interrelationships and processes in non-competitive market structures and to the heterogeneity of agents and institutions involved in the innovation process. From this perspective, a selection process is developed between productive techniques and between companies, whose survival and pre-eminence generates an evolutionary process, both in the firms' characteristics and in the predominant technologies.

The endogenous-evolutionary approach is complemented by the systemic approach, which allows addressing issues inherent to the legal and institutional framework, the context in which endogenous decisions are made, and the evolutionary processes that take place; thus, it is possible to address the relationship between micro and macro aspects in innovation processes. The systemic approach is structured around three essential elements: the system (agents, institutions and organizations, public and private, that interact with each other with different frequency and with different objectives), innovation (identification, use, generation and diffusion of knowledge, its applications and technological and organizational improvements) and the scope (geographic—national, regional or local—and/or sectorial contextualization), while also including an evolutionary and dynamic component. The differences between systems and their results (innovative, growth, competitive, or of any other nature) are largely explained on the basis of differences in terms of capacities (technological and innovative, absorptive and social).

In summary, the current focus in the economic analysis of innovation and technological change is the result of a complex conceptual and methodological "distillation" process, which considers innovation as

endogenous to the economic system, which generate an evolutionary path in innovation and growth, having effects on the whole system. As a result, Innovation Systems constitute a powerful tool, with theoretical robustness, to explain differential dynamics in development paths identify the determinants of these differences, promote the benchmarked practices and strategies of existing system and design policies to correct inefficiencies or weakness when detected.

However, certain limitations arise, mainly derived from lower attention paid to sociopolitical factors (power relations, trust in institutions and their efficiency…), generally considered as an exogenous conditioning factor, while the main attention is paid to techno–economic factors. Therefore, there remains significant room for improvement via reinforcing attention to sociopolitical aspects, so that the systemic approach gains the capacity to analyse and make recommendations to enhance the so-called "social capacities" or to identify which institutions promote the functioning of the innovation system and enhance the results of the other capacities.

References

Abramovitz, M. (1956). *Resource and Output Trends in the United States since 1870* (pp. 1–23). National Bureau of Economic Research, Inc. https://www.nber.org/books-and-chapters/resource-and-output-trends-united-states-1870/resource-and-output-trends-united-states-1870

Abramovitz, M. (1986). Catching Up, Forging Ahead, and Falling Behind. *Journal of Economic History, 46*(2), 385–406.

Aghion, P., & Howitt, P. (1990). *A Model of Growth Through Creative Destruction*. NBER Working Papers. https://www.nber.org/papers/w3223

Antonelli, C. (2008). *The Economics of Innovation*. Routledge Major Works.

Archibugi, D., Denni, M., & Filippetti, A. (2009). The Technological Capabilities of Nations: The State of the Art of Synthetic Indicators. *Technological Forecasting and Social Change, 76*(7), 917–931.

Archibugi, D., & Michie, J. (1998). Technical Change, Growth and Trade: New Departures in Institutional Economics. *Journal of Economic Surveys, 12*(3), 313–332.

Barro, R. J., & Sala-i-Martin, X. (1992). Convergence. *Journal of Political Economy, 100*(2), 223–251.

Bell, M., & Pavitt, K. (1995). The Development of Technological Capabilities. In I. u. Haque (Ed.), *Trade, Technology and International Competitiveness* (pp. 69–101). The World Bank.

Benhabib, J., & Perli, R. (1994). Uniqueness and Indeterminacy: On the Dynamics of Endogenous Growth. *Journal of Economic Theory, 63*(1), 113–142.

Castellacci, F. (2011). Closing the Technology Gap? *Review of Development Economics, 15*(1), 180–197.

Castellacci, F., & Natera, J. M. (2016). Innovation, Absorptive Capacity and Growth Heterogeneity: Development Paths in Latin America 1970–2010. *Structural Change and Economic Dynamics, 37*, 27–42.

Cohen, J. A., & Harcourt, G. C. (2003). Whatever Happened to the Cambridge Capital Theory Controversies? *Journal of Economic Perspectives, 17*(1), 199–214.

Cortright, J. C. (2001). New Growth Theory, New Growth Theory. *Technology and Learning: Technology and Learning: A Practitioner's Guide A Practitioner's Guide*.

Cozzens, S., & Sutz, J. (2014). Innovation in Informal Settings: Reflections and Proposals for a Research Agenda. *Innovation and Development, 4*(1), 5–31.

De Long, J. B. (1988). Productivity Growth, Convergence, and Welfare: Comment. *The American Economic Review, 78*(5), 1138–1154.

Dutrénit, G., Natera, J. M., Puchet, A., & Martín-Vera-Cruz, A. O. (2019). Development Profiles and Accumulation of Technological Capabilities in Latin America. *Technological Forecasting and Social Change, 145*, 396–412. https://doi.org/10.1016/j.techfore.2018.03.026

Dutrénit, G., Puchet, A., & M., Teubal, M. (2011). Building Bridges Between Co-evolutionary Approaches to Science, Technology and Innovation and Development Economics: An Interpretive Model. *Innovation and Development, 1*(1), 51–74. https://doi.org/10.1080/2157930X.2010.551061

Edquist, C. (1997). Systems of Innovation Approaches – Their Emergence and Characteristics. *Systems of Innovation: Technologies, Institutions and Organizations, 1989*, 1–35.

Edquist, C. (2001), The Systems of Innovation Approach and Innovation Policy: An Account of the State of the Art. In *DR UID Conference, Aalborg*, pp. 12–15.

Edquist, C. (2004), "Systems of Innovation: Perspectives and Challenges". En Fagerberg, Jan; Mowery, David y Nelson, Richard (eds.), *The Oxford Handbook of Innovation*. : Oxford University Press.

Elster, J. (1992). *El cambio tecnológico: Investigación sobre la racionalidad y la transformación social*. Gedisa.

Erbes, A., & Suárez, D. (2020). Capítulo 5. Sistemas nacionales de innovación: antecedentes y debates. In Diana Suárez, Analía Erbes y Florencia Barletta (comp.) Teoría de la innovación: evolución, tendencias y desafíos, pp. 161–196. Ediciones Complutense, Madrid.

Fagerberg, J., & Verspagen, B. (2007). Innovation, Growth and Economic Development: Have the Conditions for Catch-Up Changed? *International Journal of Technological Learning, Innovation and Development, 1*(1), 13–33.

Freeman, C. (1974). *The Economics of Industrial Innovation*. Penguin Books.

Freeman, C. (1982). *The Economics of Industrial Innovation*. University of Illinois at Urbana-Champaign's Academy for Entrepreneurial Leadership Historical Research Reference in Entrepreneurship. Available at SSRN 1496190.
Freeman, C. (1987). *Technology Policy and Economic Performance: Lessons from Japan*. Pinter.
Freeman, C. (1995). The 'National System of Innovation' in Historical Perspective. *Cambridge Journal of Economics, 19*(1), 5–24.
Freeman, C. (2002). Continental, National and Sub-national Innovation Systems – Complementarity and Economic Growth. *Research Policy, 31*(2), 191–211.
Freeman, C., Clarck, J., & Soete, L. (1982). *Unemployment and Technical Innovation*. Frances Pinter.
Freeman, C., & Pérez, C. (1988). Structural Crises of Adjustment, Business Cycles and Investment Behavior. In G. Dossi, et al., (Eds.), Technical Change and Economic Theory, (pp. 39–62). London: Pinter.
Garegnani, P. (1970). Heterogeneous Capital, the Production Function and the Theory of Distribution. *The Review of Economic Studies, 37*(3), 407–436.
Grossman, G. M., & Helpman, E. (1991). Trade, Knowledge Spillovers, and Growth. *European Economic Review, 35*(2–3), 517–526.
Hayek, F. A. (1937). Investment That Raises the Demand for Capital. *The Review of Economic Statistics*, 174–177.
Heertje, A. (2006). *Schumpeter on the Economics of Innovation and the Development of Capitalism*. Edward Elgar.
Hong, S., Oxley, L., & McCann, P. (2012). A Survey of the Innovation Surveys. *Journal of Economic Surveys, 26*(3), 420–444.
Hufbauer, G. C. (1966). *Synthetic Materials and the Theory of International Trade*. Duckworth.
Islam, N. (1995). Growth Empirics: A Panel Data Approach. *The Quarterly Journal of Economics, 110*(4), 1127–1170.
Johnson, B., Edquist, C., & Lundvall, B-Å. (2003). Economic Development and the National System of Innovation Approach. *First Globelics Conference*, Río de Janeiro.
Kaldor, N. (1957). A Model of Economic Growth. *The Economic Journal, 67*(268), 591–624.
Kim, L. (1997). *Imitation to Innovation: The Dynamics of Korea's Technological Learning*. Harvard Business Press.
Kyriakou, D. (2002). El progreso técnico y su impacto en el crecimiento: pruebas. *The IPTS Report, 62*, 30–33.
Lall, S. (1992). Technological Capabilities and Industrialization. *World Development, 20*(2), 165–186. https://doi.org/10.1016/0305-750X(92)90097-F
Lazzarini, A. (2011). *Revisiting the Cambridge Capital Theory Controversies: A Historical and Analytical Study*. Pavia University Press.
List, F. (1841). *The National. System of Political Economy*. Longsman Green.

Lucas, R. E., Jr. (1988). On the Mechanics of Economic Development. *Journal of Monetary Economics, 22*(1), 3–42.

Lundvall, B. A. (1992). *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. Anthem Press.

Malerba, F. (2005). Sectoral Systems of Innovation: A Framework for Linking Innovation to the Knowledge Base, Structure and Dynamics of Sectors. *Economics of Innovation and New Technology, 14*(1–2), 63–82.

Malerba, F. (2008). *Sectoral Systems of Innovation*. Georgia Institute of Technology.

Mankiw, N. G., Romer, D., & Weil, D. N. (1992). A Contribution to the Empirics of Economic Growth. *The Quarterly Journal of Economics, 107*(2), 407–437.

Motta, J., & Moreno, H. (2020). La teoría moderna de la innovación y sus antecedentes en el pensamiento económico. In D. Suárez, A. Erbes, & F. Barletta (Comp.). *Teoría de la innovación: evolución, tendencias y desafíos: herramientas conceptuales para la enseñanza y el aprendizaje*. Ediciones UNGS Universidad Nacional de General Sarmiento y Ediciones Complutense, Los Polvorines y Madrid. Colección Ciencia, innovación y desarrollo no. 14, pp. 23–69.

Natera, J. M. (2016). Las dinámicas de los Sistemas Nacionales de Innovación. In A. Erbes & D. Suárez (Eds.), *Repensando el desarrollo latinoamericano. Una discusión desde los sistemas de innovación* (1st ed., pp. 69–102). Universidad Nacional de General Sarmiento.

Natera, J. M. (2022). The Tree Lives Beyond Its Leaves: Freeman's Legacy on System Thinking for Innovation Studies. *Innovation and Development, 12*(1), 77–84.

Neffa, L. C. (2000). *Las innovaciones científicas y tecnológicas. Una introducción a su economía política*. Lumen Humanitas / Asociación Trabajo y Sociedad (ceil-piette conicet).

Nelson, R. (1997). How New Is New Growth Theory? *Challenge, 40*(5), 29–58.

Nelson, R., & Winter, S. (1982). *An Evolutionary Theory of Economic Change*. Harvard University Press.

Nelson, R. R. (Ed.). (1993). *National Innovation Systems: A Comparative Analysis*. Oxford University Press on Demand.

Palma Martos, L. (1989). *Teoría Económica, Innovación Tecnológica y Estructuras de Mercado*. PhD dissertation, Universidad de Sevilla.

Pasinetti, L. L., & Scazzieri, R. (1990). Capital Theory: Paradoxes. In J. Eatwell, M. Milgate, & P. Newman (Eds.), *Capital Theory*. The New Palgrave. Palgrave Macmillan.

Patel, P., & Pavitt, K. (1997). The Technological Competencies of the World's Largest Firms: Complex and Path-Dependent, But Not Much Variety. *Research Policy, 26*(2), 141–156.

Pérez, C. (1983). Structural Change and the Assimilation of New Technologies in the Economic and Social System. *Futures, 15*(4), 357–375.

Pérez, C. (1996). Nueva concepción de la Tecnología y Sistema Nacional de Innovación. *Cuadernos del CENDES, 31*, 9–33.
Posner, M. V. (1961). International Trade and Technical Change. *Oxford Economic Papers, 13*(3), 323–341.
Rae, J. (1834). *Statement of Some New Principles on the Subject of Political Economy, Exposing the Fallacies of the System of Free Trade, and of Some Other Doctrines Maintained in "The Wealth of Nations"*. Hilliard, Gray and Co.
Ricardo, D. ([1817] 2001). *On the Principles of Political Economy and Taxation*. Electric Book Co.
Robinson, J. (1953). The Production Function and the Theory of Capital. *The Review of Economic Studies, 21*(2), 81–106.
Romer, P. M. (1986). Increasing Returns and Long-Run Growth. *Journal of Political Economy, 94*(5), 1002–1037.
Romer, P. M. (1990). Endogenous Technological Change. *Journal of Political Economy, 98*(5, Part 2), S71–S102.
Romer, P. M. (1994). The Origins of Endogenous Growth. *Journal of Economic Perspectives, 8*(1), 3–22.
Rosenberg, N. (1974). Karl Marx on the economic role of science. *Journal of Political Economy, 82*(4), 713–728.
Rosenberg, N. (1976). *Perspectives on Technology*. Cambridge University Press.
Rosenberg, N. (1982). *Inside the Black Box: Technology and Economics*. Cambridge University Press.
Rosenberg, N. (1994). *Exploring the Black Box. Technology, Economics and History*. Cambridge University Press.
Ricoy, C. (2003). Marx on division of labour, mechanization and technical progress. *The European Journal of the History of Economic Thought, 10*(1), 47–79.
Sala-i-Martin, X., Doppelhofer, G., & Miller, R. I. (2004). Determinants of Long-Term Growth: A Bayesian Averaging of Classical Estimates (BACE) Approach. *American Economic Review, 4*(94), 813–835.
Schmookler, J. (1965). Technological Change and Economic Theory. *The American Economic Review, 55*(1/2), 333–341.
Schumpeter, J. A. ([1912] 1976). *Teoría del Desenvolvimiento Económico*. Fondo de Cultura Económica.
Schumpeter, J. A. ([1942] 1976). *Capitalism, Socialism and Democracy*. Routledge.
Shaikh, A. (1978). Political economy and capitalism: notes on Dobb's theory of crisis. *Cambridge Journal of Economics, 2*(2), 233–251.
Smith, A. ([1776] 1999). *The Wealth of Nations*. Penguin.
Soete, L., Verspagen, B., & Weel, B. (2010). Systems of Innovation. In B. Hall & N. Rosenberg (Eds.), *Handbook in Economics of Innovation*. Elsevier.
Solow, R. M. (1956). A Contribution to the Theory of Economic Growth. *The Quarterly Journal of Economics, 70*(1), 65–94.

Solow, R. M. (1957). Technical change and the aggregate production function. *The review of Economics and Statistics, 39*(3), 312–320.

Solow, R. M. (1967). Some Recent Developments in the Theory of Production. In *The Theory and Empirical Analysis of Production* (pp. 25–53). NBER.

Solow, R. M. (1994). Perspectives on Growth Theory. *Journal of Economic Perspectives, 8*(1), 45–54.

Stoneman, P. (1983). *The Economic Analysis of Technological Change*. Oxford University Press.

Suárez, D., & Erbes, A. (2021). What Can National Innovation Systems Do for Development? *Innovation and Development, 11*(2–3), 243–258.

Vernon, R. (1979). The Product Cycle Hypothesis in a New International Environment. *Oxford Bulletin of Economics and Statistics, 41*(4), 255–267.

Von Tunzelmann, N. (2003). Historical Coevolution of Governance and Technology in the Industrial Revolutions. *Structural Change and Economic Dynamics, 14*(4), 365–384.

PART III

Some Specific Controversies Solved

CHAPTER 10

On the Capital Controversies as a Choice of Paradigms

Ramiro E. Álvarez and Jose A. Pérez-Montiel

10.1 Introduction

The question of income (and wealth) distribution is currently attracting increasing interest in both the political and academic spheres, chiefly (although not exclusively) in the wake of the publication in 2014 of *Capital in the Twenty-First Century*, by Thomas Piketty. However, the discussion is framed as a contrast between predictions and empirical observation, rather than in terms of the formal logical consistency of the conventional economic approach (otherwise known as neoclassical or marginalist approach).

R. E. Álvarez (✉)
National University of Moreno, Moreno, Argentina

National Scientific and Technical Research Council, Buenos Aires, Argentina
e-mail: ralvarez@unm.edu.ar

J. A. Pérez-Montiel
University of the Balearic Islands, Palma, Spain
e-mail: jose.perez@uib.es

E. Trincado Aznar, F. López Castellano (eds.), *Science, Technology and Innovation in the History of Economic Thought*, Palgrave Studies in the History of Economic Thought,
https://doi.org/10.1007/978-3-031-40139-8_10

In this respect, the recent debate has not re-addressed the controversies surrounding the neoclassical theory of distribution, or more specifically, the controversies regarding the notion of "Capital", which were at their height during the post-war period (1953–1976). Existing literature refers to these discussions as the *Capital Controversies* or the *Cambridge-Cambridge Controversies* (hereinafter CCCs).[1] We think it is important to re-visit these post-war controversies, as any analysis that focuses on a contrast between neoclassical predictions and observation necessarily disregards the concessions made by the marginalist tradition itself as a consequence of the debate in the 1960s and 1970s.

In this chapter, we shall be analysing how the CCCs arose and evolved, as well as how they apparently came to an end in the 1960s and have now been forgotten (and in fact are completely absent from books on the history of economic thought). To this end, our research makes use of Thomas S. Kuhn's characterisation of the history of scientific thought. Over the course of this chapter, we shall be looking to lay out the existing arguments regarding the theory of capital, in order to present the debate as a real choice between paradigms. We shall see how answers to the question of *why the CCCs did not lead to a Scientific Revolution that would bring about the demise of the neoclassical hegemony* fall outside the logical rigour of the competing theories and reflect the inherent circularity of the communication between paradigms (Kuhn, 1995 [1962]). In order to fully understand the direction taken by the debate, we shall briefly introduce the origins of the neoclassical theory of capital before examining in depth the CCCs that took place between 1953 and 1976.

