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The Rebound Effects of Automation

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Abstract

This contribution argues for a shift in the paradigms by which we assess the impact of automation on work. The suggested theoretical lens provides an explanation for the paradox of rising employment figures despite continuous automation. Capitalist development entails tendencies of rising complexity and acceleration of economic relationships, tendencies that are taken to extremes in digital capitalism. Therefore, we need to acknowledge countertendencies to a substitution of work, framed as three rebound effects of automation: rising complexity of production and the division of labour, work related to the introduction of automation and work needed to mitigate the societal consequences of capitalist development. Using short case studies on work in logistics, industry and care, the implementation of digital technology is shown to be partly motivated by the labour market situation – automation technologies are introduced to mitigate labour shortages. However, the case studies also illustrate the exuberant expectations about the effects of digitalisation in this respect. While the narratives behind the introduction of digital technologies are heavily shaped by the motivation to combat labour shortages, the actual technologies are barely equipped to do so. Conflicts about the (relief from) an excessive burden at work begin to take on centre stage in industrial relations.

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1 Introduction

The advent of generative AI has triggered yet another uproar about job losses. A recent study concludes that "LLMs [large language models, FB] such as GPTs […] could have considerable economic, social, and policy implications" as they affect between 47 and 56 percent of all tasks on the US labour market (Eloundou et al., 2023). This study is just the latest incarnation of concerns over job losses through technological change. Others came before that. Frey and Osborne's seminal contribution (2017) has profoundly shaped the thinking of an entire generation about the impact of artificial intelligence on the labour market and it was rapidly adopted by policy makers and consultants around the globe. If indeed more than 60% of workers in Bangladesh were employed in industries with a high risk of automation, as a study based on Frey and Osborne's method found, technological change would surely bring about social upheaval, and consequently policy think tanks and trade unions have pondered about possible reactions. Yet, comparable predictions also were present when CNC machinery and computers entered the workplace. They seem to be a constant feature of modern societies. A number of classical economists like John Stewart Mill and David Ricardo argued that technological change would result in lasting unemployment and such notions certainly had an influence on Karl Marx, who pondered about the possibility of full automation in his "fragment on the machines" and John Maynard Keynes who coined the term "technological unemployment".

To be sure, there has been a substitution of work by machines throughout the history of industrial societies, and sometimes with tremendously destructive effects on societies. Consequently it does make sense to interrogate the potential effects of technological change on employment. Particularly, the issue of the effects of generative AI on knowledge work is a hot topic that deserves our attention. There is however, a tremendous gap between recent projections of unemployment and the actual labour market situation. The recent diffusion of digital technologies so far has not at all brought about mass unemployment. On the contrary, most labour markets in advanced industrial economies experience severe labour shortages, not only of high-skilled professionals, but also in jobs that demand medium or low qualifications. There is something profoundly wrong about the dominant way in which the relationship between technological development and employment is perceived.

My contribution argues for a paradigm shift in our way of thinking about capitalist development, automation and employment. It highlights that the coming decades will be shaped not by mass unemployment, but by increasing labour shortages, not only as a consequence of demographic change, but also because of a tendency of acceleration and growing complexity in capitalism that continuously creates additional demand for labour. Acknowledging this constellation, we need to change the way we think about technology. Digitalization is not about to wipe out employment. But the desire to react to labour shortages is a major driver of the adoption of labour-saving technologies, and it is likely that this trend will intensify in the near future. Yet, technology often does not live up to the expectation of easing the excessive workload in the context of labour shortages. Arguments and struggles about the strain of work at insufficiently staffed workplaces hence take on centre stage in industrial relations.

This argument is unfolded as follows: After a brief examination of what is wrong about the standard notion of the susceptibility of employment to automation, I confront projections about the substitution of work with data from OECD labour markets that demonstrates an increase of the volumes of work and the number of workers. I then explore theoretically why there has been an increasing demand for work although automation has been a constant feature of capitalist development. I identify the tendencies of increased complexity and acceleration as the main reasons, both of which are enabled and enhanced by technological change. In the third section, I condense these findings by identifying "rebound effects of automation" and formulating assumption about the relationship between technology and work in the current period. In the fourth section, I explore this relationship in case studies from logistics, manufacturing and care work. In the final section, I summarize the findings and provide an interpretation about the future of social conflict in the context of automation and labour shortages.

2 Flaws in speculations about the substitution of work

The fundamental methodological problem with projections such as the ones by Frey and Osborne, this has been pointed out repeatedly, is the inherent abstraction from real-life considerations of management and actual work processes. Frey and Osborne's study asks about how susceptible jobs are to computerisation based on a comparison of expert opinions about the future capabilities of technology and labour market data on skill composition. There are four reasons why this method is not suited to deliver reliable projections on real-life labour market developments:

First, digital technologies in general, and AI in particular, can be characterised as "promising technologies" (Hirsch-Kreinsen, 2016, 2023). Projections by technology providers in our venture-capital dominated innovation landscape often are inflated (Bialski, 2024). More importantly, the perspective on work is flawed since it is assumed that routine elements of jobs can be easily substituted by technology. As labour sociologists have pointed out, to have routine in certain tasks also means to be proficient, and even repetitive work schedules are characterized by significant degrees of improvisation and cognitive intervention (Pfeiffer, 2007; Pfeiffer & Suphan, 2018). Thus, both the underlying assumptions in Frey and Osborne's study about the capabilities of technology and the capabilities of human workers are erronous.

