# Transformation of Economic Systems: The Bio-Economy Case

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**Abstract** To improve sustainability, the global economic system has to undergo severe transformation processes. This chapter deals with the possibility of an innovation-triggered transformation towards a knowledge-based bioeconomy, which is supposed to overcome the current lock-in into a fossil fuel-based $CO_2$-intensive production. To do this, a Neo-Schumpeterian view is applied that highlights the complex interplay in knowledge-generation and -diffusion processes between firms, consumers and government institutions. By applying the Neo-Schumpeterian approach it becomes obvious that innovation and economic growth are part of the solution and not part of the sustainability problem. The shift from quantitative growth—prevailing in textbook economics—to qualitative development—prevailing in Neo-Schumpeterian economics—makes the difference and affects all agents and institutions in an economic system, which needs to be designed as a *dedicated innovation system* supporting the transformation towards a knowledge-based bioeconomy.

## 1 Introduction

After more than 200 years of industrial production, large parts of the world population are richer than ever before. Simultaneously, past industrial production is closely linked with the exploitation of natural resources and the strong accumulation of environmentally harmful greenhouse gases, thereby endangering human survival. It is evident that things cannot continue as before. But how can future development be shaped without threatening our natural basis of life and contributing to a high and increased level of welfare at the same time? At the beginning of the twenty-first century, many economies all around the world place big hope in the so-called *knowledge-based bioeconomy*. Is this a possible way out? Can economic growth and development, widely the cause of the problem, also become part of the solution? The following contribution discusses the possibility of transforming the global

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production system towards a knowledge-based bio-economy from the perspective of modern innovation economics.

Almost all economists agree that technological development substantially triggers quantitative growth in income per head. However, there is less consensus with respect to the qualitative characteristics of economic development: whereas mainstream-oriented parts of economics—often summarized under the heading neoclassical economics—focuses only on quantitative aspects and thus shows a short-term orientation, Neo-Schumpeterian economics focuses on qualitative aspects and thus on a change of fundamental economic structures over longer periods.

Generally, change can be either of an incremental type in terms of small improvements along well-known trajectories, or it can be more fundamental, leading to structural changes like the emergence of new and the disappearance of old industries. To simplify, we assume that incremental technological changes are based on existing technological solutions, whereas radical technological changes question major existing production processes. They might lead to massive changes of the global production system in the sense of "creative destruction" (Schumpeter 1943).

This chapter deals with a fundamental transformation of production systems: overcoming the lock-in situation of present production systems towards fossil fuels (Unruh 2000) and establishing a knowledge-based bio-economy at the same time (Pyka 2017; Pyka and Buchmann 2016). Without doubt this transformation process is radical, qualitative, and effective in the long-run only and it has to be considered under the Neo-Schumpeterian approach to innovation economics. It was already in his work *Business Cycles,* published in 1939, when Schumpeter revitalized *Kondratieff's Theory of long waves* in order to explain this process as a *regular process* in long-term economic development. His illustration of this change, which is characterized by its discontinuous nature, is famous: "*Add successively as many mail coaches as you please, you will never get a railway thereby*" (Schumpeter 1934, p. 64). Industrialization around the year 1800 represented the first long wave and was fueled by the steam engine and by cotton processing. Then, starting around the year 1850, the widespread availability of steel and the diffusion of railways constituted the second long wave that was again, at the beginning of the twentieth century, replaced by electrical technology and the chemical industry. In the middle of the previous century, the third long wave gained momentum by mass production and the automobile as well as the petrochemical industries. Thus, manufacturing activities focused on oil as a second fossil fuel apart from coal. Since the 1980s, one refers to the fifth long wave, which is reflected in the fast and ubiquitous diffusion and application of information and communication technology solutions.