The CCCs will be presented following the dynamics set out by Kuhn (1995 [1962]), in other words, *Normal Science–Extraordinary Science–Normal Science*, while distinguishing two stages in the debate, as was done by various authors (Mirowski, 1989; Garegnani, 2012; Lazzarini, 2013). For this purpose, we shall introduce the phenomena of *re-switching* and

[1] We speak of the Cambridge-Cambridge Controversies (Harcourt, 1969) because the debate was led by economists from Cambridge in the USA (specifically from the Massachusetts Institute of Technology, MIT) and from Cambridge in the United Kingdom. The economists from MIT (mainly P. Samuelson, R. Solow, D. Levhari, C. Ferguson, and M. Blaug) defended the marginalist paradigm, while the critical side was represented by economists such as J. Robinson, P. Sraffa, L. Pasinetti and N. Kaldor. It is nevertheless true that some economists from Cambridge UK also stood in favour of the neoclassical side, namely, F. Hahn and C. Bliss, and that critical economists, such as P. Garegnani, worked at both MIT and Cambridge UK.

reverse capital deepening as *anomalies* that cannot easily be assimilated into the marginalist paradigm, before looking at a stage where their (partial) assimilation entailed the flexibilisation of some of the commitments around which the neoclassical *normal research* was structured. In this second phase of the discussion, we shall examine the worsening problems of communication between the two sides of the controversy, which eventually bogged down the discussion. Finally, we shall briefly present our main conclusions.

10.2 The Notion of Capital in Value Terms. From the Theory of Surplus to Factor Supply and Demand Curves

The neoclassical theory of capital originated as an extension of the Malthusian Theory of rent to other remunerations, namely, wages and profit rate (Pasinetti, 2000, p. 389). Such an extension represented a revolutionary departure from the traditional theory introduced by physiocrats and further developed by classical theorists, particularly Ricardo (1815, 1817) and Marx (1871), which centred on the notion of social surplus appropriated by those who control the production process (capitalists) once the reproduction of consumption goods and capital goods has been ensured. This approach, known as the Classical Surplus Approach and synthesised in Ricardo (1815, 1817), favoured logical rigour and attracted criticism as well as acceptance.

With the fervour of the Industrial Revolution, the accumulation of capital became the centre of attention of Political Economy theorists, putting an end to the identification of land as the main source of wealth. The *Marginalist Revolution* thereby involved, firstly, applying the differential calculus toolbox of the Ricardian theory (where it was applied only to the product of land) to the theory of human behaviour (diminishing marginal utility) before extending it to all means of production (labour and reproducible means of production or capital goods). Yet it is important to consider that, just as the Malthusian Theory[2] of rent involved the variability of

[2] Following on from Dobb (1973), it can be stated that the work of T.R. Malthus, *An Inquiry into Rent*, had a profound influence on the formulation of the Ricardian Theory of Distribution. With the Malthusian Theory of Rent, which focuses on the notion of diminishing returns related to the decreasing labour productivity brought on by intense agricultural production, Ricardo managed to define rent as a surplus.

labour input per unit of land (with a view to addressing the decreasing productivity of land), extending it to capital goods requires variability of the proportion of capital per worker.

However, the alternative methods of production differ more by the kinds of capital goods used than by the proportion to labour in which each of them is employed; in other words, the presence of physically heterogeneous capital makes an extension of the theory difficult. The neoclassical theory found that the individual behaviour of savers (who maintain theirs savings in terms of money) provided not only the necessary malleability of capital but also the possibility of making the capital endowment compatible with the variability of the physical specification of capital goods required by the condition of the uniformity of the profit rate, the latter being an intrinsic condition of the *long period method* (hereinafter, LPM) shared both by classical and neoclassical theorists in the first half of the twentieth century (Kurz & Salvadori, 2003).[3] This reflects the implications entailed by the generalisation of the Malthusian theory of rent to the remuneration of other productive factors, such as capital goods, given that uniformity of returns for their productive services can be attained only when the physical composition of the capital goods endowment is fully adjusted to the production techniques adopted in normal positions. However, an endowment that is considered to be fixed can only adjust fluidly if it is conceived in the same terms used by Walras for savers, that is, by expressing capital goods in value terms.

In summary, we can already assert that expressing capital goods in terms of value seeks to satisfy the homogenisation required by the extension of the Malthusian theory of rent, but essentially it is aimed at obtaining the malleability necessary to ensure a uniform rate of return for a fixed capital endowment in value terms (for the purposes of correspondence between theory and observation).

The question of how to define the factor capital within the theory had already begun to monopolise the attention of the main neoclassical theorists in the nineteenth century. Böhm-Bawerk (1891) tried to measure capital as an "average production period", a unit of measurement that was intended to be independent of prices and return rates. However, this required certain assumptions that were particularly problematic for the marginalist theory. According to Garegnani (1990), ascertaining this time

[3] In this respect, the contribution of León Walras, of which we will speak below, was fundamental (Dvoskin & Lazzarini, 2013).

element required interest to be calculated through simple rather than compound capitalisation, which is incompatible with the principle of profit maximisation on which free competition is based. On the other hand, and even more problematically, the existence of more than one original factor means that the reduction to dated quantities of labour derives an average production period which depends on rate of wages and rent, rather than solely on the technical information associated with the different quantities of labour employed over different periods of time. This therefore raises a problem of circular logic, whereby an unknown variable needs to be ascertained to construct the data from which that very variable must be determined.

On the other hand, Wicksell (1934 [1901]), unsatisfied with the solution provided by Böhm-Bawerk (1891)—as it does not consider compound interest and accepts only one factor other than labour—conceived capital as a single magnitude in value terms, asserting that the only common feature of physically different capital goods is that they can be expressed in monetary terms.[4] Wicksell thus suggested treating physically heterogeneous capital goods as a factor expressed in value terms and as homogeneous as land or labour (of the same quality), bypassing (or at least appearing to, as we shall see below) the difficulties of Böhm-Bawerk's approach described above.

The Neoclassical Theory was consolidated in Clark's work (1899), who uses competition between factors and companies to ensure the full employment of productive factors as a result of the possibility of substituting those factors. Therefore, the return rate of each "factor", as well as being equivalent to the production added by the last unit of factor introduced in the production process (the marginal product), is a mere reflection of its relative scarcity (a result known as the "Neoclassical Parable").

The neoclassical theory of distribution was founded on the idea of substitution between factors in order to minimise the cost of production, deriving negative and monotonic relationships between remunerations and the incentives for increasing the factor proportions. Consequently, by using the known data (factor endowments, preferences and technology),

[4] *"Capital includes the raw materials (…) and other commodities which must be saved-up. This, of course, is the commonly accepted sense of the term. [A]ll [different capital goods] have only one quality in common, namely, that they represent certain quantities of exchangeable value so that they may be regarded as a single sum of value, a certain amount of the medium of exchange, money"* (Wicksell, 1934 [1901], pp. 144–145).

the theory can determine the unknown variables (wages, rent, interest rate, prices) through demand and supply functions. This constituted the foundation of the "capital demand curve" which lays the ground for treating the different factors of production symmetrically.[5]

It is nevertheless clear that treating reproducible means of production as "capital", that is, as a homogeneous magnitude in value terms, poses a logical problem given that, in contrast to the available amount (or endowment) of existing land or labour, we cannot use data that depends on the variables (the prices of capital goods) that have yet to be ascertained from that very data. This issue will constitute a central theme of the CCCs.

10.3 The First Phase of the CCCs (1953–1970): The Re-switching as an *Anomaly* for the Marginalist Approach

The post-war years did not bring any paradigmatic stability to the field of Political Economy. The marginalist theory, which had managed to defend itself from the critique in Keynes (1936) after the Neoclassical Synthesis, was still far from the unanimous consensus about its capacity to explain phenomena (*anomalies* in terms of Kuhn), such as the unequal exchange between economic systems, persistent underdevelopment or deflation. In this section, we shall describe the scientific community's growing awareness of the existence of an *anomaly*, namely, the *re-switching*. This can be described as the possibility of yielding a result regarding the choice of techniques that contradicts the neoclassical factor substitution mechanism, thereby potentially generating a paradigmatic crisis.

According to Dobb (1973), Piero Sraffa's 1951 edition of *Work and Correspondence of David Ricardo* offered an interpretation of Ricardo's work, which was different from that of the neoclassical school in the early twentieth century at the hands of Alfred Marshall. In line with Kuhn's

[5] The substitution mechanism that underlies the construction of decreasing demand function relationships between the rate of profit (or interest) and the capital-labour ratio does not operate only in the case of changes of technique but also where a single technique is applied to the production of heterogeneous consumer goods. In this case, which is known as an indirect substitution mechanism, goods are distinguished according to the relative proportion of productive factors in the method of production of the consumer good. Distributive changes therefore tend to be associated with changes in the relative costs and, consequently, with the quantities demanded by consumers, which changes the demand for factors of production (Petri, 2021).

image of science, Sraffa (1951) *disputed the assimilation* of the classical tradition by the neoclassical theory, offering a new version both of the theory of profit (i.e. as a residual determined by institutional factors) and of the Ricardian search for an invariable measure of value. In terms of Kuhn, the proliferation of different versions of one theory is a very common symptom of a crisis in the dominant paradigm (Kuhn, 1995 [1962], p. 156). The resurgence of a new vision of Ricardo's theory may have laid the ground for the consideration of phenomena that had been forgotten by the neoclassical paradigm. Kuhn's epistemological approach can help us understand the subsequent criticism of some neoclassical theoretical elements by Joan Robinson, Nicholas Kaldor and Richard Hahn, such as the Aggregate Production Function (APF).

Robinson (1953–1954) reprised the contributions of Wicksell (1934 [1901]) to criticise the notion of "capital" as a factor of production, as well as the continuous nature that technology acquires in an APF. The Cambridge economist thus moved towards identifying a circular logic in the neoclassical analysis, by pointing out that the expression of "capital" is dependent upon prices that are themselves dependent upon the rate of profit or interest (an unknown variable to be determined by the theory). This takes us to the process of reaching *awareness of the anomaly*, or *emergence of scientific discoveries*, which are addressed in Chapter VI of Kuhn (1995 [1962]). However, following on from Garegnani (1970a) and Lazzarini (2011), the scope of Robinson's critique is limited to her objections to the notion of "equilibrium" which is encompassed (as we shall see below) in the LPM.

In short, the arguments in defence of the neoclassical side (Solow, 1955–1956; Champernowne, 1953–1954; and Samuelson, 1962, amongst others) exposed the partiality of this first criticism when they pointed out that the problems of aggregation are not limited to "capital" but rather common to all factors of production. This seems to reveal a lack of understanding of the logical differences between capital aggregation and aggregations of other factors of production (labour and land): while the latter take place in physical terms, the aggregation of heterogeneous capital goods occurs in terms of value.

The work of Piero Sraffa, *Production of Commodities by Means of Commodities*, published in 1960, constituted a dividing line in the critical discussion, even though the demonstration of the *anomalies* that threatened the generality of the derivation of monotonic decreasing capital demand curves was secondary to the true purpose of the work, which

consisted in a critique of the neoclassical theory by reviving the classical surplus approach. While for Kuhn, the *discovery commences with the awareness of anomaly, that is, with the recognition that nature has somehow violated the paradigm-induced expectations that govern normal science* (1996 [1962], p. 52), Sraffa (1960) could be presented as a contribution associated with the discovery of the *re-switching*. In this respect, the subheading by Sraffa (1960), *Prelude to a Critique of Economic Theory*, is a good reflection of the true aim of the piece: to lay the foundation for a new paradigm, closer to the classical approach that had been dethroned by the extension of the Malthusian theory of rent to the determination of the interest rate and wages.

In his work, Sraffa shows that changes in a distributive variable (for instance, a drop in real wages in the face of a sudden increase in the labour endowment) can entail the adoption of a new production technique in which the value of the capital goods per worker can be greater than, smaller than or equal to that observed in the previous technique. These phenomena occur because production techniques differ in their ratios of each capital good to labour, and therefore choosing the optimal technique (that which minimises production costs) depends on the prices of those (capital) goods, which themselves vary according to the changes in the distributive variables (Petri, 2021. This result, which was also fully presented in Pasinetti (1969) and Garegnani (1970a), implies that there is not a univocal relationship between changes in distribution and changes in the "factor intensity" of the different production techniques. Furthermore, there could be an inverse or direct relationship between the demand for capital in value terms and the *rate of profit (or interest rate)*, which means we could end up with multiple equilibria or extreme values of distributive variables such as wages or interest rates equal to zero (Petri, 2021, Vol. I, p. 134).

The exceptionality of the monotonic relationship between the interest rate and the value of capital goods per worker can be demonstrated through what was called reduction to dated quantities of labour. This means specifying the prices as the sum of a vertical series of production stages spread backwards over time, where each stage of production is made up of the sum of the labour input and of the commodities that make up the means of production. In turn, these commodities are the product of a previous stage, each with its labour input having its attached date in the vertical series. (Dobb, 1973, p. 253). Thus,

> *The result is that the relative price of two products may move, with the fall of wages, in the opposite direction to what we might have expected on the basis of their respective 'proportions'; besides, the prices of their respective means of production may move in such a way as to reverse the order of the two products, as to higher and lower proportions (…).* (Sraffa, 1960, p. 15)

Breaking the monotony of the relationship between the interest rate and the value of capital goods per worker means recognising the dependence of the choice of "capital-intensive" techniques on the distributive variables. This implies that the demand for "capital" (in value terms) can experience both downward and upward slopes with respect to interest rate, tearing down the stability and uniqueness of the equilibria upon which the neoclassical theory of distribution rested (Lazzarini, 2011, p. 132). In short, distribution cannot be explained through factor supply and demand curves because the different production techniques that form those curves depend on distribution.

Sraffa's critique not only adopted the arguments presented by Robinson (1953–1954) but also redirected the debate towards the founding principles of the neoclassical theory: the possibility of deriving "demand" curves of factors of production. In fact, Lazzarini (2013) does not consider the APF to be an essential element of the neoclassical paradigm; instead, it was conceived for the purpose of empirically testing the theory of growth. The *re-switching* thereby becomes a type of anomaly that *"(…) clearly calls into question explicit and fundamental generalizations of the paradigm"* (Kuhn, 1995 [1962], p. 82).

The seismic shift brought on by Sraffa's work forced the scientific community which had subscribed to the neoclassical theory to reconsider some of its reactions to the debate up to that point, which had been based on the defence of the methods of aggregation of production factors. Contributions such as that of Levhari (1965) radically changed the direction of the neoclassical rhetoric by asserting that the *re-switching* occurs at the level of individual industries, without affecting the derivation of capital demand curves for the economy as a whole. Thus, Levhari seems to be unaware that such a phenomenon originates in the logical inconsistencies of the factor substitution principle.

It is possible that this unawareness resulted from the difficulties inherent in the arguments emanating from both sides of the debate. Taking into account that "*debates over theories-choice cannot be cast in a form that fully resemble logical or mathematical proof*" (Kuhn, 1995 [1962], p. 199),

communication between the two sides was not entirely impossible and, in the case of the CCCs, the Symposium of December 1966, organised by the *Quarterly Journal of Economics*, enabled the establishment of basic premises on which to base the discussion. In this respect, the Symposium can be understood in Kuhnean terms as a *facilitator and opportunity for comparison between different paradigmatic theories.* In the words of Pasinetti: "*The 'Symposium' contributors were well aware of the theoretical implications of these findings* (this refers to re-switching)*, which are devastating for the neoclassical theory of income distribution, since they deprive of any general applicability that the relationship (…) between the price of the 'factor' capital and the corresponding quantity (…)*" (Pasinetti, 2000, p 406).

The consequences of the Symposium were devastating for the neoclassical theory. For example, Paul Samuelson came to recognise *the universal invalidity of the parables of Jevons, Böhm-Bawerk, Wicksell and other neoclassical authors.* Further proof of the crisis faced by the neoclassical paradigm lay in the declarations of Charles Ferguson, for whom being able to make any statement at all about the relationship between production and competitive markets of factors and final goods constituted a *matter of faith* (Ferguson, 1969). This is in line with the image of science put forward by Kuhn. In the Epilogue of 1969, reacting against the criticism aimed at Kuhn (1995 [1962]), the author delved deeper into the concept of paradigm by associating it with the disciplinary matrix, recognising the values shared by the scientific community as components that are specific to it. The importance of these shared values "*emerges when the members of a particular community must identify crisis or, later, choose between, incompatible ways of practicing their discipline*" (Kuhn, 1995 [1962], pp. 184–185). Nevertheless, Kuhn recognised that values (simplicity, consistency and plausibility) of the chosen theory vary in their applicability, which may be determined by the behaviour of a particular group.

During this first phase of the CCCs, neoclassical economists varied considerably in their appraisal of the results achieved in the Symposium of 1966. Paul Samuelson is the most emblematic example of this, given that, before that date, he had tried to confine the re-switching as a very specific deviation from the Clark Parable (the surrogate production function), while subsequently accepting that the existence of the phenomenon threatened the generality of the neoclassical paradigm. After 1966, however, Samuelson would refer to the CCCs as a mere "headache" or as a

"pathology" that does nothing more than reflect the "healthy physiology" of the neoclassical apparatus (Samuelson, 1966).

This setback on the neoclassical side was a circumstance considered in the image of science put forward by Kuhn. Although Kuhn recognised that "(…) *Faced with an admittedly fundamental anomaly in theory, the scientist's first effort will often be to isolate it more precisely and to give it structure*" (Kuhn, 1995 [1962], p. 179), the reluctance to discard all crisis-ridden paradigmatic commitments was a fundamental issue. Cohen and Harcourt (2003) asserted that there were two main neoclassical responses for that situation. The first consisted in questioning the empirical probability of the results of the re-switching; this was the case, for instance, of Ferguson (1969) and Blaug (1975).[6] The second consisted in redirecting the debate towards intertemporal general equilibrium models with disaggregated capital endowment, which were considered immune to "Hahn's logical objections". This leads us to the second phase of the CCCs.

10.4 The Second Phase of the CCCs (1971–1976): Abandoning Lexical Homology

In this section, we shall present the communication difficulties of the CCCs that arose in the 1970s as a result of *different taxonomic structures* (Kuhn, 1983) associated with the central issues of each theory's rhetoric. We shall conclude that the answers of the neoclassical side in the 1970s brought problems of *incommensurability* to the debate, which ended up miring the communication that had characterised the first phase of the controversies in 1953–1970.[7]

[6] It is important to stress that this strategy has recently gained new impetus from some contributions, such as D'Ippolito (1987) and Potestio (2010). The replies to this argument are presented in Ciccone (1996), Petri (2011) and Dvoskin & Petri (2017).

[7] The Symposium *Commensurability, Comparability, Communicability* of 1982, organised by the Philosophy of Science Association, introduced the notion of incommensurability to the debate. In Kuhn (1983), the author analyses in greater detail what he considers to be one of the main omissions of Kuhn (1195 [1962]): the few references to language change as a mutation associated with the emergence of anomalies that alter some part of the language (Kuhn, 1983, pp. 682–683). With this, he could not avoid a certain amount of overlap with the notion of scientific revolution, and he tried to temper his assertions about incommensurability between successive paradigms, as well as differentiate the tasks of interpreting and translating theories.