Second, not every technological possibility is necessarily implemented. Projections about the impact of technology on the labour market mostly do not consider basic economic considerations about return on investment. They do not consider the complicated mediation between the invention of automation technology and the economically-driven investment decisions by management. For this reason, the projection about the substitution of work in Bangladesh referred to above is misleading. Automation technologies of this kind do exist, for instance automating the labour-intensive knitting process in the garment industry (cf. Andersson et al., 2018), but they require investments that are extraordinarily high and barely feasible in a very cost-competitive business environment where cheap labour is available. Likewise, the implementation of so-called Industry 4.0 has been an up-hill-battle so far, mostly because return on investment has remained questionable (Butollo et al., 2023).

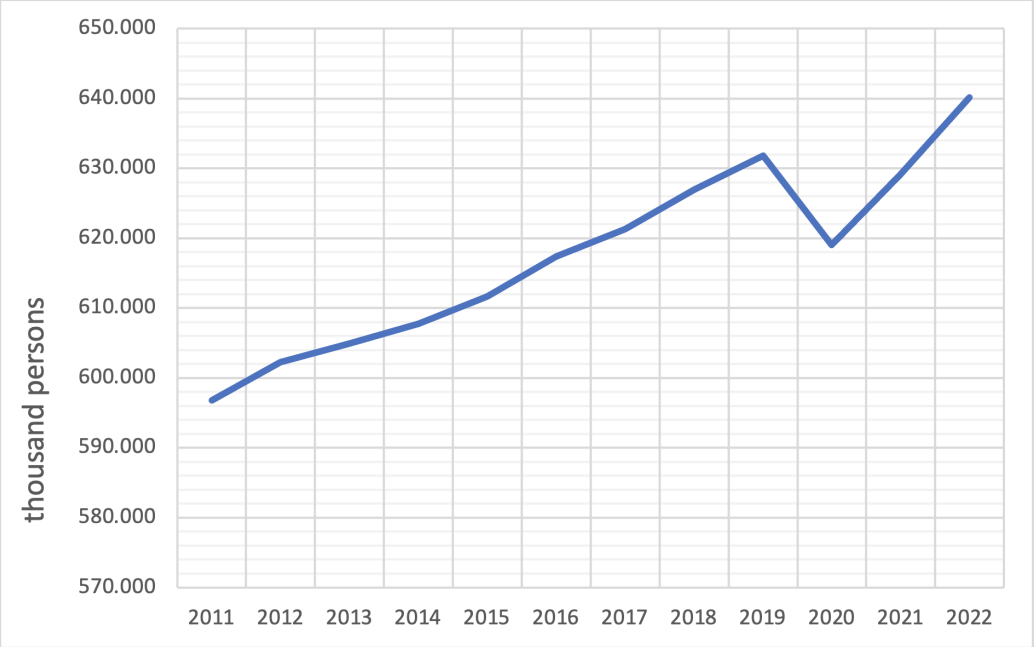
Third, the substitution of job tasks is not equivalent with a substitution of jobs. Historically speaking there are examples of jobs that have been automated away, such as the work of switchboard operators that used to manually connect telephone conversations within an organization. Yet, most professions grew and evolved in interaction with technological changes (Autor, 2015). Work content shifted towards new tasks and there was a constant addition of new occupation throughout the history of capitalism. Most labour market projections do not consider newly emerging tasks and occupations, and, needless to say, their outcomes in terms of employment are particularly hard to foresee.

Fourth and fundamentally, there is a tendency of rising complexity inherent to capitalist development, as will be discussed in detail in section 3. Products and services become more differentiated and customized and there is the addition of layers over layers of activities, which results in the multi-dimensional and globalized division of labour that capitalism represents today. Digitalization rather adds to this complexity and creates high demand for a broad range of workers, from low-paid staff in Kenya that annotates raw data to employees with sophisticated programming skills in the high-tech metropolises of advanced economies. Before we pick up this notion and explore the underlying reasons for rising complexity theoretically, the predictions about job losses will be confronted by real-life labour market data.

3 Automation and the real-life labour market

The most obvious flaw of the much-cited projections about the susceptibility of employment to automation is that they are not met by real-life labour market developments, at all. In the first decade since the original publication of the study by Frey and Osborne in 2013, labour markets across OECD countries have substantially expanded, not contracted.