Now, at the beginning of the twenty-first century, another paradigmatic change is in the air, being characterized, however, by one major difference to previous revolutions: whereas previous cycles were driven by technological bottlenecks and their overcoming, humans in the twenty-first century face the vital question of how to restore environmental sustainability of economic activities. The k*nowledge-based bio-economy* plays a key-role in this transformation process which, of course, like previous radical changes is characterized by fundamental uncertainty (Knight 1921).

Today, literature provides many alternative terms for the massive change shaking global production systems: Freeman (1991) and Dosi (1982) call them *techno-economic paradigm changes*, Sahal (1985) uses cartographic analogies and refers to *technological guideposts* that are pointing to *technological avenues*. All authors highlight the confrontation with profound changes economic systems are faced with over longer periods of time which question all established production approaches. Not a single technology is responsible for this phenomenon, but several complementary developments that include, apart from a package of mutually dependent technologies (e.g., combustion engine, petro chemistry, assembly line production), numerous infrastructural developments (e.g., road structure, filling station network), behavioral changes (e.g., suburbs and commuter flow, shopping malls outside the city centers) as well as institutional changes (e.g., spatial planning and commuter allowance, etc.). The old paradigm will not be replaced by the new one until all these elements interact.

The Neo-Schumpeterian approach provides us with crucial hints on the process of the forthcoming change. For this purpose, we introduce in the second section to the economic discussion of transformation processes and shortly outline the consideration of growth-pessimistic approaches that enjoy great popularity, such as *post-growth* or *de-growth* approaches. These are contrasted with the growth-optimistic approaches that cherish Schumpeter's intellectual heritage and rely on the creative forces of capitalistic economic systems to overcome the fundamental problems of the human society. Innovations are supported by the discovery and successful spread of new knowledge. Therefore, knowledge-based economies organize *innovation systems* composed of different actors which establish a creative environment for mutual learning and knowledge creation. That is what the third section of this chapter is about. No innovation would have ever been established if it had not attracted consumers' interest and if it had not been leveraged by their purchasing power. We will focus on these questions in section four. Knowledge-based societies consider new concepts in the sense of 'responsible innovation' that are decisive in bringing an entire economy on a new sustainable trajectory shaping growth and development. Section five deals with the massive economic impacts originating from these technological and knowledge-driven changes. It requires, besides technological change, also institutional change in a co-evolutionary fashion, if new sustainable technologies are to achieve the aspired transformation of the economic system.

## 2 Limits to Growth

The sustainability of a capitalistic organization of production, as it has been set up in western industrialized economies since the beginning of the industrial revolution at the end of the eighteenth century, has been questioned at the latest since 1972 when "The Limits to Growth" was published by the *Club of Rome* (Meadows et al. 1972). Since then, two fundamentally different solution strategies are being discussed within society: *conservation of resources by the abstinence from growth* on the one hand or *decoupling of growth and resource exploitation* on the other hand. The supporters of the first approach (Blewitt and Cunningham 2014; Kallis et al. 2014), summarized under the headings of "abstinence" and "downscaling", claim a renunciation of a way of life that is based on consumption and increasing deployment of resources. According to these approaches, market-oriented economic systems are not believed to manage endogenously a change towards sustainability. There are considerations that even call for a return to small-scale regional agriculture or subsistence economies, respectively. This is considered the only way to enable a sustainable and resource-friendly lifestyle and form of economic activity. To summarize, it is easy to see that these approaches are based on the neo-classical line of thought with the underlying assumption of stable economic structures and an understanding of economic growth as a sheer quantitative process.

The second approach, instead, is strongly characterized by the observation that innovations, market forces, structural change, and urban ways of life are both, part of the problem and part of the solution to the sustainability problem. This second approach is assigned to the Neo-Schumpeterian perspective with its qualitative perspective on economic development. Innovation-triggered development is characterized by both, a quantitative, i.e., income-increasing dimension and a qualitative, i.e., structure-changing dimension. In particular, at the end of the twentieth century and at the beginning of the twenty-first century, capitalist-oriented economies have demonstrated impressively their global power of change: in a short time more people are brought out of poverty (one of the 17 objectives of the UN's agenda 2030) by creative entrepreneurship in free markets than before by 50 years of development policies. Obviously, these developments have aggravated the resource problem and pollution to some extent; however, higher income economies move along the environmental Kuznets curve and organize cleaner production (Fagerberg et al. 2015). New creative solutions are able to reform our future economy in the sense of sustainability, thereby supporting the achievements of the UN's objectives towards a sustainable development and ensuring growth and development at the same time (Mazzucato and Perez 2015).

