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WHAT IS THE DIFFERENCE BETWEEN ECONOMIC GROWTH, ECONOMIC DEVELOPMENT AND ECONOMIC TRANSFORMATION? THE BIOECONOMY EXAMPLE

Abstract. *Qual è la differenza tra crescita economica, sviluppo economico e trasformazione economica? L'esempio della Bioeconomia.* Una migliore comprensione del rapporto tra innovazione e cambiamento climatico in economia è ostacolata dalle nozioni radicate di crescita economica. Anche la nozione più ampia di sviluppo economico si avvicina solo un po' alla radice del problema affrontando lo sviluppo qualitativo guidato dall'innovazione, ovvero il cambiamento strutturale sul versante industriale. Tuttavia, il superamento della crisi climatica richiede una ristrutturazione fondamentale dei sistemi economici, che da un lato non può prescindere dalla creatività di aziende e imprenditori, ma dall'altro implica anche l'attuazione di nuovi stili di vita sostenibili da parte dei consumatori. Attraverso l'interazione tra innovazione, imprenditorialità e nuovi stili di vita, si può attuare un circolo virtuoso che rende irreversibilmente più probabile un'organizzazione sostenibile delle attività economiche.

Keywords: Sustainability, paradigmatic change, complexity, tipping point.

JEL: A11, A12, O00, O44, Q55

1. Introduction

For more than 25 years, the question of restoring sustainability has been the major topic of worldwide social and political discussion (e.g. Kyoto Protocol from 1997). Despite huge other global crises, the attention to this issue is growing with the urgency of the problem, which is continuously emphasized by climate scientists (e.g. IPCC, 2023). Major changes in greenhouse gas reductions and resource intensity have not yet been observed; on the contrary, especially in the case of greenhouse gas emissions, there is even a trend towards further growth in recent years.

There is a widespread perception that the issue does not sufficiently lead to reactions from politics, economy and society, which is why nationally and globally active non-governmental organizations have made it their task to keep the prioritization of climate change present in the public consciousness through demonstrations and diverse actions to emphasize overall awareness. Preventing and combating man-made climate change plays the central role, in particular challenging the way we produce and consume. The attribute *man-made* or the imminent proclamation of the *Anthropocene* by the global geological association make it clear that the economy is held responsible for the problem and that therefore answers are expected from the world of business and, from an explanatory point of view, from economics. One thing is certain: The close correlation between economic growth and the accumulation of greenhouse gases in the atmosphere is undisputed.

Since innovation is also undisputed in economic research as a crucial driver of economic growth, approaches critical of growth and innovation have now formed (e.g., Kallis et

al., 2015, Raworth, 2017). Past innovations are undoubtedly largely responsible for the looming climate catastrophe. Nevertheless, the question remains whether an innovation-critical approach can be used to achieve effective and actionable change. The numerous new technology fields from the area of so-called *green innovation* suggest that innovations are not only the cause but also the supposed solution to the problem, at least they can play a very important role in the necessary achievement of sustainability goals. One of the most important new fields of technology, which we will use later for examples illustrating our reasoning, is represented by the *knowledge-based bioeconomy* (see, e.g., Dabbert et al. 2017), whose goal is to drastically reduce mineral oil in the economy by tapping new biological and thus renewable raw materials. The crucial question, which has yet to be answered, is how to successfully set up a corresponding innovation process in order to achieve a significant reduction in the future instead of a further deteriorating relationship between economic growth and greenhouse gas emissions.

What is economic research doing in the face of these major challenges? Obviously, not very much so far, and what little is being done much too slowly. Butler-Sloss and Beckmann (2021) have brought to light a devastating result in a large-scale bibliographic analysis of the most important economics journals. Between 2000 and 2019, a vanishingly small proportion of articles in the top 300 journals in the field deal with issues of climate change, ecology, biodiversity, etc. How can this be? Observations that climate change is man-made and the proclamation of the Anthropocene virtually demand that a scientific discipline that claims to be concerned with people's economic choices and their impacts take responsibility. Economics, of all disciplines, which should make a significant contribution to these issues, obviously so far refuses to do so to a large extent.

An important, and at first glance not obvious, reason for this, is that there is no thorough intellectual understanding of the terms economic growth, economic development and economic transformation and their role in the sustainability of economic activity. These terms are used almost synonymously in everyday life. This leads to confusion and to an incomplete or incorrect assessment of the facts.

Especially in the political and scientific debate, growth is still the central concept. Since the 1980s, economic growth has often been supplemented by the demand for economic development, a term that has so far been limited to the economies of the southern hemisphere. Recently, the term transformation has also appeared in the context of the sustainability debate.

These three concepts are linked almost arbitrarily, with innovations being given an important role: If the topic of transformation to sustainability is invoked in the scientific discussion, reference is made to necessary green innovations that will already bring about economic development and thus the necessary structural change. Or reference is made to the close correlation between innovation and economic growth, so that the problem of the lack of sustainability will solve itself if there is sufficient innovation-driven economic growth and a functioning price system. The conditions that must be met for an innovation process to achieve the sustainability goals, the feedbacks that are required in the economic system for this to happen and what a supposed reorganization of the economic system

should look like are not discussed further. We argue that this is precisely the difference between the concept of transformation in relation to growth and development, and that therefore the concept of transformation is the crucial concept to bring us further in the sustainability question.