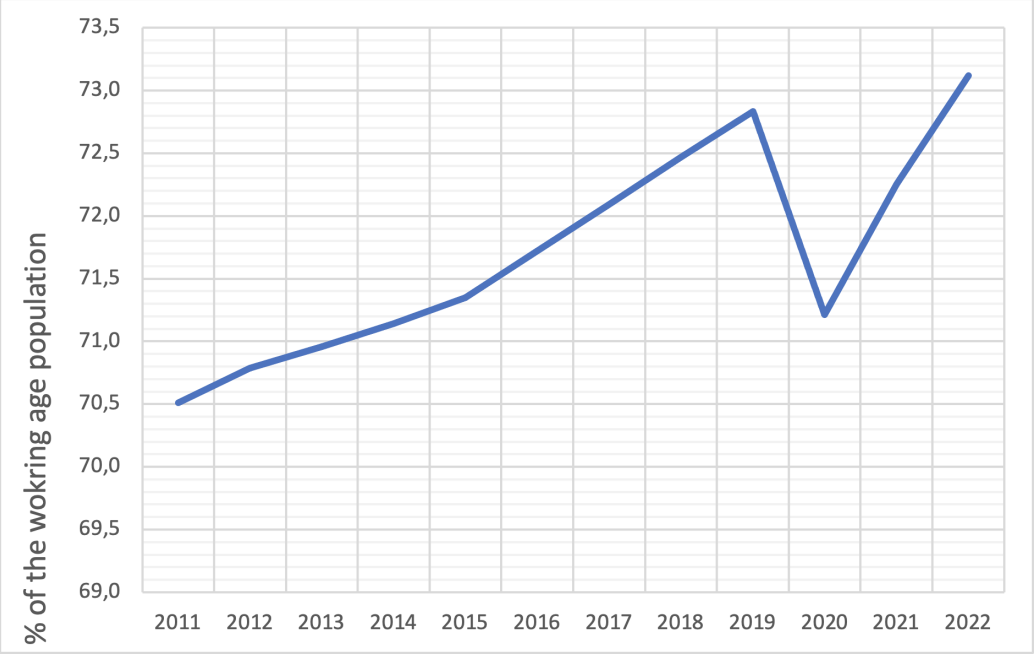
Figure 1a: Development of the labour force population (aged 15 to 64 years) in the OECD



Source: Own visualization based on OECD's "infra-annual labour statistics", retrieved 21.03.2024.

Employment in aggregate numbers has increased by roughly 7.5 percent from 632 million in 2013 to 679 million persons in 2022 (cf. figure 1a). The employment participation rate increased from 71.1 percent to 73.2 percent during the same period (cf. figure 1b).

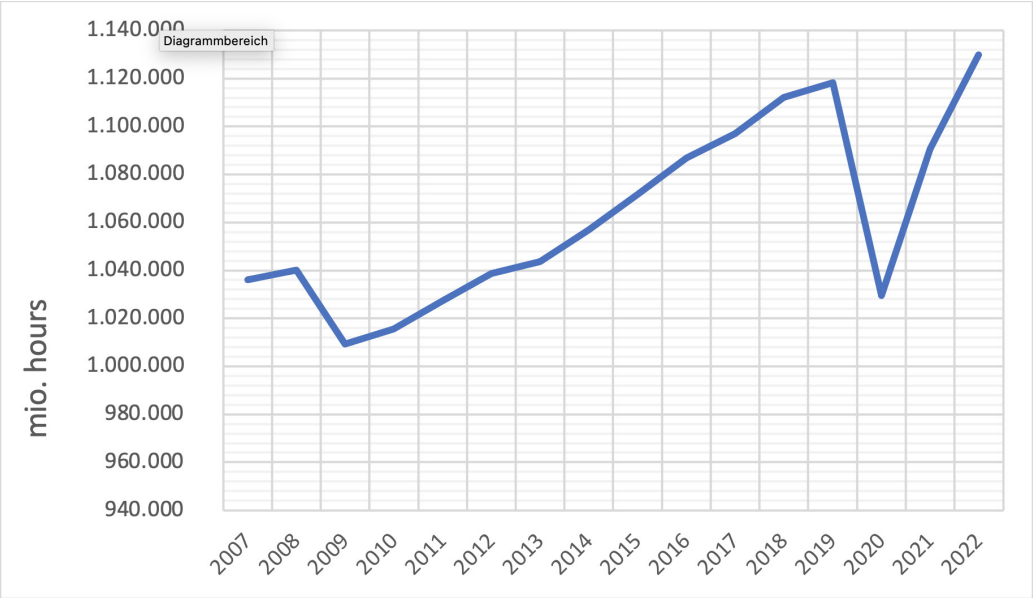
Figure 1b: Labour force participation rate (aged 15 to 64) in the OECD



Source: Own visualization based on OECD's "infra-annual labour statistics", retrieved 21.03.2024.

In the 2000s, the increase of employment figures in absolute numbers did not correspond to an actual increase of the amount of work, but rather reflected the impact of labour market reforms that led to the increase of non-standard and precarious forms of employment (cf. Dörre, 2014). Much of the increase in the number of employees hence represented an increase in workfare schemes and part-time jobs. Precarious forms of employment in this way concealed that there was an ongoing societal problem of underemployment.

Figure 2: Volume of work in the OECD (total number of working hours per year)