The leading idea of a knowledge-based economy is based on the notion that abstinence in the sense of economic down-scaling is neither the first nor the only solution. In principle, the opinion is shared—which includes both demand side and participatory elements—that, in accordance with the supporters of the first method, certain past patterns of production and consumption require urgent adjustments. Especially concepts resulting in a more intensive use of goods and therefore contributing to the economization of resources ('*sharing-economy*') are important. The same applies for closed-loop material cycles, recycling systems, and intelligent waste treatment. These concepts are perfectly applicable to triggering learning and behavioral changes on the demand side. However, the core idea consists of *supplying and demanding* new technological solutions within a comprehensive economic transformation process (Geels 2002), i.e., different goods and services are produced and demanded in different ways, which are characterized by sustainability. Realizing the technological possibilities of the bio-economy not only creates new investment opportunities but is also the prerequisite for a necessary socio-economic and cultural change. The consumers' acceptance of bio-based products and their demand are a conditio sine qua non for a successful change. Consequently, innovations, functioning markets, and changed consumer attitudes are complementing conditions for the creation of a sustainable production system.

Supporters of the Neo-Schumpeterian school (Dosi et al. 1988; Lundvall 1992, 1998; Nelson 1993) emphasize the systemic character of innovation processes in knowledge-intensive economic sectors. So-called innovation systems consist of different actors (companies, research institutions, political actors, consumers, etc.) and linkages between these actors (flows of goods, R&D cooperation, knowledge transfer relationships, user-producer-relationships, etc.). These linkages are required to ensure mutual learning and common knowledge development to solve complex innovation challenges. Such systems are characterized by their dynamic and co-evolutionary nature and are thus enormously complex, as both, actors and their knowledge and linkages and interactions between actors, may change over time.

Dosi (1982) takes this systemic conception as a starting point in defining technological paradigms as "[ . . . ] set of procedures, or a definition of the 'relevant' problems and of the specific knowledge related to their solution". Transferred to the knowledge-based bio-economy, the core idea is substitution, i.e., replacing carbon-based materials and energy with bio-based materials and energy. This can only be achieved by applying a variety of technological processes in the entire breadth and depth of the value-added chain. In this process the exploration of economic complementarities in terms of cross-fertilization of different knowledge fields matters. For example, to a large extent, digitalization allows for an extension of value chains by increasing the added value in new sustainable production sectors in a $CO_2$-neutral way (e.g., by electric mobility based on renewables, by development of smart grids, etc.). The concept of technological paradigms also illustrates that a paradigm shift is not possible at any time. A *window of opportunity* will only occasionally be opened and allow for a paradigm shift when several interconnected technologies are established and the creation of conducive demand-side and institutional conditions happens simultaneously. This, of course, holds for the emergence of a new bio-economic innovation system, too.