The element that characterised the first period of the CCC was the neoclassical consideration of capital as a homogeneous magnitude (similarly to land or labour), but expressed in value terms, where that factor was susceptible to adopting endogenously the specific form of physically heterogeneous capital goods required by the cost-minimising technique and was able to guarantee a rate of interest (or profit) that was uniform in the prices of those goods and that would clear the savings-investment market. In the second phase of the discussion (1971–1976), however, the neoclassical approach was defended by specifying capital as a vector of endowments of the collection of physically heterogeneous capital goods rather than as a magnitude expressed in value terms.

The origin of this second way of treating the factor capital (and its endowment) can be found in the work of León Walras, who also highlighted that, in the savings-investment market, investors demand capital goods in terms of a single commodity, expressed in value, which he called perpetual net income (Walras, 1954 [1926], p. 274). However, specifying a vector of given quantities of capital goods clearly does not sit well with the reproducible nature of these goods. This treatment would avoid the circular logic of assuming a given quantity expressed in value. In this sense, we can say that there is a duality in Walras's treatment of capital: while, on the one hand, it considers capital as a single commodity demanded by investors, on the other, it recognises the need to take as datum a vector of given quantities of capital goods rather than homogeneous and aggregated capital goods expressed in value terms (Garegnani, 1990).

In the second phase of the CCCs, the neoclassical side returned wholeheartedly to treating capital endowment as a vector of capital goods just as Walras had done towards the end of the nineteenth century, dissatisfied with the treatment of capital endowment in value terms. However, as we shall explain below, this has important implications in the determination of the rate of interest (or profit) associated with the supply price of those goods, with profound methodological and epistemological consequences.

In the 1970s, the neoclassical side thus questioned the results of the critical side (re-switching and its consequences) in terms that were radically different from those formulated from the mid-1950s, giving greater prominence to so-called neo-Walrasian economists. In particular, the criticism by Bliss (1970) of the results produced by Garegnani (1970a) was based on the non-inclusion of expectations and future expected prices in the system of equations from which phenomena such as re-switching can

be derived.[8] However, the notion that Garegnani and other critical authors had been challenging was one of capital conceived in terms of a magnitude homogenised by the aggregation in value terms of capital goods. This notion was compatible with the derivation of persistent equilibrium prices, that is, long-period prices capable of yielding a uniform rate of return, with no incentives for variation over time and, therefore, with no reason to include price expectations different from equilibrium prices. In this respect, Bliss's reply to Garegnani reflects a rift in the notion of *equilibrium*, where Bliss uses the short-period equilibrium of neo-Walrasian analysis as *equivalent* to the gravitational centres of LPM on which Garegnani and the neoclassical theory had (up to that point) framed their discussions.

In summary, the neo-Walrasian intervention reveals that Bliss's critique of Garegnani (1970a) limited itself to terms that were different from those that had been accepted by all those who had participated in the first phase of the debate. The untranslatability of terms such as *normal prices of LPM* (characteristic of the classical tradition but also of the marginalists who had endorsed and defended the Neoclassical Parables until 1970) and *temporary* or *intertemporal equilibrium* (specific to the neo-Walrasian tradition) constituted an insurmountable obstacle to communication and was the main element that determined the result of the CCCs. Bliss's translation of Garegnani, and of the terms in which the debate had been presented up to that point, generated the confusion that would engulf the CCCs in the 1970s. To deal with this, Garegnani (1976, 1990, 2012) had to resort back to John R. Hicks's interpretation of Walras's work in *Value and Capital* of 1939.

As exposed above, Walras was a central character in the process of extension of the Malthusian theory of rent to the determination of the rate of interest and wages, as he put forward the notion of capital as a single commodity in what he called "perpetual net income". However, he did not take into consideration the incompatibility between that treatment and the inclusion of a vector of given quantities of physically heterogeneous capital goods in his systems of equations of general equilibrium. On this basis, the system of equations is logically consistent only if the

[8] Bliss argues that one of the most striking conclusions in Garegnani (the possible non-existence of equilibrium in the savings-investment market due to reverse capital deepening) is contradictory to the results produced by Debreu, who included the same conditions used by Garegnani but showed the existence of equilibrium (Lazzarini, 2013, p. 138).

condition of uniformity of the profit rate is eliminated (in other words by determining different rates of return on the capital goods supply prices) and, with it, the condition of stability of the resulting equilibrium.[9]

In short, the possible existence of equilibrium in the savings-investment market, which Walras had managed to free from the inconsistency into which had fallen Böhm-Bawerk, Wicksell and Clark, entailed the transformation of the notion of long-period equilibrium which the classical and neoclassical theorists had linked to the idea of a gravitational centre. This change was introduced for the first time by Hicks in 1939, in his work *Value and Capital*, and was later adopted by other economists inspired by Walras. We can say that Hicks (1939) is an *interpretative work*, where Hicks himself puts forward innovative concepts such as *short-period or temporary equilibrium* when re-reading and re-visiting the work of Walras, having found it impossible to find any reference to these in the neoclassical "mother" language, which was based on treating capital as a homogeneous magnitude expressed in value terms with prices and quantities of capital goods that adapt to yield a uniform rate of return.

Garegnani (2012) characterises *Value and Capital* as being central to the discussions that Hicks had with D. H. Robertson during the 1930s on the principle of factor substitution. At that time, *"[b]oth authors stressed the necessity that 'capital' endowment be allowed to change form in order to give rise to marginal products and, more generally, to sufficient substitutability between factors"* (Garegnani, 2012, p. 1424). So the temporal element in the notion of temporary equilibrium enabled Hicks to comply with the "malleability" of physical capital goods endowment required by the marginal analysis.

Whereas Walras did specify the condition of uniformity of the rate of return in his system of equations, this condition was completely absent

[9] In fact, Walras (1954 [1926]) attempts to make the theory of distribution based on factor supply and demand compatible with the derivation of normal positions by introducing an auction mechanism in the market of capital goods that would enable the uniformity of profit rates on the supply prices of those goods. However, Garegnani (1976, 1990) and Petri (2021), among other contributions, show that this attempt was unsuccessful because it required potential adjustments in the set of capital goods available, while these are determinants of prices, quantities and distributive variables obtained previously. In other words, the Walrasian treatment of capital introduces impersistence among the determinants of the neoclassical theory (see Petri, 2021, Vol. I, p. 628), which is at the very root of Hicks's (1939) short-period equilibrium and the need for intertemporal equilibrium's unrealistic assumptions (such as Arrow & Debreu, 1951).

from the system of general equilibrium in Hicks (1939). This reflects the interpretative character of Hicks (1939) and its divergence from the notion of stationary-state equilibrium prices which had framed the works of neoclassical economists such as Walras, Wicksell and Clark, as well as Samuelson himself.

It is worth mentioning that in the 1930s, the neoclassical community did not accept the proposals of Hicks. For a start, it was quickly understood that abandoning the LPM would affect the explanatory power of the very nature of temporary equilibrium, where the forces governing these positions had to be persistent enough to prevent accidental forces from altering the resulting equilibrium. Secondly, the implications of including unobservable variables (expected prices) in the set of independent variables made the theory run the risk of rendering the equilibrium undefined. This argument was recognised by Hicks himself.

When looking at these discussions, it is impossible not to draw parallels with the image of science and choice of paradigms proposed by Kuhn (1995 [1962]):

> *And all crises close in one of three ways. Sometimes normal science ultimately proves able to handle the crisis-provoking problem despite the despair of those who have seen it as the end of an existing paradigm. On other occasions, the problem resists even apparently radical new approaches. Then scientists may conclude that no solution will be forthcoming in the present state of their field. The problem is labelled and set aside for a future generation with more developed tools. Or (…) a crisis may end with the emergence of a new candidate for paradigm and with the ensuing battle over its acceptance.* (Kuhn, T. 1995 [1962], pp. 175–176)

The debates of the 1930s reflected the crisis surrounding the fundamental notions of the theory of distribution based on factor supply and demand. The crisis-provoking problems resisted attempts at assimilation by radical approaches such as those laid out in Hicks (1939). But that did not mean that those approaches would not resurface at a later and more advanced stage of the discussion:

> *It was (…) the emergence two decades later of the striking phenomena of reswitching of techniques and reverse capital deepening (…) that rendered finally untenable the notion of capital as a single factor at the level of pure theory and opened the way to the treatment of capital on Walrasian lines with the associated necessary reformulations of the concepts of equilibrium.* (Garegnani, 2012, p. 1425)

This explains the almost three-decade delay in the recognition of the arguments presented in *Value and Capital*, as the phenomenon of re-switching first had to emerge before authors were ready to re-formulate the general equilibrium models of the neoclassical paradigm in neo-Walrasian terms.

In conclusion, the neo-Walrasian school of thought, which originated in Hicks (1939), reprised Walras's approach in *Elements of Pure Economics* of taking as datum the endowment as a vector of physical capital goods, and readily accepted the resulting non-uniformity of profit rates.[10] The variables that are determined in these models are therefore not conceived in terms of long-period positions, but rather constitute *temporary equilibria* that shift towards an *intertemporal equilibrium* provided that conditions of equality are incorporated between effective prices and expected prices from an initial moment, by offering an instantaneous mechanism of tâtonnement rather than a time-consuming mechanism that tends towards full employment. Garegnani (2012) identified this as the great paradox of the Hicksian approach that explicitly incorporates the assumption that the economy is always in equilibrium.

The circular logic present in the discussion between neo-Walrasians and the critical side was not resolved with Garegnani's response to Bliss (1970). Garegnani (1970b) believed that Bliss had resorted to a short-period approach in order to circumvent the uncomfortable inconsistencies resulting from his use of "capital", exposed through his long-period analysis. Garegnani (1970b) did not yet put forward the methodological and epistemological commitments required by the change in the notion of equilibrium forming the basis of neo-Walrasian analysis. The untranslatability of the central premises of each theory may help explain the silence of the neoclassical side, where consensus was reached regarding the assimilation of re-switching to the theory of distribution based on short-period equilibrium models.

We can therefore assert that there was an absence of what Kuhn (1983) referred to as *homology of lexical structure* between Garegnani (1970a) and Bliss (1970): the normal positions derived by Garegnani (and intrinsic to LPM) could not be translated into Bliss's *temporary* or *intertemporal equilibria*. These incompatibilities led to a divergence in the way each theory

[10] As is explained in the works of Garegnani (2012) and Lazzarini (2013), the neoclassical theory evaded a well-known and accepted problem during the first phase of the controversy: a uniform rate of return in the supply prices of capital goods cannot generally be determined in a framework of general equilibrium with Walrasian capital.

described the world, since *"(…) language is private, and communication ceases until one party acquires the language of the other"* (Kuhn, 1983, p. 69).

The positioning of Walras's work at the centre of the disputes, displacing the traditional theorists of capital (von Böhm-Bawerk, Wicksell and Clark), is apparent not only in Bliss's counter-arguments, but also in the interventions of von Weizsäcker and of Stiglitz. Hahn (1982), on the other hand, is seen as the most representative and memorable synthesis of the answers obtained by the critical side, given that from the start of his article, he makes it clear that he intends to assimilate Sraffa (1960) into the intertemporal general equilibrium model.

In *The neo-Ricardians*, Hahn did not hesitate to recognise the logical inconsistencies of the Clark-Ramsey parable, while setting out his arguments from the modern perspective of Walras's work. The neo-Walrasian models consisted in presenting the pure exchange framework in intertemporal terms: *"(…) no causal relation could ever be asserted, since all the solutions emerge from a system of simultaneous equations"* (Pasinetti, 2000, p. 411). In this way, according to Hahn, Sraffa (1960) was merely a special case of that analysis, where the proportions of heterogeneous capital goods given in the initial situation are exactly those that ensure a uniform profit rate. The work of Sraffa turned out to be singular that any criticism to the principle of factor substitution based on his contributions would be meaningless and, consequently, would not merit a reply:

> *There is no doubt that neoclassical economics as in macroeconomics simple models are used in order to obtain definite answers and that simple models will not survive logical scrutiny (…) But unless one wishes to claim that aggregation is essential if a theory is to be called neoclassical, so that Arrow-Debreu for instance are not neoclassical, none of this has any bearing in the main issue of this lecture. Sraffians performed a service in showing how neoclassical arguments can be used to show neoclassical aggregation parables to be in logical difficulties. But that cannot help with a critique of marginal theory.* (Hahn, 1982, p. 373)

The broad consensus around the strength of the neoclassical paradigm in its neo-Walrasian version outweighed the limits imposed by the redefinition led by Bliss (1970). This highlights the success achieved by Hahn (1982) through his highly persuasive discourse. His call to ignore the *neo-Ricardians* resulted, firstly, in the omission of re-switching from textbooks and, subsequently, in the rehabilitation of the notions in which the

Symposium had identified problems (for example, aggregate production function).[11]

We can thereby conclude that, by refuting its arguments, the critical side forced the neoclassical paradigm to accept increasingly extreme solutions, such as the proposal of Hicks (1939). At that stage of the controversy, the neoclassical paradigm, seeking to assimilate the anomaly, abandoned the methodological commitment of deriving causal models through the analysis of normal positions, to such an extent that the critical side no longer recognised its opponent and the language of the discussion became private. The communication difficulties during the second phase of the CCCs revolved around the different taxonomic structures associated with the terminology that was central to the rhetoric of each theory.

In the words of Kuhn,

> *To the extent, as significant as it is incomplete, that two scientific schools disagree about what is a problem and what a solution, they will inevitably talk through each other when debating the relative merits of their respective paradigms. In the partially circular arguments that regularly result, each paradigm will be shown to satisfy more or less the criteria that it dictates for itself and to fall short of a few of those dedicated to its opponent.*

Subsequent works presenting the advances made by Garegnani (1976), such as Garegnani (1990, 2008, 2009, 2012), and by Petri (1978, 2003, 2021), sought to analyse the work of Walras and appeared to resolve the circular logic which had bogged down the CCCs, by trying to shed light on the neo-Walrasian reformulation of the theory of distribution based on the factor substitution principle. So, faced with the confusion generated by the change of meaning in the notion of equilibrium, the relentless search for the origins of the taxonomic structures of the neo-Walrasian language, in which the factor substitution principle was being re-written,

[11] In Epilogue: 1969, Thomas S. Kuhn scrutinises the notion of paradigm in two ways. With respect to its general character, he asserts that it refers to the notion of a disciplinary matrix, whilst in its more specific character, the epistemologist addresses the central and most novel aspect of the elements previously developed: *Shared Examples*. In essence, these embody the puzzle-solving methods employed for a new problem faced by researchers in the course of their normal research. The Aggregate Production Function, whose theoretical basis became infused with inconsistencies, today nevertheless still constitutes one of the symbolic generalisations of the neoclassical paradigm that is most used in introductory textbooks on macro and micro-economics, in the teaching of "economic" problem-resolution.

is what makes these works' real translation endeavours capable of relaunching the discussion and the resulting Scientific Revolution.

It is therefore important to highlight the radical difference between the strategy of authors such as Pierangelo Garegnani and Fabio Petri and that of other critical theorists, such as Robinson (1974). These authors, by exposing the role played by the quantity of "capital" in the neoclassical theory, delved into the origins of neo-Walrasian language, in what constituted a real *historian's work* (Kuhn, 1983). Faced with the untranslatability of terms such as *temporary equilibria* and *intertemporal equilibrium*, Garegnani and Petri enabled communication to take place between opposing theories through the interpretation and learning of the language shaped through Hicks (1939). The importance of this lies in that "*upon that expansion of attention depends an understanding, not only of translation and its limitations, but also of conceptual change*" (Kuhn, 1983, p. 683). So while Harcourt and Robinson reacted to the circularity by exacerbating the differences in the scientific language, works such as Garegnani's (2012) can be viewed as the *Rosetta Stone* that translated the meaning and intensity of the central terms of the neoclassical rhetoric (reformulated by neo-Walrasians), thereby helping to crack open the circularity that had prevented the paradigmatic substitution advocated by the critical side.

10.5 Final Comments

This chronological presentation of the arguments put forward in the controversies surrounding the theory of capital allows us to characterise this debate as a real choice between incompatible paths within the scientific community. In this way, similarly to political revolutions, as it was stated by the image of science proposed by Thomas S. Kuhn, the choice of paradigm brought about by the discovery of the re-switching was not determined by consensus-based and unanimous criteria of confirmation or rejection favouring logical correlation between successive theories.

In line with Kuhn (1995 [1962]), the resistance to paradigmatic change played an extremely relevant role in the confinement and broadening of the anomaly (the re-switching); and it is through this lens that we can understand the strategies that sought to diminish the relevance of it. By refuting its arguments (Pasinetti, 1969; Garegnani, 1970a), the critical side forced the neoclassical paradigm to accept increasingly radical solutions, even when these had not found a good reception at the time of being proposed prior to the CCCs, such as the proposal in Hicks (1939).

At that stage, the neoclassical paradigm, seeking to assimilate the criticisms of the marginalist theory of capital, abandoned the methodological commitment of deriving causal models through the analysis of *normal* or *long-period* positions, to such an extent that the critical side no longer recognised its scientific opponent and the language of the discussion became private. So, faced with the confusion generated by the change of meaning in the notion of equilibrium, the relentless search for the origins of the taxonomic structures of the neo-Walrasian language, in which the factor substitution principle and the theory of capital were being rewritten, is what makes the contributions of Garegnani (1976, 1990, 2008, 2012) and Petri (1978, 2003, 2021) real works of translation capable of relaunching the discussion and the resulting Scientific Revolution.

References

Arrow, K., & Debreu, G. (1951). Existence of Equilibrium for a Competitive Economy. *Econometria, 2*, 265–290.

Blaug, M. (1975). *The Cambridge Revolution: Success or Failure? A Critical Analysis of Cambridge Theories of Value and Distribution*, Revised Edition. London: Institute of Economic Affairs.

Bliss, C. (1970). Comment on Garegnani. *Review of Economic Studies, 37*, 437438.

Böhm-Bawerk, E. (1891). *The Positive Theory of Capital*. G.E. Stechert, New York.

Champernowne, D. G. (1953–1954). The Production Function and the Theory of Capital: A Comment. *The Review of Economic Studies, 21*, 118–130.

Ciccone, R. (1996). Possibilit_a e probabilit_a di comportamento 'perverso' del capitale. *Studi Economici, 58*(1), 41–73.

Clark, J. B. (1899). *The Distribution of Wealth: A Theory of Wages, Interest and Profits*. Macmillan, 1925.

Cohen, A. J., & Harcourt, G. C. (2003). Retrospectives whatever happened to the Cambridge capital theory controversies?. *Journal of Economic Perspectives, 17*(1), 199-214.