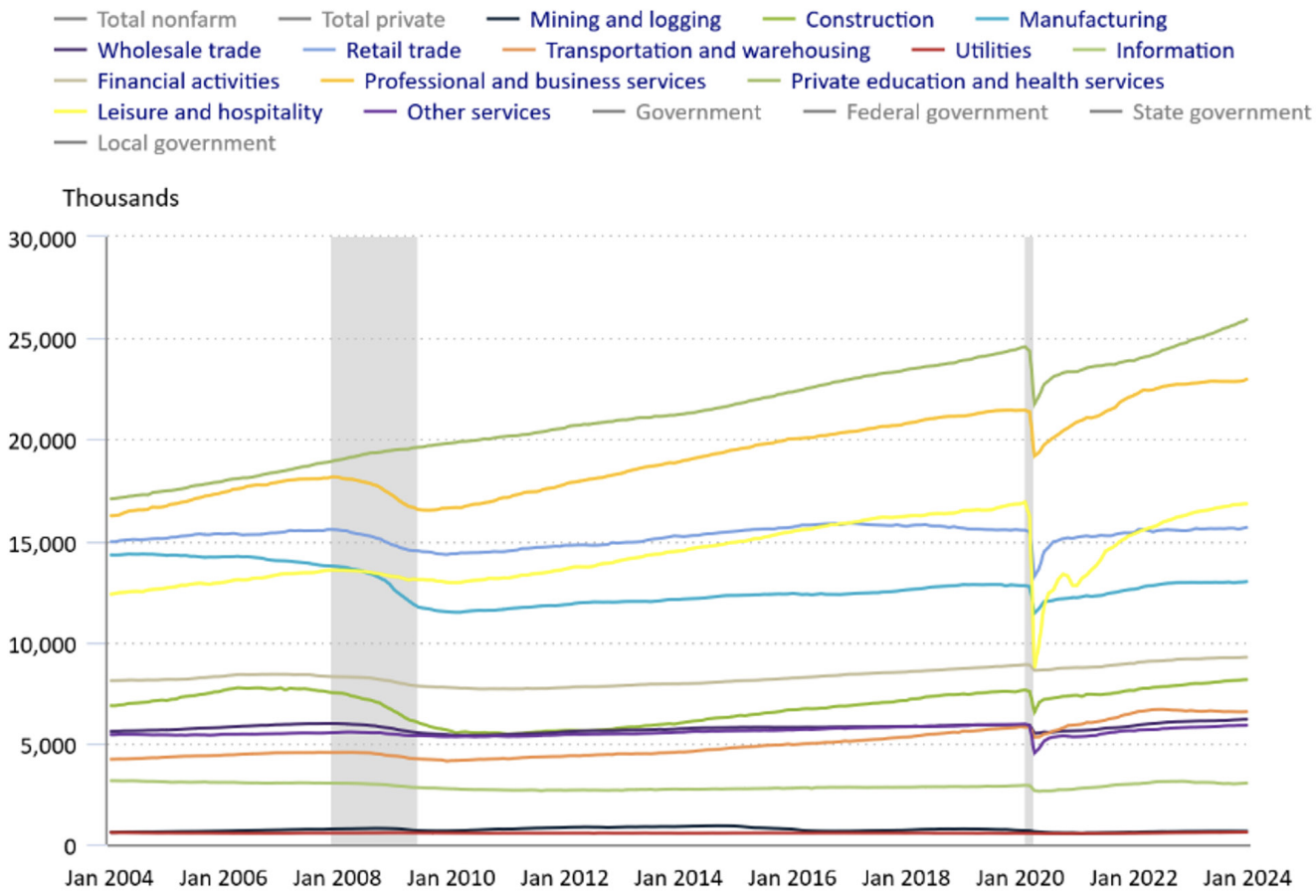
Source: Own calculation and visualization based on the OECD data on "average annual hours actually worked per worker", retrieved 21.03.2024.

Yet such forms of precarization cannot explain the root causes of employment growth in the 2010s. There has been a constant growth of total hours worked in most OECD economies. In the OECD as a whole, the total hours worked increased by more than 5 percent between 2013 and 2022, not as fast as employment in absolute figures, but nevertheless significantly (cf. figure 2).

Labour market data also shows that there is little statistical evidence of a "big quit", an interpretation that was haunting the media coverage of labour market development in the wake of the COVID-19 pandemic (Curtis, 2021). Rather, there was an astonishingly quick rebound of employment after the pandemic and employment figures now surpass the levels of the pre-pandemic period (cf. figures 2 and 3). This also and in particular accounts for the US where the debate about the "big quit" originated and gained most traction.

The disaggregated data on employment in different sectors (cf. figure 3), however, reflects a variation in the ability of enterprises to recover employment. Especially in leisure and hospitality, and to a certain extent also in construction and in transportation and warehousing the statistics show a bumpier path of recovery, which reflects the difficulties in sectors that were heavily exposed to pandemic-related restrictions and traditionally have high amounts of precarity and labour turnover.