## 3 Innovation Systems and Knowledge

The theory of industrial life cycles, which emphasizes the strong dynamics in the emergence and decline of industries, gives a first hint on the meaning of the development of a dedicated innovation system supporting the transformation towards a knowledge-based bioeconomy. Typically, industrial development is divided into four stages: (i) a development phase (new knowledge creates prerequisites for innovation), (ii) an entrepreneurial and growth phase (many market entries of smaller innovative firms), (iii) a saturation phase and consolidation phase (formation of industrial standards, mergers and acquisitions as well as market exits), (iv) a downturn phase (oligopolistic competition in only less innovative industries) (Audretsch and Feldman 1996). Although the bio-economy does not represent a well-defined industrial sector, understanding the theory of industrial life cycles is of crucial importance to structure the transformation process towards the knowledge-based bio-economy. Without doubt, the bio-economy has to be characterized as cross-sectional. On the one hand, several new sectors will emerge, e.g., in the fields of bio-plastic, waste management, or bio-refineries. On the other hand, already existing sectors in the fields of vehicle construction, battery technology, pharmaceuticals, etc., will gain new momentum by the arrival of bio-economic approaches. Therefore, we argue that new sectors will emerge by establishing bio-economical technologies, and development dynamics of some already existing industries will receive new impetus at the same time. Adjustments of old and development of new institutions (e.g., in Germany the Renewable Energy Act, the Greenhouse Gas Emissions Trading Law, etc.), adjustments of consumer habits, and the emergence of new educational opportunities in terms of co-evolution will accompany these processes and establish the institutional, the industrial, and the consumer pillars of a dedicated innovation system.

The patterns and nature of new businesses in the Bioeconomy are thus strongly influenced by national institutions and organizations (Casper et al. 1999; Whitley 1999). Institutions are defined as 'a set of rules, formal or informal, that actors generally follow, whether for normative, cognitive, or material reasons'. 'Organizations are durable entities with formally recognized members, whose rules also contribute to the institutions of the political economy' (North 1990; Hall and Soskice 2001). In this interplay between organizations and institutions, the knowledge-base of an economy is created by the education and research system and represents one of the most important prerequisites for the transformation towards a bio-economical production system (Geels 2002). This automatically relates to a high level of uncertainty in particular concerning the required right future competences. In this complex process numerous individual knowledge fields are potentially relevant for the transformation and are already identified, e.g., synthetic chemistry, process engineering, genetic engineering, food technology, or informatics. It is decisive to understand the dynamics of these knowledge fields and the possibilities of their recombination with other knowledge fields and adequate actors in order to create an innovation system. In many cases, linkages of different knowledge fields ('*cross-fertilization*') are responsible for the emergence of extensive technological opportunities: for instance, a complete new industry, bioinformatics, has been initiated by the fusion of two so far unrelated knowledge fields: database technology and molecular biology. Consequently, because the link between different knowledge fields often implies true uncertainty, governmental innovation policies matter a lot. Knowledge about future potentials is essential for supporting research and innovation policies: the analysis of knowledge and network dynamics allows for the identification of development trajectories showing sectors requiring public attention and support concerning research and development in order to close existing knowledge gaps and build bridges between still unconnected knowledge domains (Burt 2004; Zaheer und Bell 2005).

## 4 Innovation in Knowledge-Based Societies

It has already been mentioned that also consumer knowledge plays an important role for the development and establishment of sustainable consumption patterns in a knowledge-based bio-economy (Geels 2002). Therefore, the analysis of the transformation process has to include the interaction of technological development, demand, and acceptance of innovative solutions as well as sociological variables. The latter include, e.g., education, age, income and gender. All are important explanatory factors determining attention and readiness to deal with bio-economic issues. A bio-economic innovation will only be successful when consumers accept it. The direction of the transformation process is, comparable to the importance of the policy realm, determined by consumers and their demand, i.e., an important question has to deal with consumers' openness to bio-economics and its products.

Finally, (real and virtual) social networks matter for the establishment of new consumption patterns. They can contribute significantly to a diffusion of consumers' behavioral patterns and values (Robertson et al. 1996; Valente 1996; Nyblom et al. 2003; Deffuant et al. 2005). Recent studies show that attitudes are substantial for the development of social relationships and that in turn, social relationships considerably influence behavior and attitudes. In the field of renewable energies, for example, the initiative of municipal utilities' customers has led in many cases to a 'green' orientation of regional power supply. In some cases, citizens' networks finally transformed to investment companies that are engaged in wind farms.