There seems to be a repetition of a pattern that was already evident in the 1970s and which, from a scientific point of view, demonstrates a very regrettable tendency of the economic mainstream to become stagnant. Instead of approaching the new challenges with scientific curiosity and creativity, people cling to the old successes. The loss of explanatory power of demand-side economic theories that accompanied the two oil price crises in the 1970s led to a first loss of importance of economic sciences in the social perception, which initially could not provide answers to the changed world economy. This gap was filled without a scientific background by politicians such as Margaret Thatcher in the UK or Ronald Reagan in the USA with their turn to supply-side liberal economic policies, with undesirable environmental and social consequences that are sometimes still felt today. On the economic theory side, a response was not found until the 1980s with the development of a new economic theory based on the great economist Joseph A. Schumpeter, who already in the 1910s expressed his unease with the then emerging marginalist and equilibrium economic theory (Schumpeter, 1911).

The new supply-side Schumpeterian economic theory fully reflects on the theme of innovation and the economic development it spurs. In view of the worsening unemployment rates in almost all Western economies and the rapid rise of the (East-) Asian economies, topics such as combating unemployment or securing international competitiveness came to the fore. Technological innovations appeared here as a kind of panacea. Although the first warning voices regarding resource consumption and greenhouse gas emissions began to appear in the 1970s (Meadows et al. 1972), these voices remained largely unheard. Worldwide growth in per capita incomes resulting from the successes of innovation seemed to prove the Schumpeterian economists right. The fact that this growth was accompanied by a further enormous increase in resource consumption, by hitherto unimaginable greenhouse gas emissions and by a further deterioration in income distribution did not seem to bother them at first. The cardinal error of the economic mainstream, namely the one-sided focus on income growth, was thus repeated once again, this time by the original critics from the camp of Schumpeterian economists.

This is all the more regrettable because, since the 2000s at the latest, warnings of climate catastrophe have been growing louder and louder, and most of the world's economies have made a political commitment to meet emissions targets in order to contain the rise in global temperatures as far as possible. Implicit in this is a major research mandate for economics. This mandate is all the more urgent because climate scientists agree that with each delay in the fight against climate change, the economic costs will increase exponentially. However, policy practitioners are poorly equipped by their scientific advisors with recommendations related to, for example, corrections to the pricing system (e.g., carbon taxes) or the replacement of polluting technologies with supposedly environmentally friendly technologies (e.g., car powertrains). Real creative thinking through the actual problem,

which requires overcoming ingrained patterns of thinking that have been successful in the past, is not yet taking place.

At this point, one cannot help but once again accuse economics of a major omission. The discrepancy between the foregrounded research questions and the societal relevance of this research in the face of the urgency of the worsening climate crisis, grew by the end of the 2010s and ultimately led to the emergence of another, this time interdisciplinary new line of research - the so-called transformational sciences - in which economists, sociologists, political scientists, climate researchers and a few others jointly focus on the transformation process towards more sustainability (Wittmayer and Hölscher, 2017).

This article aims to bring greater clarity to the discussion of economic growth, economic development and economic transformation and to clearly identify the differences between the concepts. It turns out that economic growth is aimed exclusively at increasing per capita incomes and thus falls short for the analysis of the relevant issues. The concept of economic development, with its focus on innovation systems and qualitative innovation-driven structural change in national economies, is also inadequate, especially because the objectives for innovation systems are again based on income growth. In contrast, transformation is the desired radical socioeconomic change that becomes a self-reinforcing mechanism through the interaction of the supply and demand sides and irreversibly produces a sustainable organization of economic systems.

The article is structured as follows: In the following three sections, the concepts of growth, development and transformation are examined in terms of their explanatory power for achieving the objective of organizing a sustainable economic system. The subsequent section uses the example of the bioeconomy to demonstrate the explanatory power of the three concepts. The final section draws conclusions from this examination and offers an outlook.

2. Economic Growth

With his work on economic growth in the 1950s, Robert Solow set the starting point for modern economic growth research. To this day, growth theory centers on the long-term quantitative increase of per capita incomes in an economy, which is represented by a macroeconomic production function in the so-called *Solow growth model* (Solow, 1956). In this class of models, long-run growth is constrained by decreasing marginal productivities, leading Solow to introduce technological progress as an exogenous positive shock. The justification for this is found in his famous *growth accounting study* (Solow, 1957), in which he identifies the paramount importance of technical progress for economic growth as an unexplained residual, i.e. an exogenous factor.

Macroeconomic growth theory with its long-term perspective cannot make any statements on the innovation projects behind technical progress due to the aggregated nature of the approach and passes on the task of economic analysis of entrepreneurial and firm innovation processes to microeconomics or industrial economics. However, this not only entails a more precise perspective with regard to the choice of an optimal technology,

but also - practically unnoticed in the scientific discussion - a change with regard to the time perspective. The long-term view of growth theory implicitly becomes a short-term decision on profit-maximizing technology choice. Relative prices play a decisive role here for the selection of a cost-minimizing technology along a fully determined and continuous technology space (Stiglitz, 1987). In other words, it is a matter of the optimal use of production factors that can be substituted for each other at will; if the price of a production factor rises, it is substituted by other production factors that are now relatively cheaper (Kennedy, 1964). Innovation processes are thus degraded to a decision about the profit-maximizing factor input. The actual (process) innovation still takes place exogenously, with Solow's technology shock, which shifts the production function outward, translated into so-called unit isoquants, which shift toward the origin (Beckmann, 1955).

The failure to treat technological progress as an endogenous variable of the growth process is obviously a weakness of growth theory, which was not remedied until the 1980s. With Paul Romer's (1986) so-called *new growth theory*, long-term growth becomes possible without exogenous technology shocks. Knowledge spillovers are responsible for this, whereby the knowledge created in an entrepreneurial innovation process also benefits third parties, thereby overcoming the property of diminishing marginal returns. What remains open here, however, is the contradiction with microeconomic theory (Pyka et al. 2009), where knowledge spillovers are not regarded as positive feedbacks but as negative incentive-reducing effects. If knowledge spillovers are present, companies behave as free riders in the innovation process and the overall level of innovation in the economy remains suboptimal.