Figure 3: Employment levels by industry, seasonally adjusted



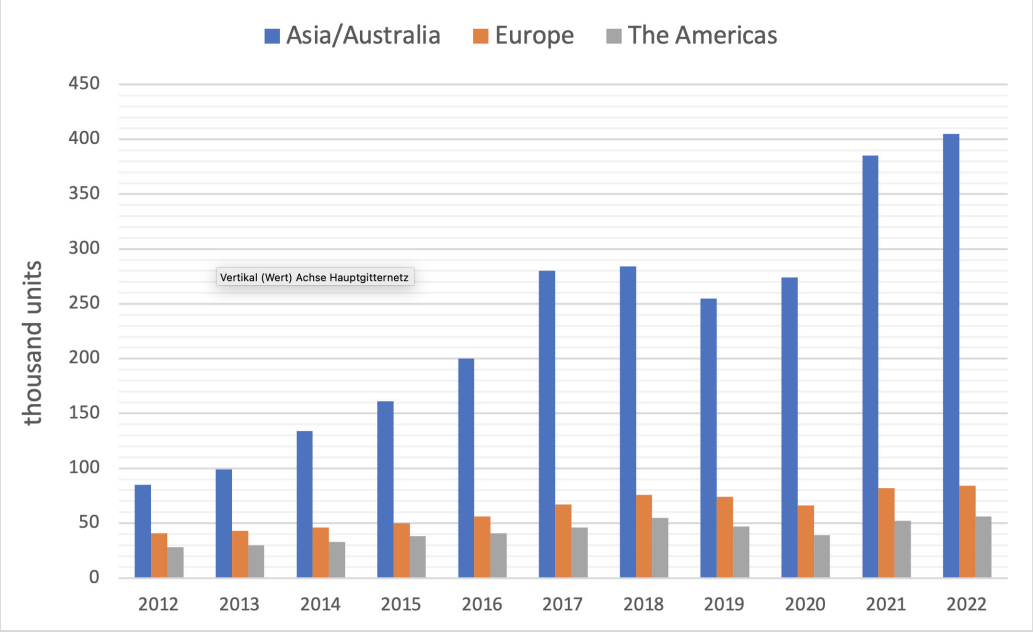
Source: US Bureau of Labour Statistics

Taken as a whole, OECD labour market data shows that during the period in which the term "Industry 4.0" was coined and speculations about robots taking our jobs reached unprecedented heights, employment did not decline, but increase.

A possible explanation for this puzzle is that digitalization did not (yet) take off. This is the path chosen by Brynjolfsson and colleagues in their reflections about the productivity paradox (Brynjolfsson et al., 2017) in which they argue that many of the efficiency gains of digital technologies have not yet materialized, as it was the case with the introduction of other base technologies that needed time to be adapted until it was discovered how their full potential could be realized. Aaron Benanav's argument (2020) more fundamentally questions whether we are experiencing a period of rapid technological development at all since fixed capital investment is historically low. No rise of the robots, in other words, as their increased technological maturity is not matched by a corresponding inclination of companies to implement them.

These arguments are correct in the sense that they address questions of a political economy of automation, i.e. the fact that investment decisions do not solely depend on technological considerations and that the ability to invest must be taken into account when discussing about the effects of automation.

Figure 4: Annual installations of industrial robots by region



https://ifr.org/img/worldrobotics/Executive_Summary_WR_Industrial_Robots_2023.pdf

However, Benanav overstretches the argument when he assumes that there is no real progress in automation. Data from the international federation of robots shows that the number of robots roughly doubled in Europe and the Americas between 2013 and 2022, while it more than quadrupled in Asia/Australia during the same period (cf. figure 4). What is more, the current wave of digitalization is not mainly characterized by the introduction of physical robots, but by a more comprehensive set of digital automation technologies. These did not expand as rapidly as the ubiquitous metaphor of a new industrial revolution suggests, but there is a constant proliferation of digital technologies that has accelerated since the pandemic (cf. for Germany: Butollo et al., 2023). In other words: employment has expanded despite constant automation. In a historical perspective, this relationship is even more striking. Industrial societies have experienced automation constantly and yet the aggregate level of employment is reaching unprecedented heights. We need to dig deeper for an explanation.

4 Capitalism and complexity

Analyses of the relationship between technology and work mostly focus on processes of rationalization. After all, industrial development comprises of the progress of labour-saving investments, by which economic organizations strive to raise the productivity of their operations. While this insight remains key to understanding the dynamics of process innovation at the firm level, it is not sufficient for interpreting the overall labour market developments in capitalist societies. A firm-centric view that interprets the role of technology merely as a tool for rationalization omits its role of technology in extending social relationships (Zuboff, 1988) and tends to paint a static picture of markets and societies that condition innovation processes at the firm level.

A different perspective is obtained when capitalism is interpreted as a socio-economic system that strives towards acceleration and greater complexity (Hodgson, 2003; Rosa, 2015). Hartmut Rosa places acceleration at the heart of his theory of modernity. For him, acceleration is rooted in capitalism's inherent growth imperative, which translates not only into an acceleration of economic interactions, but also in an increasing pace of social life in general, including an alteration in the perception of temporality.

While Rosa is able to identify and trace this shift in his reconstruction of the genesis and evolution of modern societies, acceleration is not the only process at work. According to the institutional economist Geoffrey Hodgson, the history of capitalism can be interpreted as "a long run tendency […] toward greater complexity" (2003: 471), defined as "a growing diversity of interactions between human beings and between people and their technology" (ibid: 472). Firms strive to innovate and diversify their operations, thereby also investing in new technology or new skills—not only in order to rationalize existing processes, but to expand their operations. The result is a more diversified economy with a more complex division of labour that also requires more sophisticated organizational forms "to manage an exponentially expanding number of products and processes" (ibid: 471). Historically, capitalist development therefore can be interpreted as one in which additional layers of products and services are constantly added to the economic totality. The IT industry, which did not exist as an employment-intensive sector at all some decades ago, constitutes a recent layer of additional complexity that continues to expand in the present.