D'Ippolito, G. (1987). Probabilit_a di perverso comportamento del capitale al variare del saggio di profitto: il modello embrionale a due settori. *Note Economiche, 2*, 5–37.

Dobb, M. (1973). *Theories of Value and Distribution since Adam Smith: Ideology and Economic Theory*. Cambridge University Press.

Dvoskin, A., & Lazzarini, A. (2013). On Walras's Concept of Equilibrium. *Review of Political Economy, 25*(1), 117–138.

Dvoskin, A., & Petri, F. (2017). Again on the Relevance of Reverse Capital Deepening and Reswitching. *Metroeconomica, 68*(4), 625–659.

Ferguson, C. E. (1969). *The Neoclassical Theory of Production and Distribution*. Cambridge University Press.

Garegnani, P. (1970a). Heterogeneous Capita, the Production Function and the Theory of Distribution. *Review of Economic Studies, 37*, 407–436.
Garegnani, P. (1970b). A Reply. *Review of Economic Studies, 37*, 439.
Garegnani, P. (1976). On a Change in the Notion of Equilibrium in Recent Work on Value and Distribution. In M. Brown, K. Sato, & P. Zarembka (Eds.), *Essays in Modern Capital Theory*. North Holland. 35.
Garegnani, P. (1990). Quantity of Capital. In J. Eatwell, M. Milgate, & P. Newman (Eds.), *Capital Theory*. Palgrave Macmillan.
Garegnani, P. (2008). On Walras's Theory of Capital (Provisional Draft 1962). *Journal of the History of Economic Thought, 30*, 367–384.
Garegnani, P. (2009). Capital in Neoclassical Theory of Capital: Some Notes. AEA Meetings, San Francisco.
Garegnani, P. (2012). On the Present State of the Capital Controversy. *Cambridge Journal of Economics, 36*, 1417–1432.
Harcourt, G. C. (1969). Some Cambridge Controversies in the Theory of Capital. *Journal of Economic Literature, 7*, 369–405.
Hahn, F. (1982). The Neo-Ricardians. *Cambridge Journal of Economics, 6*, 353–374.
Hicks, J. R. (1939 [1946]). *Value and Capital*. Clarendon Press, 2nd ed.
Keynes, J. M. (1936). *The General Theory of Employment, Interest and Money*. Macmillan.
Kuhn, T. S. (1983). Commensurability, Comparability, Communicability (Vol. 2, pp. 669–688). East Lansing: Philosophy of Science Association.
Kuhn, T. S. (1995 [1962]). *The Structure of Scientific Revolutions* (3rd ed.). The University of Chicago Press.
Kurz, H., & Salvadori, N. (2003). 'Classical' vs. 'Neoclassical' Theories of Value and Distribution and the Long-period Method. In F. H. Hahn & F. Petri (Eds.), *General Equilibrium: Problems and Prospects* (pp. 216–245). Routledge.
Lazzarini, A. (2011). *Revisiting the Cambridge Capital Theory Controversies: A Historical and Analytical Study* (p. 183). Pavia: Pavia University Press.
Lazzarini, A. (2013). La controversia del capital en perspectiva histórica: reconsiderando su relevancia en la teoría económica. *Circus, Revista argentina de economía*, 5, 141–163.
Levhari, D. (1965). A Non-Substitution Theorem and Switching of Techniques. *Quarterly Journal of Economics, 79*, 98–105.
Marx, K. (1871). *The Civil War in France* (3rd edn.). London Council.
Mirowski, P. (1989). *More Heat than Light: Economics as Social Physics, Physics as Nature's Economics*. Cambridge University Press.
Pasinetti, L. L. (1969). Switches of Technique and the 'Rate of Return' in Capital Theory. *The Economic Journal, 79*(315), 508–531.
Pasinetti, L. L. (2000). Critique of Neoclassical Theory of Growth and Distribution. *BNL Quarterly Review, 215*, 383–431.

Petri, F. (1978). The Difference between Long-period and Short-period General Equilibrium and the Capital Theory Controversy. *Australian Economic Papers, 17*(31), 246–260.

Petri, F. (2003). A 'Sraffian' Critique of General Equilibrium Theory, and the Classical-Keynesian Alternative. In F. Hahn & F. Petri (Eds.), *General Equilibrium* (pp. 387–421). Routledge.

Petri, F. (2011). On the Likelihood and Relevance of Reswitching and Reverse Capital Deepening. In C. Gehrke & N. Salvadori (Eds.), *Keynes, Sraffa and the Criticism of Neoclassical Theory* (pp. 380–418). Routledge.

Petri, F. (2021). *Microeconomics for the Critical Mind: Mainstream and Heterodox Analyses*. Springer Nature.

Piketty, T. (2014). *Capital in the 21st Century*. Fondo de Cultura Económica.

Potestio, P. (2010). 'Perverse Cases' and the Debate on Neo-Classical Theory of Distribution: Recent Contributions on an Open Issue. In J. Vint, J. S. Metcalfe, H. D. Kurz, N. Salvadori, & P. A. Samuelson (Eds.), *Economic Theory and Economic Thought. Essays in Honour of Ian Steedman* (pp. 138–160). Routledge.

Ricardo, D. (1815). *An Essay on the Influence of a Low Price of Corn on the Profits of Stock*. John Murray.

Ricardo, D. (1951 [1817]). *On the Principles of Political Economy and Taxation, from The Work and Correspondence of David Ricardo* (P. Sraffa, Ed.). Cambridge University Pres.

Robinson, J. (1953–1954). The Production Function and the Theory of Capital. *Review of Economic Studies, 21*, 81–106.

Robinson, J. (1974). *History versus Equilibrium*. London: Thames Polytechnic [in Joan Robinson (1979), Collected Economic Papers 5, pp. 48–58. Basil Blackwell].

Samuelson, P. (1962). Parable and Realism in the Theory of Capital: The Surrogate Production Function. *Review of Economic Studies, 29*, 193–206.

Samuelson, P. (1966). "Paradoxes in the Capital Theory: A Symposium", with Contributions by L. Pasinetti, D. Levhari, M. Morishima, M. Bruno, E. Burmeister, S. Sheshinki, P. Garegnani, P. Samuelson. *The Quarterly Journal of Economics, 53*, 503–584.

Solow, R. W. (1955–1956). The Production Function and the Theory of Capital. *The Review of Economic Studies, 23*, 101–108.

Sraffa, P. (1951). Introduction to Ricardo's Principles. In P. Sraffa (Ed.), *Work and Correspondence of David Ricardo 1*. Cambridge University Press.

Sraffa, P. (1960). *Production of Commodities by Means of Commodities: Prelude to a Critique Theory*. Cambridge University Press.

Walras, L. (1954 [1926]). *Elements of Pure Economics, or the Theory of Social Wealth*. George Allen & Unwin.

Wicksell, K. (1934 [1901]). *Lectures on Political Economy* (Vol. I). Routledge, London.

CHAPTER 11

Technology and the Labour Market: Technological Unemployment as a Historical Debate

Elena Gallego Abaroa

11.1 Introduction

Technological unemployment has been an externality since the early eighteenth century. The modernisation of production methods has generated intensive stages of labour being replaced by capital as a factor of production, and the schools of thought have debated adjustments to the labour market based on the assumptions that form the foundations of each doctrine. Classical capitalist orthodoxy, and its neoclassical heirs, have assumed the hypothesis of price and wage flexibility that tends to balance markets over time, within the framework of *Say's Law*. From the Keynesian perspective, prices and wages are rigid downwards; in this case, if there is an economic recession, economies do not return to the path of growth

E. Gallego Abaroa (✉)
Complutense University of Madrid, Madrid, Spain
e-mail: elenagallego@ccee.ucm.es

E. Trincado Aznar, F. López Castellano (eds.), *Science, Technology and Innovation in the History of Economic Thought*, Palgrave Studies in the History of Economic Thought,
https://doi.org/10.1007/978-3-031-40139-8_11

because unemployment becomes persistent and incentives for investment weaken.

In addition, the impact of technological innovation on production opened another debate on its treatment as a variable. For Solow, technological innovation was an exogenous variable that affected the production function, while for Schumpeter it was endogenous to the evolutionary process of industrial capitalism. In both cases, technological progress had repercussions on the capital–labour combination, generating unemployment.

This chapter reflects on the consequences of technological unemployment in twenty-first-century capitalism, in a framework of greater equilibrium in the distribution of income.

11.2 Starting Point

11.2.1 David Ricardo and the Machinery Question

The classical economists who lived through the Industrial Revolution analysed the changes in the production system and the extension of the markets, using their publications to create the theoretical content of Political Economy. The first reference to technological unemployment appeared in chapter XXXI of the third edition of David Ricardo's *On the Principles of Political Economy and Taxation*, in 1821.

As is well known, groups of artisan workers, among them the Luddites of the nineteenth century in Great Britain, were against the introduction of machinery because of the unemployment it would generate. Their grievances were initially focused on the activities of textile producers, and in the heat of the debate Ricardo wrote: "I am convinced, that the substitution of machinery for human labour, is often very injurious to the interests of the class of labour" (Ricardo, 2003 [1821], p. 314). In his opinion, and in the short term, the decrease in the demand for labour impoverished workers. In Ricardian terminology, the argument was based on the inequality between net income (annual profit of capitalists and landowners) and gross income, which also included circulating capital (to pay the workers). Logically, when machinery replaced labour, the *wage fund* was reduced and workers would be paid less or, alternatively, there would be fewer employed workers who would have been replaced by the machinery, "the demand for labour would diminish, and the commodities necessary

to the support of labour would not be produced in the same abundance" (Ricardo, 2003 [1821], p. 317).

Underlying the explanatory Marxist theory of the *reserve army of labour* was the same Ricardian argument: unemployment was generated during the mechanisation of the production process, as can be seen in *Das Kapital*, volume I, chapter XV, sections 3, 4, 5 and 6 (Schumpeter, 1968, p. 64). Marx distinguished three forms of unemployment: floating, latent and stagnant. The floating form was technological unemployment moving from one industrial job to another, the latent form was agricultural unemployment, which migrated to the cities, and the stagnant form was the misery of the population, a necessary condition for the development of capitalist wealth (Braverman, 1983, pp. 328 and 329).

In the second part of chapter XXXI of Ricardo´s Principles, the two offsetting arguments for technological unemployment were introduced. First, the saving in wages reduced the circulating capital and would be transformed into accumulated capital for new investments, which would provide new jobs with the consequent expansion of the demand for labour. Secondly, foreign competition forced the generation of investment in machinery to lower costs by reducing the labour factor in production processes (Ricardo, 2003 [1821], pp. 320–321). In conclusion, technological unemployment was generated in the short term, but in the medium and long terms, it was offset by new jobs in other productive activities and the expansion of foreign trade.

11.2.2 What Economic Theory Says About Technological Unemployment

Institutional development paved the way for two drivers of prosperity, namely, technology and education. In the sixteenth century, William Lee, a local priest from Calverton (England), had his stocking knitting machines ready and travelled to London to apply to Queen Elizabeth I for a patent to expand textile production, but he was met with a resounding royal refusal. The Queen considered it ruinous to deprive her subjects of employment and turn them into beggars. The fear of the creative destruction of technological progress had begun. The Queen was concerned that the population displaced from their jobs might threaten her political power and turn against her. It is a historical pattern for innovation to generate resistance, not only from displaced workers but also from economic elites and governments (Acemoglu & Robinson, 2014, pp. 219–221).

For Robert Solow, in *Technical Change and Aggregate Production Function*, technology was an exogenous variable. In his research, he estimated an aggregate production function for the United States, during the period 1909–49, and innovation was the residual factor that explained 87.5% of the increases in productivity over the period (Solow, 1957, p. 320). For Joseph Schumpeter, in the *Theory of Economic Development* from 1911, capitalism was treated as a dynamic evolving process, where technological innovation represented a third factor of production, an endogenous variable in the model, whose variations generated capital gains with an impact on dynamic cyclical growth processes. This mutation was carried out by innovative entrepreneurs who were altering perfect competition, directing it towards monopolistic markets (Schumpeter, 1944, pp. 103 and 217).

In Schumpeter´s Theory of creative destruction included in *Capitalism, Socialism and Democracy* from 1942, monopolistic competition can be more efficient than perfect competition in driving the innovative process of the economic cycle, and producing greater job creation than job destruction, with a net positive effect (Boianovsky and Trautwein, 2010, p. 260).

Macroeconomics evolved during the twentieth century from multiple perspectives and over decades characterised by deep crises and world wars. Theoretical developments took shape within the different schools of thought, with a dominant orthodoxy that can be grouped, broadly speaking, into the heirs of classical thought and the heirs of Keynesian thought. The former assumes the argument of flexibility of prices and wages and the latter assumes that they are rigid. As a result, the heirs of classical thought expect that, in the face of crises and recessions, the markets will adjust prices and wages and return to the path of economic growth following Say´s Law. The heirs of the main Keynesian streams contemplate historical periods with persistent unemployment, which paralyses a part of the productive sector, because the private sector is not sufficient to restart the drive for aggregate economic growth, so this must be offset with fiscal, monetary and income public policies.

The fact that macroeconomics has developed through successive contributions that are added intermittently to the general compendium of models makes it difficult to understand them, given that the starting assumptions in the behaviour of the variables are not homogenous and depend on who has made the contribution. For example, the classical heirs think in terms of real wages and the Keynesian ones in terms of monetary

wages, and economic growth behaves differently if constant, adaptive or rational expectations are assumed. In addition, it all depends on whether Say's Law works or not, or if the Quantity Theory of Money always explains inflation, or what part of the Animal Spirits each economic doctrine accepts.

In traditional macroeconomics text books, the labour market is linked to the market for goods and services, and everything is so aggregate that it is difficult to understand the individual behaviour of work, or grouped by profession, because they are all intermingled. We also have statistical data, such as total population, active, employed, unemployed, full employment, equilibrium wage, frictional unemployment, structural unemployment, efficiency wage, implicit contracts, internal and external workers, legal regulations, unions and business organisations (McConnell et al., 2007, pp. 511–519). We can talk about trends in the variables in a general way, but it is impossible to make specific predictions and some questions are difficult to answer, for example, does the labour market explain the equilibrium salary of a country well? Is that salary representative? Why is the interprofessional minimum wage treated as if it were an efficiency wage? Should we assume that if wages go up, profits go down in all sectors? What effects can technological unemployment have on economic sectors? What effects does technological unemployment have on the skilled population or on the unskilled?

From economic theory, technological unemployment continues to be explained in the way Ricardo established: a process of change that is reabsorbed over time, either in other production facilities or through reskilling of the workforce. It continues to generate mistrust, as is currently the case with robotics and its possible effects on jobs. And new questions arise: Can technological unemployment be explained without considering its effects on the other social dimensions, such as the possibility of reducing working hours if there are improvements in productivity? Is it possible to propose the payment of a basic wage income because of the robotisation of work?

Let´s think about the effects that an increase in the minimum interprofessional wage has on the economy of a country. Orthodoxy says that the increase in wages increases the cost of production and will be passed on to prices, losing external competitiveness and reducing the demand for employment. However, if the effects derived from job stability and security are also included, consumer demand may increase, meaning that aggregate demand can expand, which will drive more production.

Regarding this debate, David Card, a US Labour Economics scholar and Nobel Prize winner in 2021, in his work *Do Minimal Wages Reduce Employment, A Case Study of California 1987–89?* used his data to show that increases in the minimum wage did not reduce employment (Card, 1992, p. 54).

To move towards modern capitalism, we can go back to two reflections by John Stuart Mill. The first refers to the support for union demands to recognise their bargaining power to increase subsistence wages, in this case by expanding the Wage Fund. The second, by admitting the coming together of interests between workers and capitalists, where capital gains have a sufficient margin to establish efficiency wages (Gallego, 2009, pp. 61, 62).

11.3 The Technological Unemployment to Come

The impact of new technologies, especially robotics as machines designed to automatically carry out tasks to replace traditional labour, is a current fact. The unemployment of professionals who will not be needed for productive tasks as they will be replaced by artificial intelligence is looming, for example, in production lines with robotic arms, object recognition machinery, information processors, robots, air and sea navigation assistants and driving motor vehicles, and the management of all kinds of services, such as financial, tourist, security, etc.

There are four ways of thinking about the labour impact of the new technologies:

- Substitution automation (dominant approach, in which machines drive workers into unemployment, technological unemployment is guaranteed)
- Pragmatic approach (digitalisation and robotisation will generate and destroy jobs in a labour framework of different jobs, technological unemployment uncertain)
- Integration automation (digital work through requalification of employees, technological unemployment uncertain)
- Multiple automation (digitalisation and robotisation is a priority for the new working conditions, profound transformation of the labour market with qualified jobs)

Substitution automation is the most pessimistic option and assumes that the destruction of jobs will not be offset by job creation in new occupations. The pragmatic approach is the most optimistic because it assumes that the loss of jobs could be offset by the new professions in demand, the supply of jobs normally expanding with digital advances. Integration automation is the second derivative of the pragmatic approach and opts to strengthen the digitalisation and robotics process. Here a debate opens up about the consequences for the demand for employment of different groups of workers: the highly qualified, the semi-qualified and the unqualified. Multiple automation comes from research in computer science with real experiences in artificial intelligence, for example, from platforms like Google or Amazon, which manage markets for digital goods and services with the processed information from the customers themselves, but which still hide great dependence on low-skilled and poorly paid human labour (Lahera, 2020, pp. 3–10).

Robotisation has spent decades advancing in multiple areas, with examples such as Tesla, Nintendo, Microsoft and PrimeSense. Some companies and sectors are ready for the imminent development of the industry. Compared to the past, where historically textile production was one of the most automated in countries like the United States, labour has already been replaced by machinery and there is a low labour/capital ratio. It must be remembered that this process is not only due to the substitution of labour for capital, but also to the fact that textile manufacturing has been moving towards countries with very low wages, such as China, India and Mexico, and this opens another reflection derived from the previous one: What will robotisation mean for the countries that have developed their international competition on the basis of low wages? How will a robotisation process affect China?

Robotisation is normally focused on the manufacturing industry, but it has many other ramifications in areas such as services and agriculture. In the West, the services sector accounts for a large proportion of active workers, as in the case of Spain with the financial and tourism sectors. For example, in the United States, there are already fast-food establishments that have automated the production of hamburgers, which, if it became widespread, could mean a sharp drop in employment for low skilled workers. And the same is happening in the retail sector, given the increase in internet sales which has already altered the physical presence of sellers to one involving other professions for the storage and distribution of products, with an army of poorly paid workers, on many occasions appearing

falsely to be self-employed to lower the labour costs of large companies. Similarly, self-service machines are replacing jobs in shopping centres, as is access to financial services through ATMs or Internet banking.