This brief description is intended to illustrate that economic growth is a very abstract concept that has the advantage of analyzing the long-term increases of per capita incomes in national economies. However, it is concerned exclusively with quantitative changes in per capita incomes. How these incomes are generated, what contribution different sectors make to them over time, or even what the nature of technological progress is in the long term, i.e. whether innovations give rise to new industries and old industries have to exit the markets, is not considered. Of course, the same applies to the consideration of sustainability, which explicitly plays no role. Solow (1996) himself wrote that sustainability "… has nothing necessarily to do with growth". This is the price to be paid for the quantitative consideration of the growth process, which, by and large, applies also to the so-called new growth theory.

Ultimately, it should be noted that mainstream growth theory, due to its quantitative orientation, has so far failed to take into account any structural change that may occur over longer periods of time. The theory is fundamentally structurally conservative, which has been intensively criticized at the latest after the two oil price crises. The economic world has left the equilibrium growth path of the postwar period and is now in more troubled waters. One effect from this period that continues to reverberate on economic structures today is the digitization that began with the introduction of the computer, which is greatly changing all industries and consumer behavior. Significantly, this is also referred to as the *Solow Paradox*, because Robert Solow (1987) himself elaborated, "You can see the

computer age everywhere but in the productivity statistics." Behind this is ultimately to be seen the desperate attempt to deny the significance of any kind of qualitative economic development and to continue to search for productivity-increasing effects, i.e. ultimately process innovations. The hopelessness of this endeavor has brought to mind, among a group of critical economists, Joseph Alois Schumpeter, who already at the beginning of the 20th century (Schumpeter 1911) took issue with the then newly emerging economic theory, since the focus was not on economic development but on a static equilibrium-based view.

3. Economic Development

The fundamental critique of traditional growth theory has given rise to new approaches to economic theory in various parts of the world that, in the spirit of Schumpeter, focus on the great power of qualitative economic developments brought about by innovations. Foremost among these are Richard Nelson and Sidney Winter (1982), who synthesized their critical work from the 1970s into the centennial book *An Evolutionary Theory of Economic Change*, giving birth to modern evolutionary economics or Schumpeterian economics (see Nelson et al. 2018). Outside the U.S., in 1984, for example, in Germany, the chairman of the German Council of Economic Experts, Herbert Giersch, proclaimed "The Age of Schumpeter." In the UK, the Science Policy Research Unit (SPRU), founded by Chris Freeman as early as the late 1960s, had an almost paradigmatic impact in the 1980s and laid the foundation for modern innovation economics with its theory of innovation systems, which still enjoys great popularity today (see Dosi G. et al. 1988).

The consideration of qualitative developments, which is reflected in the change of economic structures, makes it necessary to look at knowledge creation and dissemination processes. Knowledge is not an exchangeable public good and therefore not fungible (Hidalgo, 2023). It is sector-specific, cannot be easily acquired, and knowledge development is subject to fundamental uncertainty (Knight, 1921) and thus eludes an optimization calculus that relies on determinism. Knowledge development involves experimentation and trial and error, which opens up the possibility of failure. Only by accepting the possibility of failure do entrepreneurs create new sectors (Schumpeter, 1911), which develop in coexistence with established sectors along dynamic industry life cycles (Klepper 1997). This accounts for the qualitative changes in the economic system. If this were not the case, then the approximate fivefold increase in incomes in Europe since the end of World War II would result in Italians having five Fiat Cinquecentos, French five Citroën 2CVs, and Germans five Volkswagen Beetles in their garages. This is obviously not the case, i.e. besides the quantitative increase of income, there are many more, and for economic agents much more important qualitative developments. To explain these qualitative developments in economic theories became the claim in the new Schumpeterian and evolutionary economic theories.

As a consequence, approaches based on optimization considerations are being replaced by approaches that rely on the experimental behavior, i.e., learning, of the actors.

Innovation competition is displacing price competition and reopening the view of long-term processes. Schumpeter (1942) himself propagated this change from price- to innovation-competition: "But in capitalist reality as distinguished from its textbook picture, it is not that kind of competition which counts but the competition from the new commodity, the new technology …. This kind of competition is as much more effective than the other as a bombardment is in comparison with forcing a door, and so much more important that it becomes a matter of comparative indifference whether competition in the ordinary sense functions more or less promptly."

Innovation thus takes on a completely new meaning: quantitative economic growth becomes qualitative economic development. Structural change is driven by innovation and the emergence of new industries. A further most important consequence is related with the overall architecture of the economic systems under analysis: The simple systems of neoclassical economics thus become the complex systems of evolutionary economics (see Chen et al., 2023).

The analysis of the interdependent knowledge creation and diffusion processes in a complex systemic context is carried out within the framework of theories of innovation systems, which have meanwhile enjoyed great popularity in science and application in numerous forms, for example as national (Lundvall, 1992), regional (Cooke et al., 1997), sectoral (Malerba, 2002) and technological (Carlsson and Stankiewicz, 1991) innovation systems. Gregersen and Johnson (1997) aptly describe innovation systems as a "system which creates and distributes knowledge, utilizes this knowledge by introducing it into the economy in the form of innovations, diffuses it and transforms it into something valuable, for example, international competitiveness and economic growth".