In contemporary capitalism, the ecological crisis and the crisis of social reproduction are additional drivers of complexity. As Karl Polanyi has shown, capitalist development rests on societal preconditions that are simultaneously undermined by its development (Polanyi, 2001). This notion is highly topical. In "cannibal capitalism" (Fraser, 2022) the growth imperative resulted in the culmination of a series of societal crises of which the ecological crisis and the crisis of social reproduction are but the most pressing ones. As will be shown below, both are a major driver of the demand for work, which counteracts the effects of labour-saving technologies.

Technological innovation partly reflects human efforts to control increased complexity. This is argued, for instance, in the tradition of sociological systems theory by Armin Nassehi, for whom pattern recognition represents the gist of the current digitalization thrust. He sees societal complexity as the overarching problem and digital pattern recognition as a means to manage this complexity by detecting patterns out of data in order to increase the systemic, cybernetic capacities of control (Nassehi, 2023). A recent, stimulating interpretation of artificial intelligence argues in a similar vein that the probabilistic paradigms of machine learning match the requirement to tackle the increased complexity of social processes. It is best suited to deal with contingency and emergent phenomena and resembles an indirect and adaptive mode of control that is responsive to constant change (Heinlein & Huchler, 2023).

Hence, there are indications that digital technology holds complexity at bay. In fact, the present fascination with AI may be rooted in the promise to enhance the controllability of complex systems in logistics, production, energy distribution and the like. Yet, if desire to control complexity is one reason to invest in digital technologies, it is unlikely that the overall systemic complexity can be reduced. In Hodgson's view,

> [t]echnology cannot make the problems of complexity go away. Innovation and change mean that there will always be new problems of analysis and the potential for cognitive and computational overload. Furthermore, the nature and dispersion of knowledge means that there will always be difficulties in dealing with tacit, idiosyncratic, and context-specific knowledge. The new information technology can help us deal with some but not all aspects of growing complexity, and it cannot neutralize its underlying forces (ibid: 471).

What is more, digitalization in its present form reflects and reinforces the acceleration and growing complexity of the economy. Recent analyses of "digital capitalism" point out that one of its characteristics is the development of technological solutions and organizational forms to address diversified demand (Pfeiffer, 2022; Zuboff, 2019). This is the gist of the Industry 4.0 narrative that envisions highly customized production without efficiency losses that require the construction of more complex, engineering-heavy production units (Butollo & Schneidemesser, 2021). Beyond the narrative, the excessive complexity and the high capital requirements of Industry 4.0 are among the main reasons why the proclaimed industrial revolution has not yet taken off (Benanav, 2020; Butollo & de Paiva Lareiro, 2020).

While technological change in the realm of production has by and large rather proceeded incrementally, the nexus of platforms, data and (AI and non-AI-based) data analytics has led to disruptive changes in many interactions that concern the relationship between customers and service providers. The recent interpretations of economist Mariana Mazzucato (2018) and the sociologists Sabine Pfeiffer (2022) and Philipp Staab (2023) all converge in the observation that the thrust of the economic use of digital technologies is not the production, but the realization of value, i.e. the distribution of products and services. Enterprises thereby react to cultural phenomena that place increased emphasis on the singular and the unique (Reckwitz, 2020), and its economic expression as more diversified markets. However, in the context of fierce competition and often stagnating aggregate demand, they also drive such processes of differentiation by pushing options of customization and configuration. The nexus of e-commerce and influencers on social media exemplifies such processes of acceleration and growing complexity and the way in which these are enabled by digital technologies.

5 The rebound effects of automation

My core assumption is that because of these tendencies, we can identify similar kinds of rebound effects in the field of automation like those that have been identified in the field of political ecology. In this literature, rebound effects are defined as follows:

> Technological progress makes equipment more energy efficient. Less energy is needed to produce the same *amount* of product, using the same *amoun*t of equipment – *ceteris paribus*. However, not everything stays the same. Because the equipment has become more energy efficient, the cost per unit of services of the equipment falls […]. A price decrease normally leads to increased consumption. Part of the ceteris paribus gains is lost, because one tends to consume more productive services, and the extra demand for productive services from the equipment implies *more* energy consumption. This lost part of the energy conservation is denoted as the rebound effect (Berkhout et al., 2000).

With regard to the effects of automation, the results are similar. The labour-saving effects of automation are partially lost because the economic context is not static, there is no *ceteris paribus*, "not everything stays the same" (ibid). Because of the constant increase of speed and complexity that is reflected in a constantly increasing amounts of diversified products and ever-expanding layers of production and services, labour-saving effects at the single unit are offset. Based on the discussion above, three kinds of rebound effects can be identified:

1. **More work through more complex production and distribution:** A point in case is the automotive industry, which by far has absorbed the highest amounts of automation investment in the past decades. As Martin Krzywdzinski shows in his comparative historical treatment on automation in the automotive industry of Germany, the US and Japan (2021), employment stayed more or less constant in this industry, although robot density has tripled since the 1990s. The composition of employment, however, has dramatically shifted in the three countries towards "indirect" areas of production like development, construction, and planning. Digitalization in these areas has helped to reduce the work effort of individual white-collar functions, however:

   \ [T]his has been more than compensated for by the rapidly increasing complexity of development and planning processes due to increasing model diversity, shorter model cycles, increasing component diversity, growing demands regarding safety and quality, and the globalization and fragmentation of logistics chains (ibid: 526).