This widespread process of automation leads us to robotics in the cloud, where a centralised computing system provides and updates the intelligence of mobile robots, through a process similar to updating mobile phones. Since 2010, Google has been running a system called Googles, for robots with cameras, which through photographs can recognise the objects they come across, generating a centralised database that is continuously updated so that the devices can record the objects found.

In the case of agriculture, the use of machinery to harvest fruit and vegetables is already common. In Spain, machines have been used for years to harvest grapes and olives, and this can be extended to nurseries and greenhouses to replace the staff responsible for looking after the plants. In Japan, there is a robot that can pick strawberries based on changes in their colouration. In Australia, the University of Sydney's Robotics Institute has developed devices that take samples of the land surrounding each plant to then inject the specific quantities of fertilisers and water they need at all times, with the consequent reduction in costs and chemical fertilisers, which will benefit aquifers (Ford, 2016, pp. 19–38).

11.4 Some Proposals for Dealing with It

Making economic predictions is complicated, even more so for the case at hand, as it means interpreting the impact of new technologies on the demand for and supply of employment. Economic orthodoxy accepts the pragmatic approach with some unpredictable changes in what will happen, more so if one considers the extent of globalisation and the differences between developed and emerging countries. This is hard to predict. The question is whether the consequences of technological unemployment can influence the capitalist ethics of the twenty-first century and determine active policies, public and private, to offset it. For example, it is already possible to imagine, due to this being introduced by some companies, a reduction in working hours to four working days per week, with no pay reduction.

Facing a near future characterised by continuous technological changes, with direct repercussions on production and employment, we can reflect on the dynamics of some reforms and ask questions such as: How can we deal with the wave of automation? What will be the impact on developed

economies? How could it affect China and the emerging countries? The answers will differ depending on whether they come from a public or private perspective, and depending on the country that introduces the new technologies.

Technological unemployment is reabsorbed over time, but the main question is: How long is that time? Growing technological unemployment implies social punishment that could be mitigated with macroeconomic labour strategies. Continuous training is required to reskill in the area of digital work, appropriate for the times ahead, and it may be necessary to establish policies to maintain some jobs. For example, in the year 2022, a pool of older clients inexperienced in digital banking management appeared in Spain, which required the extension of personalised services hours.

From another perspective, in relation to consumer rights, it is interesting to recall the reflections of Shoshana Zuboff in her book *The Age of Surveillance Capitalism*, in the final chapter of which she talks about the loss of reciprocity of information that economic agents have when they interact in markets. Zuboff reminds us that Smith spoke of an atomistic market and Hayek of a mercantile democracy, which assumed information was distributed equally among all economic agents. These assumptions have disappeared with the new technologies of Internet purchases, which allow large companies such as Google, Amazon, Apple and Meta to collect data and consumer purchase histories to manage the information. Then, the transparency of the market disappears, and the suppliers become oligopolies with the consequences that have for controlling prices and increasing the profits of companies, to the detriment of consumers. Another derivative is the comparison between good and bad information on social networks, indistinguishable for new technologies and that confuses people's decisions. The objective of information transparency should be prioritised in modern societies (Zuboff, 2018, pp. 657–693).

The possibility of earning a universal basic income, as Piketty proposes in *Le Capital au XXI Siècle,* is justified by the inequality of capitalist economic systems, and could be offset with political decisions on progressive tax reforms for global capital, with national compensatory incomes and investment in education, within the framework of a participatory and circular economy where private property and the profits of capitalism must be balanced with the rights of workers and consumers (Piketty, 2013, pp. 15–16, 835–839).

Hayek's economic pragmatism led him to develop arguments in favour of a universal basic income, to provide a safety net for the public and preserve individual freedom of action, thus avoiding the interprofessional minimum wage and other social assistance, while reducing spending on the welfare state because a basic income is expected to entail lower administrative management costs (Hayek, 1977, pp. 54–55).

There are two main problems for a state planning a basic wage: incentives to work and funding the wages. Economic orthodoxy considers that universal income coverage creates a disincentive to work and thus slows down the drive for productivity. In this case, it would be necessary to perform research for each population to compensate for this, for example, linking those earnings with an obligation to take part in continuous job training, especially focused on sectors with the greatest demand for work; and stimulate entrepreneurship, since having a guaranteed income can encourage people to complement it with small businesses. The funding of a basic income must reflect the budget of each country, linked to the tax structure on its income and the coverage of public spending it has. Transparency in the management and operation of each country is crucial to avoid having high margins from underground economies, and that depends on the ethical levels of each society. Avoiding political and social corruption and having a good legal system that quickly and fairly manages any disputes that arise is crucial in moving towards richer and more egalitarian societies (Ford, 2016, pp. 240–255).

Another outstanding issue in this debate of ideas is to say what the macroeconomic growth objectives of countries are or should be, these normally being associated with increased employment and national wealth. How do you measure the progress of a society? To deliberate on this question, we can return to John Stuart Mill and his idea of the stationary state. In chapter VI of the fourth book of the *Principles of Economics*, titled *Of the Stationary State*, in which he discusses progress in society, the main question is what we mean by progress and why we assume there will be a confrontation between capital and labour. As Mill says, one cannot look at the stationary state of capital and wealth with the disgust that the *old school* did. "I am not charmed with the ideal of life held out by those who think that the normal state of human beings is that of struggling to get on; that the trampling, crushing, elbowing, and treading on each other's heels, which form the existing type of social life, are the most desirable lot of human kind, or anything but the disagreeable symptoms of one of the phases of industrial progress. … But the best state for human nature is that

in which, while no one is poor, no one desires to be richer, nor has any reason to fear being thrust back, by the efforts of others to push themselves forward." In the words of Mill, "industrial improvements would produce their legitimate effect, that of abridging labour" (Mill, 1871, pp. 641–643).

In short, Western economies with high average income levels and strong administrative organisation and institutional development can face and resolve the challenges of twenty-first-century capitalism in a more egalitarian way.

11.5 Conclusions

This chapter reviews the historical question of technological unemployment as a problem. The orthodox solution of time solving everything with market adjustments and incentives through price and wage flexibility does not seem to be the best, due to the enormous social cost of hardship that entails for workers. Likewise, it cannot be solved by increasing public spending on traditional social protection policies offering partial coverage. These are not questioned in this work, because they help to improve the standard of living of the most disadvantaged people, but they do not solve the unemployment issue.

Debates on technological unemployment are focussed on the new challenges for western societies in the twenty-first century. The capitalist system in its evolution must limit a growing process of inequality that favours nobody. The following reflections are proposed for discussion:

a. Technological unemployment is a reality that must be tackled.
b. Measures can be taken in both the private sector and the public sector.
c. Measures taken by the private sector can help to reduce current working hours, with the consequent greater availability of leisure time.
d. Policies can be implemented to maintain jobs to offer greater personal service to certain segments of the population.
e. It is necessary to complement macroeconomic growth targets with other objectives for a greater balance in the distribution of income, to broaden the purchasing power of the most precarious labour sectors, which could increase aggregate demand and with this, corporate profits.

f. On-the-job training aimed at digital training is necessary and must be permanent.
g. There is the possibility of proposing a universal basic income as a macroeconomic objective.

References

Acemoglu, D., & Robinson, J. A. (2014). *Por qué fracasan los países.* Deusto.
Boianovsky, M., & Trautwein, H. M. (2010). Schumpeter on Unemployment. *Journal of Evolutionary Economics, 20*(April), 233–266.
Braverman, H. (1983). La estrutura de la clase trabajadora y sus ejércitos de reserva. In L. Toharia (Ed.), *Mercado de trabajo: teorias y aplicaciones.* Alianza Universidad.
Card, D. (1992). Do Minimum Wages Reduce Employment? A Case Study of California, 1987–89. *Industrial and Labor Relations Review, 46*(1), 38–54.
Ford, M. (2016). *El auge de los robots.* Paidós.
Gallego Abaroa, E. (2009). *Historia breve del mercado de trabajo.* Ecobook.
Hayek, F. (1977). *Law, Legislation and Liberty, Vol. 3. The Political Order of a Free People* (pp. 54–55). University of Chicago Press.
Lahera Sánchez, A. (2020). El debate sobre la digitalización y la robotización del trabajo humano del futuro: automatización, pragmatismo, integración y heteromatización. *Revista Española de Sociología, 30*(3), 3–10.
McConnell, C. R., Brue, S. L., & Macpherson, D. A. (2007). *Economía Laboral.* McGraw Hill.
Mill, J. S. (1996) [1871], *Principios de Economía Política*. Fondo de Cultura Económica.
Piketty, T. (2013). *Le capital au XXI siècle, Madrid.* SEUIL.
Ricardo, D. (2003 [1821]). *Principios de economía política y tributación*, Madrid Pirámide.
Schumpeter, J. (1944 [1911]). *Teoría del desenvolvimiento económico.* Fondo de Cultura Económica.
Schumpeter, J. (1968 [1942]). *Capitalismo, Socialismo y Democracia.* Madrid Aguilar.
Solow, R. (1957). Technical Change and the Aggregate Production Function. *The Review of Economics and Statistics, 39*(3), 312–320.
Zuboff, S. (2018). *La era del capitalismo de la vigilancia*. Paidos.

CHAPTER 12

Humanity Is Facing Its Sustainability: Will Technological Progress Make the Future Unsustainable?

Javier Arribas Cámara

12.1 Introduction

One of the most significant challenges facing humanity today is to achieve sustainable development, that is, development that meets the needs of the present without compromising the ability of future generations to meet their own needs. To achieve this, a holistic approach is needed that considers the interaction between the economy, the environment, and society and how these elements interact.

In this sense, technology can play a pivotal role in the quest for sustainability. Technology can be used to address the environmental and social challenges we face and to create a more sustainable and equitable future

J. Arribas Cámara (✉)
Complutense University of Madrid, Madrid, Spain
e-mail: javierarribas@ucm.es

E. Trincado Aznar, F. López Castellano (eds.), *Science, Technology and Innovation in the History of Economic Thought*, Palgrave Studies in the History of Economic Thought,
https://doi.org/10.1007/978-3-031-40139-8_12

for all. However, more than technology, sustainability is needed to be achieved—an integrated approach that includes sustainable policies, regulations, and business practices is required.

This chapter addresses how digitalisation and technological developments can impact the sustainability of our planet, both positively and negatively. As the demand for energy and resources increases, it is essential to consider how technology can be part of the solution while mitigating its inherent risks.

We will discuss how advances in artificial intelligence and computing face physical and energy constraints, leading scientists to look to biology for inspiration to design more efficient and sustainable computing systems. Finally, we will examine the growing concern over data centres' energy consumption and carbon footprint, exploring innovative solutions, such as installing data centres in space to take advantage of low temperatures and reduce energy consumption.

On the other hand, we will discuss how the rapid accumulation of e-waste represents an urgent challenge in terms of sustainability and how innovators are tackling the problem by transforming waste into revenue streams by extracting precious minerals.

Finally, we will address the need for policies and regulations at national and international levels that promote sustainability and equity in the digital age. This includes monitoring and analysing the energy evolution of ICT and digitisation, incorporating environmental regulatory responsibilities in the digital sector, and ensuring that the Global South is included in the digitisation process.

In this chapter, we aim to provide a comprehensive and balanced view of how technology and digitalisation can be both a driving force for sustainability and a challenge to overcome. By addressing the dilemmas and opportunities presented by technological progress, we seek to provide a sound basis for debate and informed decision-making in the quest for a sustainable future for humanity.

12.2 A Brief Bibliographic Review

To better understand the complex relationship between technology and sustainability, it is essential to examine various key texts. One such text is *The Limits to Growth* (1972) published by the Club of Rome, a group of political and social science experts, and written by Donella Meadows, Dennis Meadows, Jørgen Randers, and William W. Behrens III. The book

studies the limits of long-term economic and population growth in a finite world and uses mathematical models to predict the future of global growth. The book concludes that continued economic and population growth, as practised then, would lead to a collapse in the twenty-first century due to natural resource scarcity and environmental pollution. The study emphasised the need for long-term planning and a shift towards a more sustainable approach to development. *The Limits to Growth* significantly impacted public awareness and environmental and economic policy. It was highly controversial at the time, but it also inspired many to take action to address environmental challenges and promote sustainability. The report further discussed the limits to growth and the need to balance economic growth with environmental protection.

Subsequently, in 1973, another reference text was published, *Small Is Beautiful: A Study of Economics as if People Mattered* (Schumacher, 1973). In the book, Schumacher argues that modern economics and its focus on economic growth at any cost are damaging society and the environment. Instead, Schumacher argues for a more humane and sustainable economic approach, focusing on basic human needs and environmental protection. He proposes an economy based on "intermediate technology" and the "economy of enough." This idea refers to simple technologies adapted to the needs and resources of local communities, which can improve the quality of life without harming the environment. Intermediate technology is an alternative approach to modern, large-scale technology that is often costly, inappropriate to local needs, and causes adverse environmental impacts. An example of an intermediate technology could be a low-cost, energy-efficient irrigation system for local farmers that allows them to improve crop production without relying on fossil fuels and without significant environmental impacts.

On the other hand, the "economy of enough" is an economic philosophy that focuses on meeting basic human needs rather than encouraging overconsumption and waste. In this perspective, steady economic growth is not necessarily desirable if it does not translate into a real improvement in people's quality of life. Rather than measuring economic success by the rate of GDP growth, the economics of enough proposes an assessment of the human and environmental well-being of communities and using broader and more meaningful indicators to measure economic success. This economic philosophy suggests that a sustainable economy should be focused on meeting human needs and protecting the environment rather than maximising economic growth.

One such text is the Brundtland Report of the World Commission on Environment and Development, *Our Common Future* (Brundtland, 1987). This report sets out the widely accepted definition of sustainable development and examines the interactions between the economy, the environment, and society. The *Our Common Future* report was published in 1987 by the United Nations World Commission on Environment and Development, also known as the Brundtland Commission, after its chair, former Norwegian Prime Minister Gro Harlem Brundtland.

The report defines sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." The report recognises the interdependence between the economy, the environment, and society, and stresses international cooperation's importance in addressing global challenges. The report highlights the importance of citizen participation and the role of businesses and governments in promoting sustainable development.

Natural Capitalism: Creating the Next Industrial Revolution was published at the turn of the century (Hawken et al., 2000). The book proposes a new industrial development model based on natural resource conservation and sustainable use. The authors argue that the current economic system, based on the exploitation of natural resources and short-term profit maximisation, is unsustainable and has led to an environmental and social crisis. Instead, they propose a new way of thinking about the economy that recognises the value of natural resources and treats them as "natural capital."

The book explores several examples of companies and organisations that have adopted sustainable practices, reduced costs, increased efficiency, and improved their employees' and local communities' quality of life. The authors also propose several strategies for achieving a sustainable economy, including adopting more efficient technologies, redefining economic metrics, and encouraging innovation and collaboration.

Another introductory text is *Cradle to Cradle* (2002) by William McDonough, and Michael Braungart proposes a sustainable design and production model that considers a product's entire life cycle, from its creation to its disposal. Through this text, one can understand how technology can help to create more sustainable systems and close material cycles.

The Triple Bottom Line: How Today's Best-Run Companies Are Achieving Economic, Social and Environmental Success—and How You Can Too (2006) was published by authors Andrew Savitz and Karl Weber. This book introduces the concept of the "triple bottom line" (TBL), which

refers to the idea that companies should measure their success not only in terms of economic profit but also in terms of social and environmental impact. The authors argue that companies adopting a triple bottom line approach can improve their long-term profitability and create value for their shareholders, employees, and society. The book includes several examples of companies that have adopted the TBL approach, including Patagonia, Nike, Starbucks, and Unilever. In addition, it explores how these companies have integrated sustainability into their business strategies.

The book *The Fourth Industrial Revolution* (2016) by Klaus Schwab describes a new era in human history, characterised by the convergence of digital, physical, and biological technologies fundamentally transforming how we live, work, and relate to each other. Schwab describes how emerging technologies such as artificial intelligence, robotics, the Internet of things, biotechnology, and 3D printing radically change the nature of work, the economy, and society. Rather than simply continuing the third industrial revolution based on electronics and information technology, the fourth industrial revolution represents a qualitative shift in how technologies are integrated into everyday life.

According to Schwab, the implications of the fourth industrial revolution are enormous. Its impact will be felt in all aspects of life, from how we work and communicate to how we interact with the natural world. The book looks at the opportunities and challenges these new technologies present and offers a vision of how society can adapt and make the most of the fourth industrial revolution.

Schwab highlights the need for greater collaboration between the public and private sectors and the importance of developing effective policies and regulations to guide the use of these technologies ethically and responsibly. He also focuses on the importance of education and skills development to prepare people for the new economy and the need to build a robust digital and physical infrastructure to support the new era of technology.

Although these texts address sustainability and technological progress from different perspectives and at different points in history, they share some common ideas. First, they all recognise the importance of a holistic approach considering the interdependence between the economy, environment, and society. Secondly, many of these texts propose solutions based on innovation and design, either through creating more sustainable products and services or through implementing circular production models. Finally, many of these texts advocate a change in the way we evaluate

business success, including social and environmental considerations into the equation. In this context, the book *Natural Capitalism* also addresses the need for a more sustainable economy, arguing that environmental protection and efficiency in using natural resources are not only necessary from an ethical point of view but also to ensure long-term business success.

In addition, *Cradle to Cradle* and *The Upcycle* (2013) offer an innovative approach to sustainable design, arguing that eliminating the concept of waste is essential to creating a more sustainable future. Instead of the traditional "cradle to grave" of linear production, the authors propose a circular economy in which materials and products are designed to be continually reused and recycled.

Finally, *The Triple Bottom Line* offers a business perspective that recognises the need to address financial success and the business's social and environmental impact.

These texts have contributed to raising awareness of the importance of addressing today's environmental and social challenges and promoting innovative and practical solutions. Some of them have had a significant impact on government policy and decision-making, as well as on business strategy and innovation.

However, there are also criticisms and limitations to the applicability and effectiveness of some of these proposals. For example, some may be seen as utopian or idealistic, while others may be considered too focused on the market and economic profit. In addition, there may be challenges in implementing some of these solutions due to the political and economic complexities involved.

These texts offer a broad and varied view of addressing today's sustainability and technological progress challenges. It is important to note that each can be seen as one element of a broader set of solutions and approaches to achieving a sustainable and prosperous future. Combining these perspectives and adopting an interdisciplinary and collaborative approach may be the key to addressing these challenges effectively and sustainably in the long term. *The Limits to Growth* was one of the first texts to highlight the physical limits of the planet and the need to address environmental challenges. However, some critics have argued that the catastrophic predictions presented have not come true. The text ignored the possibility of technological advances and changes in human behaviour that could reduce the ecological footprint.