The progress made in innovation economics since the 1990s has also provided important new impetus for growth theory, now in an evolutionary fashion. In particular, the one-sided quantitative consideration of the increase in per capita income is being replaced by a consideration of qualitative changes in economic structures over time. An economy is no longer described by an aggregate production function, but is composed of different co-existing sectors (Saviotti and Pyka, 2004a). While new industries and their innovation systems are constantly emerging over time, initiated by creative entrepreneurs, old industries are also disappearing, which means that different sectoral dynamics characterize the respective industrial life cycles, but the economy as a whole can grow, driven in particular by the younger sectors, i.e. it can generate positive income increases.

Here, a mechanism appears that has been discovered in management research at the corporate level since the 1960s and is now considered an established finding. At that time, Cyert and March (1963) also left the path of scientific management based on traditional economic theory, as did innovation economics more than 20 years later, and described with their theory of firm behavior that for long-term success in the innovation process, two different innovation processes, namely *exploration* and *exploitation*, must be combined, which represents a great challenge for companies and can often lead to the unexpected and sudden exit of established long-standing market leaders.

Exploitation describes the strategy of a company to achieve world market leadership

or at least national market leadership in a technology through technological excellence. This is practically only possible through absolute concentration on one technology and the associated mastery of knowledge (so-called *focus on core-competences*). In the course of technological development, however, it becomes increasingly difficult to achieve further success in a particular technology; the technological respective opportunities are not unlimited. This is the moment when one can either profit from the results of the second track of innovation processes, namely exploration, and move into new technological areas with so far unexploited opportunities, or painfully feel the omission of exploration, namely when new companies enter the markets, grow rapidly and displace the incumbent companies from their leading position.

The situation is very similar at the macroeconomic level: The sectoral innovation systems help the participating companies to achieve a technology leadership position, which generates profits, income and jobs. At the same time, future fields of technology are to be developed in a national innovation system, which can then be occupied when, as a result of structural change, the established industries have reached the end of their industrial life cycle. In very many cases, it can be observed that this long-term exploratory research process is difficult to assert against the interests of the established successful sectors. The established companies lack the *absorptive capacity* (Cohen and Levinthal, 1989; Cantner and Pyka, 1998) to take care of new technologies and business models in time, and economic policy shies away from the uncertainty of a long-term structural adjustment policy and persists in measures of structural conservation.

It is certainly one of the great merits of innovation systems theory and evolutionary growth research to have transferred these complementarities between exploration and exploitation to the macroeconomic level and thus to have pointed out the long-term interplay of the two mechanisms. Literally this can be seen as an endogenous mechanism to replace the exogenous shocks in traditional growth theory.

In the transition from traditional to evolutionary economic theories, a fundamental conceptual change has taken place. Whereas traditional economic theory relies on a very restrictive set of assumptions to reduce the complexity of reality to the point where the model of thought can be applied from optimization and equilibrium considerations, now complexity is no longer hidden but can unfold. As already mentioned, the "simple systems" of traditional economic theory thus become the "complex systems" of evolutionary economics, for example with the consequence that the decline in production and employment in an older industry can be absorbed by activities in new sectors. Sectoral difficulties arise, such as frictional unemployment, mismatch unemployment (Saviotti and Pyka, 2004b), etc., but the co-existence of numerous industries at different stages of their life cycle makes the economic system resilient and able to handle these temporary difficulties.

At this point, it should be noted that, as Gregersen and Johnson (1997) point out, the objectives of innovation systems research are, however, limited to employment goals and international competitiveness. Thus, these new developments resemble the traditional growth-oriented paradigm in terms of their focus. The great advantage of the new approaches is thus limited to the fact that long-term considerations come into play

in innovation competition and that the qualitative effects of economic development are considered in this way.

Innovation systems are the infrastructure of creative knowledge flows and explain the resilience of capitalistically organized economies, which remain strong drivers of innovation despite violent fluctuations. The other side of the resilience coin, however, is the fact that deeply undesirable systemic patterns of socioeconomic systems that produce, among other things, economic inequalities or environmental degradation also tend to linger and are extremely difficult to overcome. It remains unclear how sustainability considerations can make room for themselves here.

To a certain extent, economic policy can act on this with a top-down design aimed at promoting and enforcing new technologies. Recently, the so-called *mission-oriented approach* (Mazzucato, 2021), embedded in the notion of innovation systems, has become very popular here and justifies the renaissance of an industrial policy that is particularly committed to the sustainability goal. For the establishment of a sustainable economic organization, however, the exclusive focus on supply-side innovation competition falls short, which has led to renewed criticism of economics in recent years and is expressed in the emergence of a new interdisciplinary scientific discipline, the so-called transformation sciences.

4. Economic Transformation

We have seen that even after the important change of perspective from short-term purely quantitative to long-term and qualitative, nothing has changed in the actual goal of economics, namely to increase income. The desire, with an improved understanding of economic processes and dynamics, to contribute to the goal of increasing per capita income is quasi-paradigmatic in economic sciences. This observation leads to the demand in the so-called *transformation sciences* that the sustainability goal should be set equal to the income goal, i.e. what one wants to achieve with innovation systems can no longer be limited to income and competitiveness (see Pyka and Urmetzer, 2023).

Obviously, the innovation systems approach as we know it today is subject to some limitations. The idea of innovation systems is to strengthen innovation performance and thus competitiveness. This was seen as an effective tool to combat rising unemployment in Western industrialized economies in the 1980s and 1990s, when these approaches were developed as alternatives to traditional economic theory. The systemic boundaries, however, were much too narrowly defined, and despite the systemic focus, the emphasis is on economic systems in a narrow sense, as well as their use (and consequently a path-dependent research of existing technologies).