Critical issues are to be dealt with in democratic processes in order to be widely accepted. Not everything that is technically possible is also socially desirable. In the field of the bio-economy, this may, for instance, include the use of genetically modified organisms in agriculture. In fact, these organisms promise efficiency advantages with regard to the consumption of land and water etc., but their long-term health and environmental risks cannot be completely (as with any new technology) anticipated. Accordingly, technological developments require consumers' acceptance and attitude and thus depend on the level of education in an economy. This raises the question of a society's openness towards innovations that are fundamentally associated with uncertainty. The concept of *Responsible Innovation* summarizes the future-oriented organization of development and is currently discussed with a high priority by European policy makers and institutions. A comprehensive working definition has been developed by von Schomberg (2011). He describes responsible innovation as "a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society)." This means that innovations are not exclusively evaluated by their economic efficiency, but different aspects (e.g., consumer protection or ecological aspects) also matter and are to be evaluated. Discussions on fossil fuels ('fuel vs. food') show that both, a pure economic and a one-dimensional ethical perspective is not sufficient. The quality of these discussions depends on the discussants' mutual understanding which in turn depends on the participants' level of knowledge.

Modern plant breeding and production of seeds are bio-economical fields of innovation in which issues of responsibility are frequently and controversially discussed. German consumers are skeptical about interference with the genome of food crops, but individual points of criticism remain unclear. New breeding techniques introduced, e.g., *Genome Editing,* enable scientists to selectively modify DNA strands of crop plants. These techniques are considered innovative as they may allow breeding of potentially efficient plants in fast and cheap ways. Species developed in this way hardly differ from those of conventional breeding. The Central Advisory Committee for Biological Safety does not classify these techniques as genetic engineering, especially because no new combinations of genetic material are made. As the Genetic Engineering Act does not explicitly address these techniques, legal clarification is still necessary as to whether these techniques are classified as genetic engineering at all. Dissemination potential and acceptance are influenced by this result. Here again, the necessity to include education and information policies becomes evident to support the transformation towards a knowledge-based bio-economy.

The concept of '*Social Innovation* '(e.g., Hanusch and Pyka 2013) emphasizes the importance of active citizenship in innovation. Thus, according to the understanding of the European Commission, this term includes innovations that are social, both in relation to their objective and their instruments. In particular, this includes innovations referring to the development and the application of new ideas (for products, services and models), covering at the same time social demand and creating new social relationships or collaborations. The whole society should benefit and contribute to generate new impetus for improvement. Social innovations can make a major contribution to rural development and promote economic resilience in these regions by strengthening cooperative behavior. Rural cooperatives (e.g., regional producer and marketing associations, winegrowers' cooperatives, tourism associations etc.) can help to develop regional competitiveness considering ecological and social aspects. As a consequence, within the framework of a bio-economy, rural regions that are notably affected by the already imminent demographic change and subsequent depopulation receive new opportunities for economic development.

## 5 The Economics of Change

The sections above illustrate that a transformation of the prevailing economic system towards a bio-based economy is an extremely complex process. Various different actors participating in different roles are contributing different pieces of knowledge. In this process, innovative adjustments in already existing industries as well as the emergence of new and the disappearance of mature industries can be observed simultaneously. In addition to the substitutive relations of new bio-based industries to traditional oil-based industries, there are numerous essential complementary relations giving further momentum for the transformation process. First and foremost there are the possibilities and application fields of digitalization. Digitalization allows to replace many oil-based products and energy-intensive services simply by bits and bytes. Simultaneously, digitalization offers a wide range of opportunities by coordinating decentralized and very detailed bio-economical technologies and processes such as energy production and distribution. This affects the composition of individual sectors where a coexistence of large diversified companies and small high-specialized technology companies is a likely solution. Finally, digitalization also offers consumer platforms to efficiently organize 'sharing economy'-approaches. Finally, successful knowledge generation and diffusion of relevant bio-economic knowledge depends on dynamic innovation networks (Pyka 2002) in which different actors jointly share and create new knowledge. The consumers, represented, for example, by consumer associations or politics, will play a key role in these innovation networks and will help to establish networks in early stages of technology development.