Nevertheless, *Small Is Beautiful* is an influential text that promotes the idea that the economy should be designed to meet human needs and not

just to maximise production and consumption. However, some critics have argued that the ideas presented in the text are too utopian and do not consider the practical limitations of the real world. If we look at *Our Common Future*, it is a seminal text that introduced the concept of sustainable development to the world. Its focus on balancing economic, social, and environmental objectives has been widely adopted. However, some critics have argued that the text does not offer concrete solutions and that its focus on international collaboration and cooperation may need to be revised.

Natural Capitalism presents an ambitious vision of an economy that values natural resources and efficiency in their use. Its ideas have been widely adopted in business policy and practice. However, some critics have argued that its focus on efficiency and technological innovation may not fully address broader social and environmental challenges. *Cradle to Cradle* and *The Upcycle* are innovative texts that present a radically different approach to sustainable design. Many business leaders and governments have adopted their focus on waste disposal and the circular economy. However, some critics have argued that more than focusing on resource efficiency may be required to address broader environmental problems.

Finally, *The Triple Bottom Line* presents a business approach that values financial success and companies' social and environmental impact. It has been widely adopted in business practice and sustainability reporting. However, some critics have argued that more than the approach may be required to address the broader structural challenges of the global economy.

12.3 Digitalisation and Ecological Transition: Limits and Challenges to a Green Future

Digitalisation has been seen as an ally of sustainability in several ways. Firstly, insofar as it helps to dematerialise and decarbonise the economy, encouraging a shift from products to services, which also opens a whole new field of economic development. On the other hand, digitisation helps to have more and better information, thus enabling more efficient administration in many fields, from logistics management to optimisation of the energy system, including, for example, mobility or the development of so-called smart cities. Digitalisation is also a critical factor in innovation, especially through cooperative mechanisms such as collective intelligence

and open experimentation, which are essential for further progress in sustainability. Therefore, it is unsurprising that digital and green have been seen as allies. According to the International Energy Agency, digitalisation already consumes 3% of global primary energy and 7% of electricity, is responsible for between 2% and 4% of global greenhouse gas emissions, that is, twice the emissions of air transport. If nothing is done, digital technologies in the EU are estimated to account for 40% of greenhouse gas emissions and 10% of electricity consumption by 2030.

On the other hand, over the last 50 years, energy consumption associated with information and communication technologies (ICT) has been growing steadily, proving Jevons' paradox right (a study published in the *Journal of Physics D. Applied Physics* suggests that the widespread use of more efficient lighting technologies, such as LEDs, could increase energy consumption tenfold and double lighting-related energy expenditure by 2030): *Applied Physics* suggests that the widespread use of more efficient lighting technologies, such as LEDs, could increase light consumption tenfold and double lighting-related energy expenditure by 2030. This trend is due to the "rebound effect," whereby the cost reduction of a more efficient technology leads to higher consumption of the same technology. Researchers at Sandia National Laboratories estimate this could happen in the most extreme scenario, where solid-state lighting (SSL) technology is fully deployed, and energy prices remain stable. However, this trend could be broken once saturation of demand for artificial light is reached (Tsao et al., 2010). The study shows that efficiency gains often lead simultaneously to increased emissions. In this case, energy savings achieved through technological improvements in devices are offset by increased use of ICT.

In addition, there is the use of materials associated with digital devices, which requires minerals, some of them rare earths, which are scarce and difficult to extract, and which are at the root of numerous conflicts, some even armed, in developing countries (The 17 chemical elements known as rare earth are essential for the functioning of a wide variety of products, including computers, mobile phones, electric cars, lighting systems, and fibre optics). China accounts for 80% of the global production of these minerals, giving it an advantage in the technology and trade war with the United States. Although these elements are not scarce, they are difficult to find in sufficient concentrations to be extracted profitably. The extraction process can have environmental and health consequences and generate

toxic waste that pollutes air, water, and soil (National Minerals Information Center, 2022).

The United States has only one operational mine in California, while China has 37% of the world's reserves of these minerals and 85% of the processing capacity (National Minerals Information Center, 2022). These challenges have their distinct characteristics in the so-called global south. According to the International Energy Agency, 70% of future energy demand will come from non-OECD states by 2040, so developing countries will also be central to this issue. The global south must not be left behind in joining digitalisation, and it must do so with the same ecological transition criteria adapted to its socio-economic reality. Here, too, the ecological transition must be just (Monge, 2022).

Digitalisation and decarbonisation are two interrelated and complementary processes. Digitalisation can contribute to decarbonisation in several ways. First, digitisation can improve the energy efficiency of production processes and services, which reduces energy consumption and, thus greenhouse gas emissions. Secondly, digitisation can facilitate the production and storage of renewable energy, contributing to decarbonisation. In addition, digitisation can help reduce the need for physical transport and promote telecommuting, which reduces greenhouse gas emissions from transport. Although digitisation can contribute to the decarbonisation of the economy, it is essential to bear in mind that it is not a magic bullet. Digitalisation should be seen as another tool to address climate change and should be implemented responsibly and sustainably. It is necessary to ensure that digitisation does not create new problems, such as excessive energy consumption or the generation of e-waste, and that equitable access to technology is promoted. Furthermore, it is essential to bear in mind that decarbonisation cannot be achieved through digitisation alone but requires a combination of measures, including reducing fossil energy consumption, implementing policies and regulations to reduce emissions, and transitioning to an economy based on renewable energy sources.

A recent study published by BBVA Research suggests that digitalisation is favouring the reduction of CO_2 emissions in highly digitalised economies, such as those of the Persian Gulf, the United States, and European countries. In the medium and long terms, it should encourage decarbonisation in economies with lower levels of digitisation, such as Latin America and Africa. The study points to an inverted U-shaped relationship between digitisation and CO_2 emissions per capita, identifying thresholds or minimum levels of digitisation above which emissions generated by economic

activity begin to fall. According to this analysis, the direct marginal effect of digitisation on emissions is limited compared to that of other variables such as GDP per capita. However, once the threshold is reached, it can lead to a reduction in per capita emissions of up to 10% in fully digitised economies. However, the total effect is higher, with a maximum per capita emissions reduction of close to 45%. It also includes indirect impacts such as gains from higher energy efficiency and increased use of renewables. The study points to an inverted U-shaped relationship between digitisation and CO_2 emissions per capita, identifying thresholds or minimum levels of digitisation above which emissions generated by economic activity start to fall. According to this analysis, the direct marginal effect of digitisation on emissions is limited compared to that of other variables such as GDP per capita. However, once the threshold is reached, it can reduce per capita emissions by up to 10% in fully digitised economies. However, the total effect is higher, with a maximum per capita emissions reduction of close to 45%. It also includes indirect impacts such as gains from higher energy efficiency and increased use of renewables. The estimated digitisation thresholds for the direct and indirect effects were exceeded in 2020 by 60% and 70% of the countries analysed (Barrutiabengoa & Más Rodríguez, 2022).

Thales Alenia Space has been selected by the European Commission to study the feasibility of the ASCEND programme, which aims to install data centres in orbit to solve the problem of high energy consumption and pollution generated by terrestrial data centres. Sammy Zoghlami, vice president of Nutanix, points out that data centres in Europe, the Middle East, and Africa consume more than 90 terawatts per hour annually and generate emissions equivalent to about 5.9 million vehicles (Zoghlami, 2022). Companies like Google Cloud and Amazon are turning to carbon-free energy sources like photovoltaic farms and solar panels to reduce their carbon footprint. Thales Alenia Space, in charge of studying the feasibility of the ASCEND programme, plans to install data centres in orbit in the first half of the next decade due to the exponential increase in computing and its high energy consumption and pollution. Yves Durand, the company's chief technology officer, points out that initiatives like Google's are not enough to reduce the carbon footprint and that data centres in space seem a good alternative. To build such extensive facilities in space, Thales Alenia Space has joined a large consortium of space infrastructure specialists, including Carbone 4, VITO, Orange, CloudFerro, Hewlett Packard Enterprise, ArianeGroup, DLR, Airbus Defence and Space, and Thales

Alenia Space. Yves Durand, chief technology officer at Thales Alenia Space, says that most data centres in Europe use highly carbonised sources, and infrastructures are large energy consumers, which means that the global energy consumption of these centres is growing every year. In addition, the growing use of electric cars or hydrogen production will add even more to energy demand more to energy demand (Limón, 2022).

According to Durand's calculations, by 2050, we will not be able to meet all our energy needs at the current growth rate in demand, so taking data centres into space seems like a good alternative. The first big challenge is to build a sufficiently large facility in space. Therefore, a large consortium of leading space infrastructure specialists has been set up. Cooling is a significant part of a data centre's energy use and can account for more than 50% of some installations. Temperatures in Earth's orbits can reach -180 °C in the shade, saving cooling energy and avoiding huge consumption.

One of the significant challenges is radiation, which affects both the physical components of the system and the computation. However, Durand points out that there is already much experience with satellite constellations for telecommunications. The growing energy demands of data centres and their carbon footprint are driving the development of new solutions. A consortium led by Thales Alenia Space is studying the feasibility of installing data centres in space to take advantage of low temperatures and save energy on cooling. This item, in some cases, accounts for more than 50% of a data centre's energy consumption. In addition, such data centres in space could be a vital tool in future space exploration, enabling data collection, storage, and analysis. Applications that could benefit from these new centres include neural network computing, financial centres, and quantum computing. Although there are challenges to overcome, such as the construction of such extensive facilities in space and radiation, there is already previous experience with telecommunications satellite constellations, and the International Space Station has AI-enabled in-space computing systems. Using existing and emerging space technologies can help achieve global sustainability and accelerate decarbonisation in ten years. According to a report by Globant's Sustainable Business Studio for Inmarsat, full adoption of available systems would enable an 11.5% reduction in global emissions by 2030. Emissions savings are 2.5% and would add 9% from adding new uses. Elena Morettini, the report's lead scientist, stresses that the potential CO_2 emission reductions from satellite technologies are immense and that a lack of investment stands in

the way of tremendous sustainability success. Using satellite data can allow for significant optimisation of transport routes and greater efficiency in detecting methane emissions (Morettini, 2022).

On the other hand, artificial intelligence was developed guided by scientific geopolitics and industrial competition. Physical and energy limits constrain the technology's progress, including chip miniaturisation, globalised production, and data centre energy consumption. These problems limit the ability of algorithms and AI to continue to improve at the rate they have in the past. The current computing model is facing several hurdles, including the impossibility to further reduce chip size, the dependence on a few countries to manufacture the most advanced chips, and the consumption projected to increase to 13% by 2030. This has led scientists to look to biology for inspiration to reduce power consumption in computing. The current trend is to increase the algorithm's size to achieve "artificial superintelligence," but it is unclear that this can be achieved due to the energy limit. To make progress, scientists propose to look back to biology and design intimately related hardware and software, using analogue computing and neuromorphic chips that mimic the brain's architecture and can process continuous signals. Although such systems are costly and risky to develop, several analogue neuromorphic computers are already in operation and have demonstrated their ability to learn to compose music (IMEC) (Contera, 2023).

However, this innovation has a downside: as electronics encroach on everything, e-waste accumulates at an unprecedented rate. It is already the fastest-growing waste stream in the world and now accounts for up to 70% of the toxic waste in landfills in the United States. Approaches taken so far, while well-intentioned, have not addressed the magnitude of the problem. In the United States, the recycling rate of electronics remains stubbornly low. Attempts to pass e-waste regulations through Congress have failed. Initiatives to reduce waste, such as fair phones with easily upgradeable components, sound promising but have not been adopted on a large scale.

Only 17.4% of e-waste is recycled worldwide; by 2030 the total amount of waste will reach 74 million—currently 56 million tonnes (UNITAR United Nations Institute for Training and Research, 2023).

To make a difference, a new group of innovators has resorted to a remarkably different approach: transforming a waste stream into a revenue stream.

E-waste is often rich in precious minerals like gold, silver, platinum, and copper. The individual amounts may be small, but the total adds up

quickly. For example, the gold in the world's e-waste is estimated to equal up to 11% of the total amount of metal mined annually.

Technologies to extract these metals from waste have existed for a long time but are highly inefficient and costly. With decreasing quantities of precious metals used in electronic devices, it is increasingly difficult for large-scale processors, such as smelters, to recover the total value. For example, a considerable percentage of the gold in e-waste sent to smelters is never recovered. In addition, dozens of rare earth elements are present in today's smartphones, such as dysprosium and neodymium, which are tough metals to find and are limited to a few deposits worldwide. The small amounts of these minerals inside a phone resist easy recovery and often do not justify the extraction price.

Scientists have developed carbon nanotube technology to filter out deficient concentrations of rare earth elements. A team of researchers has developed a process to recover the minerals used to make an iPhone using underwater sound waves, as these technologies become more widespread, extraction costs decrease, making recycling and extraction of metals a profitable opportunity for companies. Instead of paying collectors to recycle our old devices, we will see companies compete to collect them.

Instead of keeping our old phones in a drawer or throwing them away, we can dispose of them in the appropriate bin every week for proper collection. At the same time, new technologies enable the extraction of precious minerals in small quantities, allowing metals to be recovered from e-waste more cost-effectively.

In addition to incentives for customers to recycle, manufacturers are also making changes to their production processes to reduce the e-waste stream. As the recovery of metals (and even non-metals) becomes more accessible, more manufacturers are expected to adopt closed-loop processes. Instead of extracting materials from the earth, they will "mine" their end-of-life products for materials. It is already much more efficient to extract a tonne of gold from old circuit boards than it is to extract it from the ground (Holgate, 2018).

Extracting just ten grams of gold requires the displacement of almost five tonnes of soil and releases multiple toxic compounds into the air and groundwater. Therefore, extracting gold directly from e-waste containing a significant amount of this metal could be a more sustainable solution, as two-thirds of the planet's gold has already been extracted. Moreover, extracting one tonne of minerals from the earth yields only 30 grams of gold, whereas one tonne of e-waste can yield up to 300 grams. Therefore,

mining operations should occur in scrap yards and recycling centres, rather than in ecologically sensitive areas and ancestral lands. However, transforming e-waste into gold still presents challenges, as some technologies are costly and inefficient. In addition, the recycling process must be carried out correctly and in a controlled environment to avoid negative environmental consequences (Holgate, 2018).

Digitalisation and decarbonisation are two critical elements of the global agenda that have not yet been adequately addressed at either the G20 or the COP level. Addressing this problem requires national and global measures, both in terms of measurement and awareness-raising among users, citizens, companies, and public administrations, with regulations that do not strangle the development possibilities of the Global South. In this regard, some proposals are to establish a centre to measure and analyse the energy evolution of both ICTs and digitalisation. Second, the new governance should incorporate environmental regulatory responsibilities for the digital sector. Third, recognise and respond to the gap in global investment in renewable energy and low-carbon technologies. Fourth, propose that the G20 recognise the carbon footprint of digitalisation. By 2040, non-OECD countries will account for 70% of energy consumption; the Global South will be central to this issue and must not be left behind in digitisation (Chiarella et al., 2022).

12.4 Conclusions

The growing demand for technology and the rapid obsolescence of electronic devices generate large amounts of e-waste, which poses significant environmental and economic challenges. On the one hand, the positive points of digitalisation are mentioned, such as the dematerialisation of the economy, efficient administration, service development, and innovation. On the other hand, the adverse effects are discussed, such as the increase in greenhouse gas emissions and energy consumption associated with information and communication technologies, the use of materials associated with digital devices, and the need for a just ecological transition adapted to the socio-economic reality of developing countries.

In addition, Thales Alenia Space's ASCEND project is presented, which aims to install data centres in orbit to solve the problem of the high energy expenditure and pollution generated by terrestrial data centres. While this could be an attractive solution, the project also faces several challenges, such as the construction of such extensive facilities in space and the

radiation that affects both the physical components of the system and the computation.

In terms of challenges, the need for a just ecological transition adapted to the socio-economic reality of developing countries is highlighted, as well as the extraction of minerals and metals from the earth, an energy- and resource-intensive process causing severe environmental and social impacts. Regarding constraints, the energy consumption associated with information and communication technologies is mentioned, which has increased over the last 50 years and can offset the energy savings achieved through technological improvements in devices.

Digitalisation can be an ally of sustainability but can also negatively affect the environment and social justice. It is essential to consider these adverse effects and work to minimise them while taking advantage of the benefits of digitalisation to move towards sustainability.

The green transition to digitisation must be fair and adapted to the socio-economic reality of developing countries to avoid aggravating the technological gap and environmental impact. The proposal to install data centres in orbit is an innovative solution that could reduce the energy expenditure and pollution associated with terrestrial data centres. This project faces technical challenges but could also be an essential tool for future space exploration and storing large amounts of data.

Further research and development of sustainable technological solutions, such as nanotubes, is needed to minimise the need for scarce materials and reduce the environmental impact of resource extraction. In addition, it is essential to work on reducing the energy consumption associated with information and communication technologies and on the proper management of e-waste to prevent it from becoming an additional source of pollution.

Digitalisation and sustainability are closely linked and must be addressed together to move towards a fairer and more sustainable future.

References

Barrutiabengoa, J., & Más Rodríguez, P. (2022). *Digitalizar para descarbonizar*. Madrid: BBVA Research.

Braungart, M., & McDonough, W. (2002). *Cradle to Cradle: Remaking the Way We Make Things*. McGraw Hill.

Braungart, M., & McDonough, W. (2013). *The Upcycle: Beyond Sustainability—Designing for Abundance*. North Point Press.

Brundtland, G. (1987). *Our Common Future*. New York: United Nations.
Chiarella, A., Quetglas Martin, G., Ortega, A., & Szenkman, P. (2022). *Towards a Global Agenda for Digitalization without Greenhouse Emissions*. Madrid: Real Instituto Elcano.
Contera, S. (2023). *The Limits of Digital Computing and Neuromorphic Chips*. Madrid: El Pais.
Hawken, P., Lovins, A., & Lovins, H. (2000). *Natural Capitalism: Creating the Next Industrial Revolution*. US Green Building Council.
Holgate, P. (2018, February 9). *How Do We Tackle the Fastest-Growing Waste Stream on the Planet?* World Economic Forum. https://www.weforum.org/agenda/2018/02/how-do-we-tackle-the-fastest-growing-waste-stream-on-the-planet/
Limón, R. (2022, December 26). *Los centros de datos se trasladan al espacio para mitigar el consumo energético y la contaminación*. ElPais.
Meadows, D., Meadows, D., Randers, J., & Behrens, W. (1972). *The Limits to Growth*. Universe Books.
Monge, C. (2022, December 9). A Marriage of Convenience: Ecological Transition and Digital Revolution. *El Pais*.
Morettini, E. (2022). *Can Space Help Save the Planet? The First-Ever Global Study of Satellite-Enable Decarbonisation*. New York: Inmarsat.
National Minerals Information Center. (2022). *Mineral Commodity Summaries 2022*. Washington, DC: USGS.
Savitz, A., & Weber, K. (2006). *The Triple Bottom Line: How Today's Best-Run Companies Are Achieving Economic, Social, and Environmental Success—And How You Can Too*. Wiley.
Schumacher, E. (1973). *Small is Beautiful: A Study of Economics as if People Mattered*. Akal.
Schwab, K. (2016). *The Fourth Industrial Revolution*. Penguin Books.
Tsao, J., Saunders, H., Creighyon, J., Coltrin, M., & Simmons, J. (2010). Solid-State Lighting: An Energy-Economics Perspective. *Journal of Physics D: Applied Physics, 43*, 354001.
UNITAR United Nations Institute for Training and Research. (2023). *Global E-waste Data*. United Nations.
Zoghlami, S. (2022, December 26). Data Centres Move into Space to Mitigate Energy Consumption and Pollution (R. Limón, Interviewer).