While the innovation system perspective determines science, technology and innovation policy today, questions of sustainability are often not considered there at all or remain decorative accessories. Innovation is seen as the panacea for all social, economic and also ecological problems - more or less without further questioning. This, however, is a misconception, as there is no automatic mechanism for steering innovation efforts in the

right direction. This has to do with a feature that is particularly pronounced in radical innovations: The results are fundamentally unpredictable (Knightian uncertainty), and developments that cannot be anticipated must always be expected, which may even be counterproductive again overall. This property is well known in complex systems and is described as a *wicked problem* (Head, 2022; Pohl et al., 2017; Rittel and Webber, 1973). There is just no longer, as in simple systems, an optimal solution that leads to economic equilibrium. Instead, adaptive management of the complex systems is required, i.e., constant readjustment or even complete rethinking with regard to the solution originally considered to be advantageous becomes necessary again and again.

The dilemma of direction cannot be resolved for innovation. But how can new solutions in the area of sustainability still be pursued?

If we understand a transformation process as a radical socioeconomic change and the comprehensive reorganization of economic activities on the supply and demand side, another property of complex systems comes into play. In the previous section we saw that the change of perspective of Schumpeterian economic research is associated with the change of analysis of simple systems to complex systems. Complex systems are characterized (within certain limits) by *resilience*, i.e., even major structural upheavals do not lead to system collapse; on the contrary, these can even spur system evolution (Langton, 1990). However, the second property of complex systems is completely different. If the developments in a complex system exceed so-called *tipping points*, then it comes to a no longer reversible development of the system, which takes a completely changed basic state (Gladwell M., 2000).

Such tipping points are currently very present in the discussions, especially in climate research. Earth scientists (Rockström et al. 2009; Will et al. 2015) leave no doubt that every day we continue as we are, we are approaching several planetary thresholds, beyond which there is a "significant risk that the Holocene state of the [Earth system] in which modern societies have evolved will be destabilized." This collapse will be sudden, not gradual. The nature of tipping points generally leaves little room for gradual adjustment.

There are also tipping points in our economic systems, the crossing of which is associated with paradigmatic changes that irreversibly overcome earlier general patterns. Industrialization at the end of the 18th and beginning of the 19th century, for example, represents such a tipping point, which irreversibly overcame the agrarian structures that had dominated for millennia. The introduction of mass production aimed at economies of scale by Henry Ford at the beginning of the 20th century, just like digitalization at the end of the 20th century, represent such tipping points. In each case, a comprehensive reorganization of economic systems took place, affecting all areas of life, which were completely different once the tipping points were passed. A particularly striking example is the transition to the so-called *golden age of capitalism* in the period after World War II. As UNESCO (2017) describes it, "The Golden Age of Capitalism spanned from the end of the Second World War in 1945 to the early 1970s, when the Bretton Woods monetary system collapsed. It was a period of economic prosperity with the achievement of high and sustained levels of economic and productivity growth." This period of prosperous

economic development which changed massively the growth trends in large parts of the world was triggered by the implementation of a *virtuous circle* between the industrial development committed to mass production, the resulting hugely increased hunger in industry for highly qualified engineers and managers, the intensively started expansion of academic education everywhere, to satisfy this hunger, and the resulting higher incomes among broad segments of the population, which generated immense growth in demand, for example, for cars, household appliances, consumer electronics, and mass tourism, creating further expansive opportunities for industrial development. This transformation from necessity goods to virtual goods built on the dynamic interrelation between new products and services developed by industry and the changed consumption patterns which together establish the virtuous circle (Saviotti and Pyka, 2013).

Thus, there are always radical upheavals of our economic systems that lead to a fundamental reorientation of the organization and economic decisions of all economic actors. Nevertheless, they are of course rare and are therefore interpreted in the economic mainstream as exogenous shocks. They also do not correspond to the idea of Kondratieff cycles, since they are not characterized by radical technological breakthroughs alone, but depend on the interaction of market actors on the supply and demand side, which is what installs the virtuous circle in the first place. They correspond most closely to the paradigm shifts described by Giovanni Dosi (1982) - to which we will return in a moment - and in which widely spread thought patterns and search heuristics play a decisive action-guiding role.

Why is this possibility of a radical and abrupt reorganization of economic systems important? Given today's situation of impending climate change and overshooting of planetary boundaries with dire consequences for the survival of humanity as a whole, it is critical that we reach a new tipping point in our socio-economic system to irreversibly implement sustainable organization, even before we pass the tipping point of the planetary system and destroy our livelihoods. There is no way around this logical conclusion.

Economic growth to increase per capita income provides, at best, for substitution processes depending on the development of relative prices. Environmentally harmful inputs, for example, are replaced by more environmentally friendly inputs. The structure does not change, and the possibility of *rebound effects* (e.g. Binswanger, 2001) may even be counterproductive. Economic development through the emergence of new, potentially environmentally friendly industries and the disappearance of the old energy-hungry dirty industries can mean a potential approach to sustainable economic activity. However, because of the Knightian uncertainty in the innovation process, a green direction is not automatically given. New techno-economic opportunities opened up by entrepreneurs in the sense of Schumpeter may relate to fundamentally new and more sustainable products and services, but then it is actually again - now on a sectoral level - about substitution, i.e. new industries replacing old industries. The shift in vehicle construction away from combustion engines and toward electric drivetrains is a good example. Steps toward improved sustainability can certainly be expected from this, but the speed and scope of the improvements will be too low to pass the tipping point in the economic system. The

transformation to sustainability will only begin - and here the difference to the other two concepts of growth and development becomes clear - when changing demand behavior and consumer habits in the form of new lifestyles join the technological developments and both processes fuel each other in a virtuous circle.