   \ The rebound exists since efficiency gains within the single unit are offset in the face of rising systemic complexity. Overall, Krzywdzinski convincingly concludes, "the analysis of automation processes must take into account the evolution of products and product architectures. The abstract estimation of automation potentials at the level of occupations or tasks […] is based on a static model, which ignores product changes" (ibid: 527).

   Comparable systematic accounts of the historical trajectory of automation in other sectors are rare. While it seems likely that some industries like, for instance, steel production or printing the labour-saving tendency outweighs the systemic increase of demand for labour, it can be assumed that many patterns show the same pattern. And some industries have experienced a significant expansion of employment. For example, the past decades have shown tremendous growth in logistics precisely because of a rising complexity and acceleration in distribution (Coe, 2014; Vahrenkamp, 2012) and this trend has increased recently with the growth of e-commerce and labour-intensive delivery and transport services.

2. **More work through digitalization:** Another significant rebound is the fact that digitalization projects require human efforts to take off. Projections about productivity growth and employment losses usually do not systematically take stock of the amount of *social innovation* that is needed to implement digital applications (Moniz & Krings, 2016). Factory automation, assistance systems, chatbots, digital logistics systems and other applications are not ready-made plug&play solutions that can simply be bought off-the-shelf. Mostly, generic hardware and software tools need to be adapt-

ed to their specific context, which involves feedback loops between IT expertise and domain-specific knowledge (Krzywdzinski & Butollo, 2022). Agile forms of software development have become the norm, in which there are several feedback loops between software providers and their customers involving reflections upon the definition of problems, possible procedures and user experience design (Boes et al., 2016). It can be suspected that the context-specific implementation also is a requirement for the introduction of generative AI at the workplace, which needs to be adjusted to the requirements of specific workplaces, organizations and the institutional context.

Yet, social innovation does not only encompass the design of technology as such, but also the way organizations are adjusted. Sociological research has shown, that technological change can best be grasped from the perspective of socio-technical systems (STS), a framework addressing the interactions between technology, organizations and individual actors (Hirsch-Kreinsen, 2020). The introduction of technologies often requires adjustments of work organization and training schemes and sometimes new requirements arise, such as the installation of IT or digitalization departments or the recruitment of data protection officers.

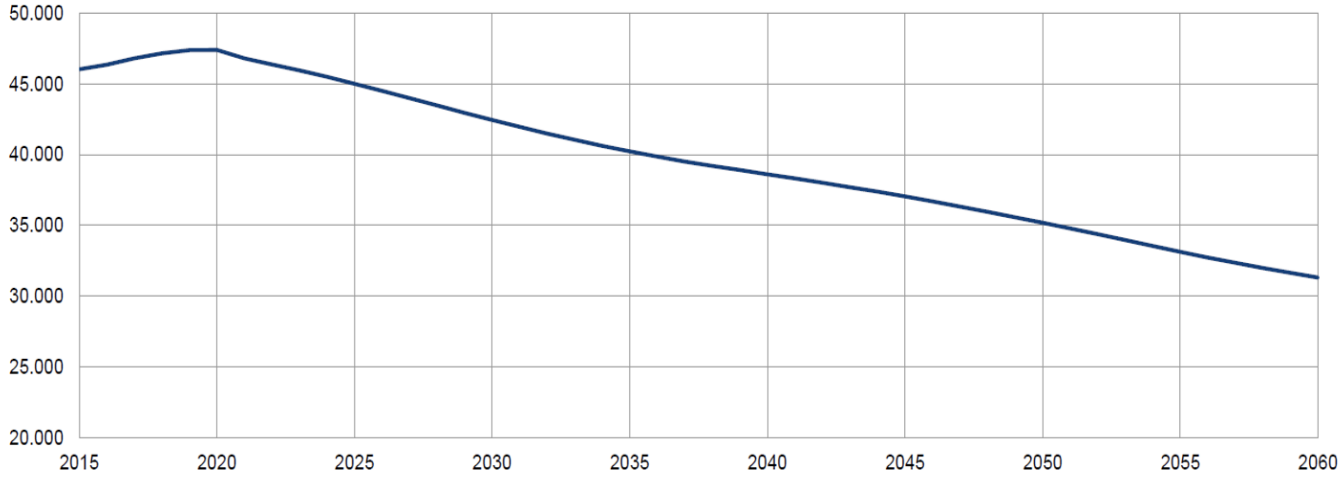
These requirements are reflected in a tremendous increase of demand in professions that deal with the implementation of digital technologies. In Germany, just like in many other OECD countries, there is a pronounced lack of IT staff of various skill levels (Flake et al., 2023). Researchers by the Oxford Internet Institute furthermore have identified that AI skills are particularly valuable on current labour markets, "increasing worker wages by 21 % on average" (Stephany & Teutloff, 2024).

Contrary to public perception, AI in particular generates employment. Machine learning algorithms rely on huge amounts of data for training purposes that needs to be acquired, prepared, cured, stored, analysed, and used. Labour-intensive data value chains (Curry, 2015) are emerging that not only encompass legions of software engineers, UX designers, project coordinators, and data protection officials, but also thousands of data annotators and content moderators that mostly toil in facilities in developing countries, often using private equipment. These jobs came into being because of AI and reflecting the growing complexity of the overall division of labour.