CHAPTER 13

Why Inventions Fail to Become Innovation? Some Examples from Spain and Italy

Juan Francisco Galán

13.1 Introduction

In Spain and Italy there are many examples of great inventions that have not become innovations and, therefore, have not contributed to economic development as it has happened in other countries.

This chapter takes some of these examples as a starting point and, focusing on the second half of the nineteenth century, reviews some of the factors that hinder or even prevent innovation.

We think that this historical analysis of how inventions become innovations can shed a lot of light on the debate currently taking place in Spain, in Europe and in the rest of the industrialized world, about the best policies that should be applied to promote innovation and, therefore, increase the productivity of our economies.

Moreover, the article states that, on many occasions, one of the main difficulties lies in the fact that the involved economic agents do not

J. F. Galán (✉)
Complutense University of Madrid, Madrid, Spain

E. Trincado Aznar, F. López Castellano (eds.), *Science, Technology and Innovation in the History of Economic Thought*, Palgrave Studies in the History of Economic Thought,
https://doi.org/10.1007/978-3-031-40139-8_13

understand properly the very concept of innovation and that this misunderstanding does not appear usually on the list of factors that drive or hinder innovation. See as an example the recent publication *The Art of Innovation* (Echeverría, 2017).

Regarding the historical period chosen, we think it is interesting because the Spain of the Restoration already had quite favourable conditions for innovation: enough stability, both political and social; a liberal legal system suitable for productive activities; an appropriate legislation on industrial property (Patent Law of 1878, much improved over the previous one), in addition to new and modern educational and research institutions, which had spread scientific and technical training (Saiz González, 1999, pp. 329–348). On the other hand, conditions in Italy after unification (1871) are quite similar to those in Spain.

The reviewed cases are grouped into three categories: in the first one, the new results are not even received by society; in the second, the industry does not react, despite being aware of the "scientific" results; finally, the third would include the inventions that do produce innovation, but only for a short period of time, before being abandoned.

The chapter concludes with the case of Isaac Peral's submarine and gives it more space considering that it is one of the best examples of a great invention that neither became an innovation nor contributed to economic development. It is also shown that, although the reasons for the failure of the submarine were various, one of the most important was purely conceptual: the confusion between discoveries, inventions and innovations.

13.2 Great Inventions That Did Not Produce Any Innovation

13.2.1 Spain and Italy in the Second Half of the Nineteenth Century

Until the 1870s, the political situation in the two countries was very unstable. Spain lives in 1868 a revolution, "La Gloriosa," which begins the revolutionary six-year period. The subsequent Restoration, led by Cánovas Del Castillo, was on the way of recovering political normality when in the year 1885 the death of the king, Alfonso XII, generated once again some uncertainty.

As for Italy, the years 1859–61 constitute the decisive stage of its unification, most of the time through armed conflicts. The process culminated in the annexation of Veneto, in 1866, and the papal territories, in 1870. Only then begins a time of peace and stability more suitable for economic progress.

In the midst of this complex political situation, Spain and Italy experienced during the second half of the nineteenth century a growing process of industrialization, process that was very heterogeneous, with great disparities between the different regions, especially between the north and the south.

Regarding innovation, the two countries had patent laws since the beginning of the century, although it is during this period when they are updated and modernized, greatly expanding the possibilities of registration and exploitation of inventions (Saiz González, 1999, p. 334).

Three examples of inventions of the time that did not lead to innovation are described below. The first of them had no impact at all, while the second and the third had little and, most of all, were only temporary.

13.2.2 Vicenzo Tiberio and Antibiotics

Vincenzo Tiberio discovered and investigated the antibiotic effects of some moulds, including penicillin, in the years 1894 and 1895, that is, 34 years before Alexander Fleming.

Vicenzo was a doctor and while destined in Naples he observed that a water tank produced more ailments in humans when it was perfectly clean than when it was covered with mould, so he decided to investigate the matter, going so far as to carry out complete tests, both in the laboratory and in real life and concluding that the moulds contained substances contrary to the growth of pathogenic bacteria ("i funghi presenti sul bordo del pozzo—svolgevano un'azione che si dimostrava contraria alla crescita dei batteri patogeni") (Di Chiero, 2017, pp. 243–258).

His results were published (and forgotten) in January 1895, in the article: "Sugli estratti di alcune muffe," included in the magazine *Annali d'igiene sperimentale*, V (1895), pp. 91–103.

It was not until 1946, the year after Alexander Fleming received the Nobel Prize, that Giuseppe Pezzi, also a doctor and a soldier like Tiberius, found the original results and released them to the world in an article published in the *Annali di medicina navale e coloniale*" (Pezzi, 1946, pp. 251–266).

13.2.3 Giovanni Caselli and the Pantelegraph

Giovanni Caselli's pantelegraph, predecessor of the fax, was a machine that in 1857 was capable of sending images over a long distance with very high quality, achieving, for example, that the autograph signature of Giacomo Rossini adorned one of his music sheets almost instantly.

But the invention failed to be applied in its homeland, Tuscany (Italy), probably because the necessary means to manufacture and start up the device did not exist there, at that time, nor were there enough potential customers to allow its commercial exploitation.

Therefore, Giovanni Caselli immigrated to France, the country where his invention was manufactured, perfected and even triumphed for ten years, from 1860 to 1870, thanks mainly to the impulse of Napoleon III and his administration, who made it the official device for his telegraphic communications.

Caselli patented his pantelegraph in 1861 in Paris and in 1863 in the United States, but sending images was too expensive, as was the maintenance of the devices, so at the end of the Franco-Prussian war, the invention first fell into disuse and then into oblivion, while its inventor returned to his homeland, Tuscany.

13.2.4 Alessandro Cruto and the Incandescent Light Bulb

Alessandro Cruto invented a process for making a filament that produced a better incandescent light bulb than Edison's, with a whiter and more efficient light, barely five months after the great American inventor, in the year 1880.

The invention was well received and Alessandro turned his laboratory into a small light bulb factory. He even ventured to find partners to build a larger factory, in which he managed to produce up to 1000 units per month, in Alpignano, close to Turin. But in a short time, his relationship with the factory management became a source of discussion and he decided to return to his inventions, leaving the industry. The factory was finally acquired by Philips in 1927.

13.3 An Example in Which the Concept of Innovation Was Not Well Understood

13.3.1 The Context

In this section, we analyse the case of Isaac Peral's submarine in greater depth. In September 1885, following the crisis of the Caroline Islands with Germany, Isaac Peral addressed Admiral Manuel de la Pezuela y Lobo, Minister of the Navy, informing him about his "submarine torpedo boat" project and the possibility of building a submarine capable of repelling or discouraging a much superior naval force, in the following terms:

> In these last days I have invented, and I have made all the necessary calculations for the construction of a submarine torpedo boat, that can carry inside, without any danger, the men necessary for its handling, without the slightest trace of the ship appearing on the surface of the water during its maneuvers. One or two of these ships would be enough to destroy a powerful squadron with total impunity in a very short time ….[1]

Minister Pezuela requests a report from the San Fernando Astronomical Observatory, which responds as follows: "This Centre believes that the project does not have a single vulnerable point. Scientifically, the problem is solved by him" (Pérez, 1935).

Pezuela consults with the head of government, Cánovas del Castillo, who does not show enthusiasm for the project. Even so, the Minister assigns Isaac Peral the necessary support from the Carraca Shipyard, a military centre for the construction and repair of ships in San Fernando (Cádiz), along with the ridiculous amount of 5000 pesetas, to start the works.

The death of Alfonso XII and the change of Minister stopped the project for a while until the determined support of the regent queen, María Cristina, obtains in April 1887 the disposition for the construction of the submarine, under the Squad Law of January 1887, by Rodríguez Arias. Thanks to this decree, Isaac Peral has the means to travel around Europe and acquire all the necessary components.

[1] PERAL, ISAAC Manifiesto de Isaac Peral. *El Matute*, Número extraordinario, Madrid, 21 febrero de 1891.

13.3.2 The Construction of the Peral Submarine

The submarine is built at La Carraca under the direction of Isaac Peral, who continues with his work as a professor at the Academy for the Expansion of Navy Studies.

On September 8, 1888, the submarine was launched in the Bay of Cádiz, in the presence of a large audience that received the submarine with great enthusiasm.

Among its many innovations the most important are the following ones:

- *Electric propulsion system*: It is the first electrically driven ship in history. Previous attempts, like Monturiol's, used a steam-based engine.
- *Immersion system*, which allowed to navigate at a depth of 10 metres.
- *Underwater navigation system*: Isaac Peral designs and manufactures an electric gyroscope capable of setting a course and reaching exactly the proposed place.
- *Periscope*, thanks to which the target can be visualized without going to the surface, that is, without putting the ship at sight.
- *Torpedo launch system*, which makes fires without water entering the ship's hull.

13.3.3 First Report and Opinion of the Superior Council of the Navy

The official tests are carried out from January 1889, supervised by a Technical Board, whose president is the Captain General of Cádiz and despite the fact that according to the scientist they are not the most convenient or appropriate (there is an excess of surface tests, when the main contribution was underwater navigation), it is stated that the experience "was perfect and complete" (Peral, 1891).

They also consider that El Peral provides a solution to the general problem of "Applying submarine ships to military art" (Peral, 1891) and it is requested to carry out tests with larger ships.

Although the results of the first tests are mostly positive, the Superior Council of the Navy issues an unfavourable Opinion, stating that "the submersible electric torpedo boat… Does not meet the conditions that its author promised," proposing that he present new plans and direct a new project "understanding that said plans, the project in general and the

execution of the works must be examined, approved and inspected by the Authorities" (Ministerio & Peral, 1890, p. 509).

Isaac Peral replies that in order to accept the proposal he needs to reserve: "the most complete freedom of action in the scientific part," he also requires that "the execution of all the works of the project…" be carried out under his exclusive direction.

The Council's response is forceful and surprising: "The Peral submarine is not the product of new principles discovered by its author, but rather an application of those already known, and a more or less ingenious use of means that the current state of science and technology industry has made available to Peral" (Peral, 1891).

It is also stated in this opinion that the submarine on the surface "governs badly," quoting tests previous in a month to the official ones. He also devotes a lot of space to describe and highlight what is being done abroad in the same field, saying that El Peral is not superior, when it seems that it really was, as well as previous.

13.3.4 Isaac Peral's Defence

We collect below some of the arguments that Isaac Peral uses in his defence:

- According to Isaac Peral, there are numerous bureaucratic obstacles, as well as a lack of resources, which make the task extremely difficult. Let's not forget that in his case, the project took almost two years to be approved and endowed, from 1885 to 1887. As it also takes another two to be executed and tested, what was really innovative in 1885 was quite known in 1990, there were already similar submarines in Europe. It even seems that some of these submarines had elements suspiciously similar to those of the Peral one.
- Regarding the imperfections of the submarine, Isaac Peral clearly says that it is only a first prototype, a test ship, which will of course have to be perfected, something that his superiors do not seem to understand. It seems that they are not aware that an innovation needs time and tests to be perfected.

Peral says: "I don't think I have to make a big effort to highlight the lightness of a Minister and a Council of the Navy who decide to withdraw their confidence from an inventor because the first test of his invention

does not turn out to be the utmost perfection." and also: "I want those gentlemen to point me to a single invention that has come out from the first test… as practical as the first one of my submarine" (Peral, 1891).

Regarding the behaviour of the submarine on the surface, Isaac Peral says literally: "I did not make my ship to be judged as a floating boat… The question that was going to be discussed with this ship was its qualities as a submarine and on this matter the test of June 7, according to the report of the Technical Board, was perfect and complete." Peral ends by saying: "Let's put together, then, now in one boat, the well-known conditions for good stability afloat with the problems satisfactorily resolved in El Peral." And he adds: "If they accuse me of little experience in the construction of submarines, neither they nor anyone in the world have it" (Peral, 1891).

One of the main arguments that Isaac Peral presents, very prudently, is that the Superior Council of the Navy may not have understood him, according to him because its members do not have enough knowledge to judge his contributions. But not because they lack capacity, but because, as he affirms, men in general do not keep their knowledge up-to-date, only specialists in each subject do. For example: "By wanting to remove novelty from the applications that I have made of electrical energy, the Navy Council commits a scientific inaccuracy…."

Isaac Peral distinguishes between the members of the Technical Board, in which he assures there are highly qualified people, and the writers of the Council Opinion, affirming: "On the other hand, for the Opinion they put to judge those who do not know or understand" (Peral, 1891).

13.3.5 The Contribution of Echegaray. The Conceptual Debate: Discoveries and Inventions

José Echegaray, who knows the submarine project in depth, began to publish on November 26, 1890, in the *Heraldo de Madrid* newspaper, a series of articles in defence of Isaac Peral in which all the concepts associated with inventions and innovations are explicitly formulated. The first one starts like this:

> The opponents of the famous sailor, or at least of his famous ship, affirm that the supposed invention is not an invention, nor a novelty, nor a discovery, nor anything other than a kind of compilation, on board of a steel hull, of

> several devices, inventions and systems as well known as vulgar, and tired of running for books, pamphlets and monographs. (Echegaray, 1891)

Echegaray, in addition to comparing one by one the existing submarines with El Peral and concluding that they are not similar at all, dedicates an entire article to discuss the concept of invention, distinguishing it from discovery and clearly stating that the submarine meets all the necessary requirements to be one of the first and refuting all the arguments of the Opinion issued by the Superior Council of the Navy.

As an example, Echegaray says that the immersion system devised by Isaac Peral is very simple and then asks: "But because it is very simple, does it lose its merit and its character of invention?" (Echegaray, 1891).

13.3.6 The Likely Political Issue

Much has been written and talked about a possible political issue in the case of the Peral submarine, but I believe that it was not a major factor, since the lack of support for the project was constant on the part of all governments, both those of Cánovas del Castillo and those of his opponent, Sagasta.

To see an example, it seems that Cánovas's reaction when the Minister of the Navy, Admiral Pezuela, spoke to him about the submarine for the first time was simply a scorn gesture: "Oh! A Quixote who has lost his mind reading Jules Verne's novel!" (Pérez, 1935, p. 34). Even after the tests of the depth apparatus, carried out with total satisfaction, Cánovas del Castillo does not believe that Isaac Peral can successfully complete the project, showing a "mental incapacity to believe that the Spanish genius could do something useful outside of arts and letters" (Pérez, 1935, p. 52).

It has also been said that the candidacy of Isaac to the Parliament for El Puerto de Santa María was a problem, since the son of the then Minister of the Navy, Beránger, was also a candidate. But these elections were held in 1890, when the submarine project was already finished and the political persecution of the engineer had begun. In fact, it seems that the candidacy was presented by Isaac Peral's friends and supporters, initially without his consent, to provide him with some protection and shelter from the general offensive that surrounded him.

Much has also been written about possible corruption in the high levels of the Ministry of the Navy, but there is no evidence to confirm this hypothesis. It does seem true that part of the technical secrets of the

invention were revealed in the Ministry itself and that they even end up being published in the Gazette, but there is no proof that it was done for money.

13.3.7 On This Thread (Personal Thoughts)

The case of Isaac Peral's submarine shows a total lack of innovative perspective, as can be seen clearly when reading that the Opinion denies that there was any invention, novelty, merit and so on because all the components were already invented.

It seems clear that to make up the Board that issues the first report, people of the Navy with great knowledge and practical experience are summoned, including men of well-known scientific reputation, both in Spain and abroad. In the Opinion issued, scientific reason prevails and that is why the submarine passes the tests with flying colours. It is even recommended that more and bigger ships be built.

It is when the project reaches the higher spheres (the political ones) that it twists and I really believe that, among other reasons, it is due to a lack of knowledge of what invention and innovation really is.

It is true that the electric engine already existed, but applied to navigation was indeed an important innovation. There were also torpedoes, yes, but the system designed and built by Isaac Peral was an important novelty and could have been incorporated into other ships, as in fact it was done later (even today the system used by submarines to launch torpedoes is quite the same).

So were the more specific instruments, such as the periscope, which was a truly innovative instrument, even if it did not bring new optical principles, or the underwater navigation system that could have been used on many other ships, especially in adverse sea conditions.

Another point in which it is evident that the concepts are not clear is when it is stated that "there are already very expert officers who know how to do what he did and taught to do" (Ministerio & Peral, 1890).

Also, the fact that the plans and technical details of the project were shown to third parties in the Ministry of the Navy indicates a lack of knowledge of the importance of the innovations introduced in it by Isaac Peral and of how necessary it was to keep them secret, at least until the completion of the submarine.

It is very sad that they force him to deliver all the components so that he cannot make another submarine somewhere else, but it's almost worse

that they don't do anything. They even send it to scrap! It seems more like a punishment, this depriving him of the means to carry out his ideas for not submitting to the marked path.

But even here it is shown that they do not understand well the matter: the key was in the designs and discoveries and, had he wanted, Isaac Peral could have easily built another submarine.

13.4 Conclusion

It seems quite clear that the transition from invention to innovation, to produce economic development, is not easy; there are many impediments that can hinder that path.

In this chapter, some of them have been reviewed, highlighting the conceptual aspect: ignorance of the true meaning of innovation. Let us remember that Isaac Peral himself affirms, prudently, that the Superior Council of the Navy may not have understood him.

There is one last element that we would like to contribute and it is that inventors themselves are very conscious of the difficulties of making an invention successful, as can be deduced from the fact that most of the great Italian inventors of the nineteenth and twentieth centuries have also tried to obtain patent rights in the United States. This is detailed in the very interesting book by Vittorio Marchis: *150 (anni di) invenzioni italiane* (Marchis, 2011), which collects 150 patents made by Italian inventors in the United States Patent Office, from the mid-nineteenth century to the present years.