In this sense, transformation means nothing less than a paradigm shift. If one reads Giovanni Dosi (1988, p. 1127), one finds the description of a technological paradigm as a "set of heuristics (e.g., Where do we go from here? Where should we search? What sort of knowledge should we draw on?)". He is concerned with the basic thinking and search patterns that delimit the search space of the innovation process. However, the community of Schumpeterian innovation researchers has so far considered practically exclusively the first part of the definition, namely (Dosi, 1988, p. 1127): "A technological paradigm is [...] an exemplar - an artifact that is to be developed and improved (such as a car, an integrated circuit, a lathe, each with its particular technoeconomic characteristics)", with the consequence of dwelling on the economic development perspective and not addressing the real transformation process.

Transformation processes are thus primarily triggered by the changed search heuristics, which practically determine the decisions of engineers, scientists and managers, as well as consumers as unchanged and unquestioned beliefs for a long time. Let us look at the main search heuristics that have guided our actions in the 20th century: (i) unlimited availability of fossil resources (e.g. energy, basic chemicals ...), (ii) meat as the most sought-after ingredient in the diet, (iii) mass production to exploit economies of scale, (iv) individual mobility as the dominant mode of transport. As meta-routines of industrialization, it follows for engineers and economists in the 20th century, on the one hand, the realization of economies of scale through mass production and, on the other hand, the increase of incomes through the unconditional realization of economic efficiency.

Clearly, the idea of mass production is already being extremely challenged by digitization and is causing quite a bit of unrest in many established industries. Henry Ford's famous saying, *you can buy the Model-T in any color as long as it is black*, has long since become obsolete, and modern CAM technologies enable the highest degree of individualization in production. Another example would be the new possibilities offered by so-called biointelligence to provide individualized medications for patients. At the same time, we are already seeing the first signs that the exclusive income goal of the neoliberal era is beginning to falter. For example, hardly any corporate, political or scientific publication nowadays does without a reference to the sustainability considerations involved, e.g. with a reference to the United Nations' Sustainable Development Goals. Numerous non-governmental organizations never tire of pointing out the urgency of the sustainability goal in protest campaigns, thus putting politics and business under considerable pressure to act.

However, changing the basic search heuristics to trigger the sustainability transformation is anything but a simple matter, and persistent tendencies, vested interests and also relapses into old behavior patterns are to be expected. The decisive role here is played by the knowledge of all market participants, i.e. not just technological knowledge, but also normative knowledge and systemic knowledge (Urmetzer et al. 2020). Changes in

consumer behavior (Wilke et al. 2021) in particular put great pressure on companies to adapt their products accordingly. If this is not possible, or if the players cling to the old business models, entrepreneurs will be called onto the scene who will enable fundamental changes with disruptive innovations and, under certain circumstances, force established players to exit the market. The newly created opportunities will then once again encourage consumers to try out or adopt the new lifestyles, increasing the market volume and again opening up new scope for further entrepreneurs. This is exactly the kind of virtuous circle that can push the economic system over the tipping point and install irreversible sustainable economic organization.

Innovation systems continue to play a crucial role in the transformation process. Let us recall the definition of Gregersen and Johnson (1997), which states that the knowledge generated in innovation systems eventually "transforms it into something valuable". However, the something valuable now includes not only international competitiveness and economic growth, but equally the goal of sustainability. To achieve this, existing innovation systems must be thoroughly restructured and new players must be involved. In these so-called *dedicated innovation systems* (Pyka, 2017), established actors can no longer set the tone and determine the direction of the innovation process. The risk of falling prey to the *not-invented-here syndrome* (Simon, 1991), or the desire not to jeopardize one's own powerful and profitable market position, the so-called *replacement effect* (Reinganum, 1983), are far too great. Decisive design principles of dedicated innovation systems are democratization, participation, transparency, perceptibility and education, in order to implement the development and adoption of new general search heuristics suitable to improve long-term sustainability performance (inter- and intragenerational equity, continuity of ecological systems, quality of life ...). Policy actors in a dedicated innovation system will still continue their top-down approach to establishing green industries. However, in a dedicated innovation system, this will be complemented and accelerated by the bottom-up initiatives of avantgarde consumers who will critically review their consumption habits in terms of their relevance for sustainability and encounter resourceful entrepreneurs who will try to exploit the new opportunities for themselves with disruptive innovations.

5. Growth, development and transformation in application: the example of the bioeconomy

The underlying understanding of growth, development and transformation is of crucial importance for the analytical consideration of developments and cause-effect relationships in different issues in the sustainability discussion. Depending on the perspective chosen, different dynamics become apparent, different drivers and inhibitors show up and, as a result, the issue under investigation is either incompletely or effectively addressed.

Using the bioeconomy as an example, we will now show the obstacles and opportunities associated with the respective perspectives. The bioeconomy is a particularly good example for two reasons: (i) The bioeconomy is considered to be of great importance for the sustainability transformation worldwide, as it is expected to make an important contribution

to overcoming the lock-in in fossil resources (Unruh, 2000). And (ii) the bioeconomy is a fundamental approach in very many different sectors and has a paradigmatic character, as illustrated for example by the EU definition (2019): "The bioeconomy covers all sectors and systems that rely on biological resources (animals, plants, micro-organisms and derived biomass, including organic waste), their functions and principles. It includes and interlinks: land and marine ecosystems and the services they provide; all primary production sectors that use and produce biological resources (agriculture, forestry, fisheries and aquaculture); and all economic and industrial sectors that use biological resources and processes to produce food, feed, bio-based products, energy and services. To be successful, the European bioeconomy needs to have sustainability and circularity at its heart. This will drive the renewal of our industries, the modernisation of our primary production systems, the protection of the environment and will enhance biodiversity."