In a knowledge-based bio-economy, investments and economic growth still represent a crucial element for employment, international competitiveness and income generation. The bio-economy can make important contributions to accelerate investments by providing new investment opportunities generated fundamental innovations and thereby bringing currently available large quantities of liquidity to a productive use. This, in turn, accelerates the technological paradigm shift (Perez 2010).

The time path of the transformation process represents another critical component and has been explored only partially so far. On the one hand, it is high time to reduce carbon-based production methods. On the other hand, there will be frictions in the transformation process being caused for example by a lack of specialists and required competences. In this context, the so-called *sailing ship effects* (Howells 2002), frequently observed with radical innovations, could be made good use of. In the middle of the nineteenth century, when the existence of the established sailing ship technology was threatened by the arrival of new steam ships, shipbuilders—not having changed their technologies for many decades, if not centuries—began to innovate again. Due to the threat of innovative technologies, adjustment reactions in predecessor technologies can be observed with the aim to prevent the ancient technologies to be quickly replaced. Such adjustment reactions are, for example, fuel-efficient combustion engines and hybrid technologies as a reaction to the emergence of electric vehicles. These adjustments are advantageous since they pursue the same environmental objectives (e.g., inner-city fine dust and noise reduction, etc.) and thus provide more time to develop new technologies. Accordingly, the transformation process will for longer periods of time feature a co-existence of traditional and bio-based industries. Furthermore, it will be important to concurrently steer the relevant innovation processes in traditional technologies. This co-existence further increases complexity. At the same time, innovation policy is given room for maneuver and yet insufficiently developed technologies are prevented from being introduced prematurely which might cause promising approaches to fail.

Distributional effects of the transformation process are important for social acceptance. A bio-based economy on an industrial scale will largely represent a knowledge-based economy. Consequently, additional demand for high-skilled workers arises whereas opportunities for low-skilled workers decrease. This means a potential loss of jobs for less skilled workers in traditional industrial production. But apart from that, there will be demand for different goods and services whose compensation potential with regard to added value and employment is still unclear, though. Moreover, it remains open to what extent companies are prepared for this transformation into the bio-economy. Transformation processes will lead to a devaluation of competences so far responsible for economic success. How do established companies deal with the so-called ‘not-invented-here-syndrome’, overcome operational blindness and shape transformation processes actively in order to obtain added value at their established locations?

From this follows that distributional effects have an important regional dimension: does the bio-economy strengthen divergence processes between regions or does it help to achieve more convergence? The approach of creating networks in the sense of the so-called ‘smart specialization principle’ (Foray et al. 2009) connecting regional strengths along value-added chains in the best possible way, is promising but only sparsely implemented so far. Thus, in general, polarization tendencies leading to economic as well as political and cultural concentration of power and resulting in strong center-periphery structures can be avoided. But it still remains unclear, how strong and operational meaningful politically induced networks are in comparison to self-organized networks and how policy might exert influence. First findings indicate signs of a potential disintegration of the networks when political support is withdrawn (Green et al. 2013).

Transformation towards a knowledge-based bio-economic production system is supposed to terminate the existing negative relations between economic growth and environmental pollution, use of resources, climate change and energy consumption, and to promote a sustainable economy. The following questions are closely linked to the basic uncertainty of innovation and cannot be answered ex ante: ‘which contributions are to be made by individual sectors?’, ‘what complex feedbacks for national and international competitiveness are to be expected?’ and ‘do so-called rebound effects possibly reduce or even overcompensate the positive effects of the transformation?’ Institutional rules, such as a self-commitment of oil-producing countries to reduce their outputs due to the declining demand caused by bio-economics, are a way to reduce these uncertainties, at least partly. It remains necessary for all actors, companies, households and policy makers to refrain from optimization approaches and profit maximization in this transformation process. The complexity and uncertainty of this process requires the awareness of all actors to experimental behavior (‘*trial-and-error*’) which always also includes the possibility of failure.