It is quite likely that the same inventors were much aware that an invention patented in the United States was more likely to become an innovation and therefore provide them with much more benefits than the same patent in the then Kingdom of Italy.

References

Di Chiero, A. (2017). Vincenzo Tiberio precursore della scoperta della penicillina, Revista Glocale. *Rivista molisana di storia e scienze sociali, IX*(13), 243–258.

Echegaray, J. de. (1891). Examen de varios submarinos comparados con 'el Peral'. *Heraldo de Madrid* Collection of articles published by the press of José M. Ducazcal.

Echeverría, J. (2017). *El arte de innovar.* Plaza y Valdés editores.

List of Italian Inventions and Discoveries. Consulted on Wikipedia, on February 1, 2023.

Marchis, V. (2011). *150 (anni di) invenzioni italiane*. Editoria Codice.

Ministerio de Mariana, & Peral, I. (1890, November 13). *Gaceta de Madrid* n° 317, 509–510.

Pantelegraph, Pantelégrafo and Pantelegrafo. Consulted on Wikipedia in English, Spanish and Italian on February 5, 2023.

Peral, I. (1891). Manifiesto de Isaac Peral. *El Matute*, Número extraordinario, Madrid, 21 febrero de 1891. Consulted on the Archivo Histórico Nacional, Portal de Archivos Españoles (PARES). http://pares.mcu.es/ParesBusquedas20/catalogo/description/7278645

Pérez, D. (1935). *Isaac Peral y la tragedia del submarino*. Ediciones Nuestra Raza.

Pezzi, G. (1946). Un italiano precursore degli studi sulla penicillina. *Annali di medicina navale e coloniale, LI*(3), 251–266.

RTVE Play, Pasajes de la Historia, episode with the title: "Que inventen ellos".

Saiz González, J. P. (1999). Invención, patentes y tecnología en la España de la Restauración. La cultura española en la Restauración (I Encuentro de Historia de la Restauración). Sociedad Menéndez Pelayo, 329–348.

PART IV

Conclusion

CHAPTER 14

Conclusion

Estrella Trincado Aznar and Fernando López Castellano

In this volume, a link has been established between Science, technology, and innovation in the history of economic thought. Innovation depends on our flexibility to change. And change is law of nature, but institutions also give us safe harbour. They address to a common reality and give sense to the common world, which allows ourselves to be carried away by the flow.

The book begins with an opening chapter where Thomas Baumert studies the etymology of the word innovation. The word was originally used with a negative connotation of subversive change, and it was not until after Shakespeare's death that the term started to be used in a positive sense. Baumert questions the point that innovation is systematic. By definition, and based on classical economists, it is much more

E. Trincado Aznar (✉)
Department of Applied Economics, Structure and History, Complutense University of Madrid, Madrid, Spain
e-mail: etrincad@ucm.es

F. López Castellano
Department of Applied Economics, University of Granada, Granada, Spain
e-mail: flopezc@ugr.es

E. Trincado Aznar, F. López Castellano (eds.), *Science, Technology and Innovation in the History of Economic Thought*, Palgrave Studies in the History of Economic Thought,
https://doi.org/10.1007/978-3-031-40139-8_14

spontaneous, unpredictable and, hence, non-systematic than is usually considered. A survey done has shown that 72% of the ideas that led to an innovation came from workers not dedicated to R&D; 20% from people (non-scientists) outside the firm; and only 8% of the ideas were due to formal researchers.

In Chap. 3, we trace the emergence of the concept of innovation into the Scottish Enlightenment. Then, a Darwinian evolutionary concept of innovation was available, based on competition between species. According to Hume, capitalism makes human psychology evolve into a love of profit. Innovation goes hand in hand with the concept of the rate of interest, as credit transfers the possibilities and capacities of action from the accumulators by abstinence to the creators and transformers of reality. However, the personality of those two characters is different; in some way, they are even opposite. Besides, love of profit leads to private and public debt; the excess of public debt will lead to the collapse of civilization. Then, a wise magistrate should only introduce gentle innovations within the old constitution and its pillars so that learning through trial and error occurs naturally. Adam Smith, however, introduced another concept of innovation. For Smith, people are led permanently by a universal, continual, and uninterrupted effort to better their own condition. Division of labour makes workers try to imagine how they could save their own labour using a mechanical device. Smith introduced the problem of knowledge and learning abilities for the development of technology, fundamental pillars of the current concept of innovation. For Smith, the only means of promoting inventions is by creating an intellectual property right for a reasonable time, without which they would be discouraged. Adam Smith's vision is present in recent studies such as those by Collier, Mazzucato and Mayer, for whom the generation of innovations is a collective process, which probably must be reflected in payment and governance. However, according to Smith, non-payment of loans can create resentment and serfdom, which makes it advisable to set maximum legal interest rate. This is a non-individualistic understanding of innovation, also posed by John Rae. However, Rae had in a much broader concept than Adam Smith, as innovation implies for him the expansion of capacities, an idea that has entered into recent developments of the Institutional Political Economy. Institutional innovation rejects the concept of equilibrium in favour of that of the process. It shows that the market and the state are nothing more than different sides of the same coin, where limitations and skills are intertwined, contrasting Robbins' idea of scarcity. Rae tried to put together

a knowledge-based theory of growth, that is, an endogenous growth model. Invention arises from science and necessity. He proposed a multi-ethnic environment similar to the global village as some type of inequality seems to be necessary to drive the desire to change: it could be the desire of profit within competition, it could be the cultural difference which make us find a reason to seek brotherhood with the otherness, or it could be the simple Smithian predisposition to persuade the others, which implies some knowledge bias between different people. A last concept of innovation which emerged in the late eighteenth century was the utilitarian one, defended by Jeremy Bentham. He promoted the encouragement of entrepreneurs who operate in new production and distribution areas, with high risk. Although uncertainty may increase, society as a whole remains intact because others will try to avoid making the same mistakes and innovations will expand throughout the economic system, whatever the fate of their original promoters.

All these concepts of innovation evolve within the historical and institutional paradigm into a quasi-random evolutionism. American institutionalism is an appealing paradigm to give sense to the relationship between science, technology and innovation. Industry is a progressive force; but businessmen may be an institution inhibitory of change. The former depends on science, instinct of workmanship and idle curiosity, on the pursuing of knowledge for its own sake. The second are moved by emulation and self-preservation. Veblen criticizes the relationship between entrepreneurs and the government, which protected their interests at the expense of the public. Schumpeter, actually, put into place all these factors of innovation as an engine driving economic development and is for him the main cause of cyclical fluctuations. In the early 1980s, Nelson and Winter vindicated Schumpeterian thought and explained competition within an innovative environment as a change in routines through the integration of incremental innovations. This evolutionary and essentially qualitative approach places a lot of weight on institutions. Developmental neo-institutionalism goes further, even stressing, as McCloskey does, that innovation is the essential character of the Industrial Revolution; not capitalism, but Innovism, which was a long-standing phenomenon. This implies not only accumulation of ideas but also letting these ideas flow, thus freeing the mind from them. Mind is outside the flow. In this sense, Institutionalist Political Economy (IPE) is stressed in the chapter, as it suggests a more systematic and general explanation of institutional change. Institutions are more than restrictions; they are "constitutive", because

they inculcate certain values. They are "enabling" instruments. Innovation is a fundamental element of economic development that implies certain routines, capabilities and replication, permanently raising the living standards of an increasing number of people over time.

In Chap. 4, Pablo José Martinez Rojo goes from Scottish Enlightenment to the seminal ideas of Friedrich List on National Innovation Systems. List stressed the need for a coordinated effort between the state, the private sector, and the academia. National Innovation System, more than a concept, has become a research method that helps to explain the degree of development and the state of national production systems, their history, and evolution. National innovation systems are interconnected institutions to create, store, and transfer the knowledge, skills, and artefacts which define new technologies. This chapter makes an original contribution by studying Charles Babbage's (1791–1871) and Johann Heinrich Von Thünen's (1783–1850) theories of innovation, the first linking the production system and education to R&D system, the second as a pioneer of localization economics, key to the very concept of the National Innovation System.

List emphasized the importance of the development of national institutions that favour the accumulation of what he called Mental Capital. The state has a key role to play in creating an environment that encourages innovation by providing funding for research and development, protecting intellectual property rights, and promoting the diffusion of new technologies and ideas. Industry is an autonomous productive power that allows the continuous improvement of labour and capital, something that delves into the importance of time and space. Charles Babbage, however, stressed the potential negative effects of manufacturing and the need for social and economic policies to address these issues. He invented the so-called Analytical Engine, a precedent of modern computing. This was an innovative failure, as the technical pretension was more advanced than the available means of the time to make it possible. Babbage then began to understand the importance of institutions that facilitate the application of inventions, along with production and marketing. Innovation is not the result of individual genius or inspiration, but rather the product of a collaborative process involving a network of people, organizations, and institutions. Johann Heinrich von Thünen, in addition to defining the first aspects of the economy of location, is also primary reference in the definition of the figure of the entrepreneur, much later adopted by Knight and Schumpeter. His ideas have been revived and even reinvented by the

so-called new economic geographers, particularly Paul Krugman and Porter's cluster approach. He elaborated a theory on the mechanics of industrial agglomeration and the formation of urban centres. The theoretical foundations of the importance of this spatial framework and the existence of externalities were also postulated by neoclassical economists afterwards, such as Marshall, and later revisited by the literature on the new growth theory of Romer.

In Chap. 5, Baruc Jiménez Contreras deals with the transhumanist movement, an emergence of the cyborg culture that tries to transfer human consciousness into a machine as its goal. Transhumanism disregards the conditions of domination and inequality, and shares with postmodernity its specific common goals, such as the need for change, the acceptance of multiple "identities", and the opposition to a fixed and universal human nature. The ultimate goal of transhumanists is the separation between the human body and consciousness. The body is conceived as a degrading burden. Therefore, transhumanism represents a contemporary vision of utilitarian values in which Hume's advocacy of suicide obtains a new solution: abandoning the human bodily experience (life itself) through a set of technoscientific goods. Consequently, all human needs are turned into commodities and the new organizational structure of mega-science may be made an instrument of global power.

In Chap. 6, Estrella Trincado and José María Vindel stress the importance of the "Jevons paradox" to address the limits of innovation. Even in the marginalist paradigm, scientific progress and resource efficiency is not a good path to the lesser use of resources. When cost of production declines due to resource efficiency, marginal utility of commodities that use the given resource declines, directly increasing the consumption of those commodities and indirectly increasing the consumption of other commodities with which they are exchanged. Then, we cannot discuss technology without also considering the economic behaviour of agents. Technical progress is the problem, not the solution. Thus, the importance of encouraging interdisciplinarity, as in the area of econophysics, or to go even further, making a deeper synthesis through transdisciplinarity.

Jevons, talking about a non-renewable energy resource, was beginning the debate on the limits to growth. The debate was elevated to a global scale with the Club of Rome in the 1960s and the publication of the famous Meadows report. The chapter stresses the contribution by Georgescu-Roegen. Along with the increase in population, exploitable materials tend to transform into materials in a dissipated state—not

exploitable. Thus, it implies ever more dispersion and increasing entropy, with a shortening of the number of years for which the current standards of living are sustainable. Even if it entirely consists of feasible recipes, a technology is not necessarily "viable", as a viable technology must have the same qualities as those of a living organism, which, in addition to performing certain specific activities, also maintains its material scaffold (its body) intact from one minute to the next.

In Chap. 7, Alfredo Macías Vázquez continues with the sociological view of Max Weber at the beginning of the twentieth century. Weber pointed out that research no longer had anything to do with the passionate dedication to solving a mystery, which required assuming that the universe had been created by God and that knowing nature meant knowing God better. Rationalization process that has dominated Western modernity gives rise to specialization in autonomous disciplines, but in a totally disenchanted and soulless world. Values in science form a subsystem that is in competition with other alternative subsystems. Calvinist asceticism, in its eagerness to separate itself from the world, unintentionally ended up giving rise to the economic system that has historically caused the largest transformation and exerted the largest control over the world. In parallel, this implied the end of the brilliant and charismatic authority, and the subordination of the individuals to bureaucratic organization, where the individuals found themselves trapped in an iron cage. For Weber, underneath the mechanistic structure, a minimum degree of freedom should be preserved in order to allow for passion to germinate and facilitate the giving of one's life to science, without everything being reduced to the rational consideration of the different options. Opposed to historicism, Marxism, and utilitarianism, the disenchantment of the world can only be surpassed through values which represent a return to ancient polytheism. But the problem does not lie exclusively in the need to liberate science from the values of other institutional subsystems, but in the fact that scientific activity no longer has any transcendental implications. Weber repeatedly warned of the danger of future societies being exclusively dominated by technology.

In Chap. 8, Manuel Santos Redondo reviews what happened to make the last quarter of the twentieth century the "Era of Schumpeter". North American competition coming from Japan and East Asia led to the importance of technological innovation. In the *Methodenstreit*, Schumpeter took sides with the "abstract" school of political economy—the so-called Austrian school of political economy—but he tried to reconcile both the

abstract and the historical, not without difficulty. He went from considering in 1911 the entrepreneur as a kind of superior man to talking about the entrepreneur as a function, which can be performed by those embedded in another economic function and even by groups, corporations, or countries. However, social mobility based on aptitude is doomed, because with the routinization of innovation by corporations, there will be no room for such a large reward for entrepreneurial aptitude. Santos goes then to examine the relationship between Schumpeter and the "Austrian" school of economics and also with Ordoliberalism.

In Chap. 9, Antonio García Sánchez, Luis Palma Martos, and Ignacio Martínez Fernández show that, in the marginalist-neoclassical approach, the attention paid to innovation was scarce as it was attributed to a "residual" factor. The response to the neoclassical growth model at the end of the twentieth century came from its treatment of two increasingly relevant variables, human capital and technology. In the "Cambridge Controversies" on capital, "reswitching" broke the monotonous relationship between interest rates and factor intensity in production techniques. If we analyse the Schumpeterian model of innovation in terms of a disruption with respect to the stationary state, innovation model could be identified with the technological gap. Incorporating technology as an endogenous element of production, and demand-pull innovation, makes the picture more complete. Theory of Endogenous Growth considers technological progress as an indirect effect of economic activity; and increasing returns in knowledge and technology drive the growth process, including innovative capacities, absorptive capacities, and social capacities. The main controversy within this neoclassical approach was related to the distinction between financial capital and technical-productive capital; besides the incorporated nature of technology in the replacement of technical-productive capital and the effects of the interest rate on the choice of heterogeneous techniques with different capital intensity. Despite this, the residual component was still around 35% of growth.

In Chap. 10, Ramiro E. Álvarez and Jose A. Pérez-Montiel discuss income (and wealth) distribution that has attracted so much attention from 2014 after the publication of the works by Thomas Piketty. However, they do it, not as Piketty who contrasts predictions and empirical observation, but in terms of the formal logical consistency of the conventional economic approach. They consider that the phenomena of *re-switching* and *reverse capital deepening* was *anomaly* in a Kuhnean sense that could not easily be assimilated into the conventional approach of neoclassical

normal research. Neoclassical theory makes a generalization of the Malthusian theory of rent to the remuneration of other productive factors, such as capital goods, or the Böhm-Bawerk measure of capital as an "average production period". Then, it is incompatible with the principle of profit maximization on which free competition is based. Wicksell thus suggested treating physically heterogeneous capital goods as a factor expressed in value terms, being as homogeneous as land or labour; but Robinson criticized the notion of "capital" as a factor of production, as well as the continuous nature of technology. Neoclassical expression of "capital" is dependent upon prices that depend upon the rate of profit or interest (an unknown variable to be determined by the theory). The work of Piero Sraffa discovered the *re-switching* and Pasinetti and Garegnani pointed out that there is no univocal relationship between changes in distribution and changes in the "factor intensity" of the different production techniques. In short, distribution cannot be explained through factor supply and demand curves because the different production techniques that form those curves depend on distribution.

In Chap. 11, Elena Gallego explores the main debates on technological unemployment along time. Having as a starting point David Ricardo's reference of technological unemployment in the third edition of *Principles of Political Economy and Taxation* of 1821, successive models have introduced different assumptions. The debate of the classical economics with current authors allows us to expand the possible future scenarios and search for alternative solutions. The orthodox solution solves the problem using market incentives and assuming price and wage flexibility; however, debates on technological unemployment in the twenty-first century consider that measures can be taken from both private and public sectors, such as cutting working hours, digital training, or universal basic income as a macroeconomic objective.

In Chap. 12, Javier Arribas Cámara talks about innovation that allows us to meet basic human needs rather than encouraging over-consumption and waste. In particular, digitalization is an ally of sustainability in several ways. Firstly, insofar as it helps to dematerialize and decarbonize the economy, encouraging a shift from products to services. Digitalization is also a critical factor in innovation, especially if promoted through cooperative mechanisms such as collective intelligence. Although digitalization also has CO2 emissions, some studies point to an inverted U-shaped relationship between digitization and CO2 emissions per capita. Once the threshold is reached, it can lead to a reduction in per capita emissions of up to 10% in fully digitized economies. To reduce the carbon footprint and

energy consumption, data centres in space seem a good alternative and can help achieve global sustainability and accelerate decarbonization in ten years.

In Chap. 13, Juan Francisco Galán shows that lack of innovation is not the same as a lack of invention. Innovation depends on understanding and on institutional embedding, so it cannot be systematized. Converting invention into innovation, that is, into economic development, is not an easy task. This is evident in Mediterranean countries, such as Spain and Italy. Study cases of different inventions, such as Vicenzo Tiberio invention of antibiotics, Giovanni Caselli invention of the pantelegraph, or Alessandro Cruto invention of the incandescent light bulb, show that inventions are finally abandoned for several reasons. And an important reason for abandonment of them is the misunderstanding and ignorance of the concept of innovation. In this sense, although adaptive conclusions (trial and error methods) could have been drawn from the fact that innovation is not easy to systematize, something that could be detrimental to the need for theory of innovation, this theory and its diffusion is found to be pivotal. The case of the submarine invented by Isaac Peral in Spain demonstrates the importance of understanding and making people understand the concept of innovation. Thus, the Spanish liberal legal system favoured industrial property through the Spanish Patent Law of 1878, but it did not allow a true innovation to be put into practice because it was met with a not rigorous Council, contemptuous of novelty. As Peral himself said, the problem was that "They had left the judgment to those who do not know or understand anything about the topic". Thus, the importance of understanding the concept of innovation, as this volume has tried to do looking at the different theories of economic thought.

Index[1]

[1] Note: Page numbers followed by 'n' refer to notes.

E. Trincado Aznar, F. López Castellano (eds.), *Science, Technology and Innovation in the History of Economic Thought*, Palgrave Studies in the History of Economic Thought,
https://doi.org/10.1007/978-3-031-40139-8