The Food - Fuel Conflict as a Problem of the Growth Perspective

In the early 2000s, strong increases in crude oil prices led to a new interest by oil companies to significantly increase the share of biofuels. This intention was additionally supported by politicians, who looked with great concern at the growing dependence on oil-producing countries. At the same time, research efforts in the fledgling bioeconomy were very much concentrated in the bioenergy sector. The consideration that, on the one hand, with rising crude oil prices and the resulting change in price relations, biofuels would become efficient in the future, and that, on the other hand, this could even be accelerated by additional research, set in motion a successive substitution process with the goal of reducing mineral oil. This led to a significant growth in demand for biomass, especially for corn, and in 2006, sharply rising prices on global grain markets caused a serious crisis in less developed economies, which were no longer able to pay the immense price increases for their food imports.

This was the beginning of the important ethical *food versus fuel debate* (e.g. Prasad and Ingle, 2019), which at the beginning almost meant the early end of the first bioeconomy walking attempts and significantly challenged the societal acceptance of bioeconomy technological approaches. The one-sided decisions to expand the bioenergy sector, based on efficiency and cost considerations, simply did not take into account the impact this would have on other vital markets. The conclusions derived from traditional growth theory were a poor guide in a complex problem area. This example is a very good illustration of the short-term nature of the growth-oriented view and the problems it entails because of the single-sided focus on economic efficiency. Only a few years later, further knowledge and technological improvements in the bioeconomy showed further enormous possibilities (e.g. in synthetic chemistry) and disqualifies an exclusive energy orientation as inefficient, also in terms of value creation. To summarize, improvements in the achievement of the sustainability goal can hardly be expected within this analytical framework.

Bioeconomic use of materials in the automotive industry

As an example of the inadequacy of the development perspective of recent

Schumpeterian approaches, consider the current efforts of the automotive industry (see also Pyka and Urmetzer, 2023) with their halfhearted efforts to improve their sustainability image. Globally, the transport sector performs worst in terms of its contribution to climate goals. Nearly all other sectors are already significantly further along in reducing their environmental footprints. Without doubt, the European goal of climate neutrality by 2050 can only be achieved if not only individual vehicles become more climate-friendly, but also the total number of vehicles is drastically reduced and mobility is completely reorganized.

The automotive industry has so far failed to provide a convincing strategy for its contribution to the sustainability transformation and has not managed to break away from its business model - developed by Henry Ford more than 100 years ago - of mass production of automobiles for individual mobility. Current efforts in this industry make it clear that, on the one hand, mobility transformation is equated with powertrain transformation (substitution approach from the growth perspective), and that, on the other hand, efforts are being made to improve recycling rates in the spirit of the circular economy and, where possible, to replace conventional oil-based materials with bioeconomic materials (Schumpeterian development perspective).

The latter approaches ensure the innovation-driven emergence of new bioeconomic supply industries, for example in the field of bioplastics, biodegradable fibers and in the field of biological insulation materials among many others, with positive effects on income, employment and international competitiveness. There is no doubt that this will also improve the environmental footprint of a single vehicle, but on the fleet size, on the space consumption of the vehicles and on the overall resource consumption, this strategy has only a minor impact. One cannot help but see a sailing ship effect here (Pyka et al. 2022), which only ensures short-term profitability but negates transformative change and thus puts the future of the entire industry at risk.

A sustainable mobility system that will operate with a much smaller fleet size, autonomous and modular mobility, and incorporate digital mobility and changing consumer habits (e.g., the use of bicycles) represents a *sword of Damocles* hanging over the established players in the automotive industry. Much like the sailing ship industry ultimately failed at the beginning of the 20th century despite its massive innovation efforts to prevent steamships from entering the market, today's players in the automotive industry face a very difficult future as a result of a truly sustainable mobility transformation.

Their current technological and economic successes - from a Schumpeterian development perspective - hide the fact that more sustainable solutions are already close to completion and are being demanded politically worldwide, especially by a growing urban population. Drastic regulations such as massively increasing parking costs, speed limits, narrowing of lanes by bus lanes and cycle paths, bans on entry for older vehicle types, and even city tolls are the first and unambiguous harbingers of a future limitation of individual traffic, at least in urban areas. In addition to vehicle-related new technologies (especially fully autonomous vehicles), these sustainable mobility systems will combine urban innovations and consumer lifestyle changes (especially bicycle mobility, modular mobility, and sharing) as well as social innovations (see Newman, Beatley and Heather 2017) and radically transform

today's mobility solutions. Clearly, vehicles will continue to play an important role in the future, but due to the retirement of the car to private ownership, just quantitatively a much smaller one. Mobility services, on the other hand, will become much more important, as will urban planning measures for traffic planning and control. Through the Schumpeterian development perspective, the advantageousness of the emergence of the new sectors in the bioeconomic segment is seen and promoted, but the interplay with the new mobility-related lifestyles as well as the change in urban living spaces are overlooked, which reduces the necessary readiness to adapt and, above all, does not question the dominant heuristic of mass production aiming at economies of scale and favoring individually-owned cars. In other words, the Schumpeterian approach to development here ultimately leads to a reinforcement of the tendency to inertia, prevents disruptive rethinking and thus provides scope for green-washing. An effect on the underlying heuristics is neither to be expected on the producers' nor on the consumers' sides.