## 6 Conclusions

Socio-economic systems have been exposed to permanent transformation processes since the industrial revolution. While development processes so far have been driven 'only' by result-oriented innovation processes, the character of the bio-economic transformation process is clearly concretized by society and politics. In the past, mainly bottlenecks caused by scientific-technological restrictions were overcome by vast technological revolutions, shifting the socio-economic system on new trajectories without giving direct instructions to the direction of the development process. At the beginning of the twenty-first century, however, the massive accumulation of greenhouse gases in the atmosphere since the beginning of the industrial revolution and the vulnerability of our present ecosystems reveal that global thresholds are almost surpassed. Thus, the level of freedom for future developments is restricted in order not to irreversibly damage natural conditions for human life and biodiversity. It is yet unclear whether this transformation process succeeds in the desired way and how it can be governed by political influence to achieve existential objectives of the global human society.

New technological developments alone are not enough to transform the socio-economic system. In a first step, they only create the necessary potential for radical changes affecting the economy as a whole. Converging trajectories and synergies that may finally introduce the paradigm shift necessarily require a broad social consensus on a specific use of these technologies. This means an initiation of a direction of development which connects investment decisions, innovations, and the tackling of basic uncertainty by politics (Pérez 2013). The 'green growth paradigm' based on bio-based technologies can be such a direction bringing together the potential of different technological developments and exploring their full potential. This requires political decisions supporting a new-orientation of research and innovation activities, exploitation of new energy sources, improvements in productivity of natural resources and new sustainable ways of living and producing (Pérez 2013). Moreover, in such a transformation process catching-up economies have to be provided with new opportunities for economic development without overstretching global natural resources and environment. Thus, a political and social direction is essential for a successful transformation process (Mazzucato and Perez 2015).

Examples include the development of new products within emerging bio-economic innovation systems. In this perspective, innovations require an interplay of actors along value added chains which might lead to the development of new industries. In the past, for example, the provision of cheap electricity led to the spread of fridges and freezers in private households which brought innovations in the fields of frozen food and packaging. Similarly, the creation of a '*Sharing Economy*' may lead to new digital coordination platforms and the creation of sustainable designs by product manufacturers in the bio-economy. *Planned obsolescence*, a phenomenon wasting resources and shortening product life cycles, would be eliminated this way and new sectors, for example, in the field of repair and maintenance services are initiated. Important determinants shaping long-term development are networks and clusters. They help to reduce uncertainty and support self-reinforcing effects. Furthermore, social changes and changing lifestyles are both, an expression and a driver of this transformation process (Mazzucato and Perez 2015).

Therefore, the role of governments is not only restricted to the correction of market failures. In fact, by ensuring investment safety and reducing risks and uncertainty, government instruments prepare the emergence and flourishing of new markets (Mowery et al. 2010). A crucial task for policies in the realm of innovation and entrepreneurship is the transition from invention to innovation, i.e., the expansion of bio-economical activities in a market. Correspondingly, a growth path based on bio-economics is more than a mere replacement of crude oil by renewable resources or renewable energies. It rather needs a *dedicated innovation system* creating synergies, knowledge transfer, and networks between manufacturers, suppliers, and consumers. It requires a comprehensive reorganization that includes the entire economy and renews production and consumption patterns in their present forms, which were shaped by previous transformation process within the oil-based paradigm.

The technological potential of a bio-economy is a necessary but insufficient condition for this transformation process. It also requires democratic consensus on the broad development and wide application of this technological potential. This includes the exploration of new trajectories and the fusion of new and existing technological trajectories. Markets in which innovations are profitable do not arise on their own but rather need feedback loops between political decisions, corporate strategies, and consumer preferences.

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