New Lifestyles and Diet

The automotive example already points in the direction of the transformation perspective and its effectiveness. In the following, we will outline an example from the food sector that has already irreversibly triggered the sustainable transformation in this sector through the successful implementation of a virtuous circle. Less than 20 years ago, vegetarian lifestyles were largely undesirable in most Western societies, especially among older members of society. Meat, especially in the post-World War II era, was considered a central element in the diet that expressed growing affluence. If you ordered a vegetarian dish in a restaurant, you got the meat dish without the meat. Resourceful entrepreneurs from the restaurant and food industry, however, quickly recognized these opportunities opened by avantgarde consumers and developed and permanently improved the vegetarian offer. As a result, it became easier and easier to maintain a vegetarian lifestyle, which led to imitator consumers entering the scene and expanding the niche once again. In the meantime, even steakhouses offer vegetarian menus and one can confidently consider vegetarian nutrition mainstream. Most of us find it perfectly normal not to have meat on the menu several days a week. Similar to other industries, diversification plays a major role and one may assume that the current attention of vegan lifestyles will have a similar career. By implementing a virtuous circle between avantgarde consumers and entrepreneurs, an irreversible transformation has taken place in the food sector, which will irreversibly ensure the achievement of sustainability goals in the relevant sectors in the medium term and change consumers' unsustainable consumption habits.

The example clearly illustrates the difference between the transformation perspective and the development or growth perspective: Through the interaction and positive feedbacks between the two market sides, food production and consumption habits have changed drastically and practically transformed themselves in a self-organizing way. The old heuristic favoring meat in the daily diet is almost completely reversed by the new heuristic to avoid meat because of health, animal welfare and environmental reasons. In this, one sees the formative transformational power of the virtuous circle.

The transformation perspective does not exclude structural change and growth. New suppliers have appeared on the scene in the food sector, and income is also earned in these new structures. Qualitative transformation thus does not exclude quantitative improvements, but the reverse is not true because with purely quantitative changes, the established search heuristics do not necessarily change and thus no paradigmatic change of the respective system occurs. Growth and development are not ineffective, but ultimately, against the background of the actual need for change in the face of the impending climate catastrophe, they are best described by the English phrase, *rearranging the deck chairs on the Titanic*.

6. Summary and Outlook

If economics wants to continue to contribute to an improved understanding of the relevant mechanisms and dynamics and thus provide relevant and responsible scientific impulses for the necessary changes in the economy, society and politics, a comprehensive opening to the transformation topic is unavoidable. This means, first of all, abandoning the one-sided quantitative orientation toward changes in per capita income. The innovations required for the underlying economic growth are not necessarily contributing to solving the sustainability problem. Rather, the underlying structural conservatism "only" produces more of the same, or, if necessary, even redirects resources to the detriment of sustainability through rebound effects. Both tend to exacerbate the climate crisis. But even qualitative development in the form of structural change, as analyzed by Schumpeterian economic research, is not sufficient for the necessary restructuring of economic systems, and there is a certain probability for the undesired features of the economic system to linger. There is a tendency today to steer these developments in the direction of green growth within the framework of a mission-oriented approach. Ultimately, however, there is no automatism for this due to the uncertainty that necessarily arises in the innovation process, the hoped-for structural change would take far too much time, and additional large emissions of greenhouse gases for further global warming cannot be ruled out.

Only the transformation perspective offers sufficient and rapid changes in the direction of more sustainability. Here, innovation efforts are steered in the sustainable direction by the behavior of demanders, and creative entrepreneurs enable a permanent expansion of new sustainable lifestyles with their sometimes disruptive innovations, opening up further niches on the supply and demand side. Such a virtuous circle is capable of crossing tipping points in economic systems and irreversibly installing new more sustainable forms of organization. Responsible for this is the formation of new fundamental routines of action and search heuristics, which include the idea of sustainability in the catalog of goals from the very beginning and as a matter of course. It seems as if the application of systemic knowledge is far easier on the side of consumers and entrepreneurs, who are not bounded to old knowledge, as can be observed in established industries.

The demanded comprehensive opening of the economic sciences also includes the (unconditional) transition to interdisciplinarity. On the one hand, not only technological

innovations play a central role in the process described, but also social innovations, for example, for the necessary technology acceptance and for the successful spread of the new lifestyles. On the other hand, the social changes are on such a drastic scale that they must be accompanied and enabled by political science and sociological research from the very beginning. The same applies to the (environmental) psychological preconditions for the establishment of the new consumption habits and behavioral patterns through which the new lifestyles are shaped. Finally, natural and engineering sciences must be brought on board to keep an eye on the possibilities of change as well as their effects on climate development.

The path to this goal will not be easy and numerous difficulties will have to be overcome. For economics, however, the focus on the transformation perspective offers nothing less than the all-important opportunity to continue making relevant research contributions in the future and thus to remain an attractive field of research in terms of responsible research, especially for younger scientists.

In addition to the difficulties that must be overcome in the transformation process, however, there are also positive expectations that allow us to hope for an increasing acceleration and facilitation in the necessary transformation process. It is now important to make rapid progress in individual sectors of the economy. The example from the food sector shows that these successes are possible and can develop long-term positive pull effects in other sectors for sustainability transformation. This is due to the expected diversification in the new sustainably organized sectors. This high level of creativity of economic systems has already ensured acceleration of economic development during the fossil age as well. For example, if we had only seen Model-T cars, development in vehicle manufacturing would very soon have reached its limits and a saturated demand (Pasinetti, 1993). Only through diversification was the long-lasting success in this industry possible. The same is true today for the development of the food industry, which has radiated comprehensively throughout the industry and has only recently been complemented by a new megatrend, vegan nutrition. Remarkable here are the spillover effects into other areas, such as the textile sector. What is actually taking place here is an increasing networking of the most diverse initiatives on the supply and demand side, a mechanism for creating critical mass, which is essential for crossing tipping points.

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