3. **Work of societal reproduction:** The third rebound exists because automation strategies are entangled with a capitalist growth imperative that tends to exhaust societal resources of reproduction. Growing labour market participation has drained the resources for care in the context of restrictive funding of public services (Dowling, 2021; Fraser, 2022). With regard to the situation in Germany, the public intellectual Jutta Allmendinger refers to a lack of "skilled labour in public households". She demands short full-time employment for all, in order to unlock additional manpower for care work in the private realm (Anger & Specht, 2023). And in most countries, hospitals, kindergartens or care facilities are severely understaffed. In our highly-automated societies, there is an increasing lack of people that support elementary functions of reproduction and this situation is likely getting worse with demographic change and given the difficulties to rationalize and automate services in these areas (Baumol et al., 2012). The societal rebound is creating strong demand for additional labour power.

The same accounts for the ecological crisis. If the necessary U-turn that saves our societies from self-destruction is to succeed, a substantial reconstruction of businesses and infrastructures is mandatory. Enterprises face the challenge of a dual transition (digitalization + decarbonization), which requires substantial resources and aggravates the labour demand to implement digital technologies mentioned above. But the ecological transition also requires to rebuild energy systems, build recycling facilities, refurbish housing and people are needed to do that. In the German case, it has been estimated that there is a lack of around 60.000 skilled staff for the installation of heat pumps, a soon-to-be mandatory type of more ecological heating (Münch et al., 2023). And this is only one out of many fields of our societies' reconstruction and refurbishment. The ecological transition requires a very high amount of work!

6 Labour shortages as the new normal



Source: Fuchs et al. 2021, without immigration effects with constant employment participation rate.

While demand for labour is rising, it is well-known that supply is dramatically shrinking because of the effects of demographic change. In Germany, the projections about labour force potential are displayed in figure 6. Even when a higher labour market participation rate and substantial immigration is accounted for, the labour force will dramatically shrink in the coming decades. It is noteworthy, that the total labour force in 2024 is still at its peak. The severe shortages of labour that are a much-debated subject in the German public are not yet the product of demographic change, but rather of rising demand for labour.

The degree to which demographic change leads to a loss in the working population differs, across countries. Nevertheless, there is a strong tendency for a shrinking working population in most OECD countries and in the OECD as a whole (Abeliansky et al., 2020; Acemoglu & Restrepo, 2022). Permissive immigration and binational work migration schemes can mitigate the effects of a loss in the working population to a certain extent. Yet, at least in Europe it is unlikely to fundamentally alter the situation and recently there has been a strong trend towards more restrictive immigration policies.

Labour supply is not only a matter of birth rates and immigration laws, however. The care crisis constitutes a barrier to significantly raise the workforce participation rate as many employees which to increase the amount of time they can dedicate to their kin. And there is a cultural dimension, as well, as the attitudes about a desirable working life are changing. This accounts for both the type of work that is chosen by younger generations and the expectations about work-life balance. Many companies in traditional sectors report difficulties in finding candidates for lifelong full-time employment because what they can offer does not correspond to the values of young entrants to the labour market. All in all, the goal to raise the labour participation rate contradicts the desire of most employees to combine work and private matters in a sounder way.

Reckoning with the rebound effects of automation and the effects of demographic change, it is obvious that labour shortages will become *a structural feature of capitalist development* in the coming decades. This conflicts our accustomed perception and has only partially been acknowledged in the social sciences. After all, the 1990s and 2000s have been characterized by mass unemployment in many advanced economies and this legacy still shapes our debates and concepts.

With regard to the subject of this paper, the relationship between digitalization and labour market developments, the acknowledgement of the structural mismatch between labour demand and supply turns widely-held assumptions upside down. I condense the likely outcomes to two hypotheses.

1. Labour shortages drive investment in digital technologies. Rather than causing unemployment, digitalization is used to mitigate the problem of not finding enough people. Automation, digital assistance systems and artificial intelligence systems are often tailored to this task and technology implementation processes are often shaped by narratives and objectives in this sense. This relationship has recently been confirmed in quantitative analyses (Abeliansky & Prettner, 2023; Acemoglu & Restrepo, 2022) and is also verified by various own qualitative case studies (among them those discussed subsequently).

2. In the context of labour shortages, collective bargaining will increasingly be shaped by conflicts about excessive work burden. The requirement of management to demand more from fewer people fundamentally conflicts with subjective expectations about a sustainable and meaningful work life and a better work-life-balance. The narrative that technology can mitigate excessive work burden has recently gained traction, but it seems unlikely that it will be able to deliver as long as the underlying causes that drive complexity are not addressed.

Labour shortages, technology, and work burden: empirical illustrations

My hypotheses on the relationship between digitalization and labour markets will subsequently be illustrated by three empirical illustrations on low-skilled work in logistics, skilled work in industry and geriatric care. The first and the second case study are based on own empirical investigations, while the third case study is derived from literature. The material from heterogenous sources is not meant to systematically test the stated hypotheses (larger research projects will be necessary to do so), but to illustrate the reasoning behind them.

a) Low-skilled work in logistics[1]

Contemporary employment regimes in logistics have become an anachronism in the context of labour shortages (Butollo & Koepp, 2020). They evolved in the context of excessive labour supply and logistics warehouses often were built in proximity to deindustrialized zones with high rates of unemployment (Moody, 2017). Very high rates of labour turnover are a characteristic of most warehouses. In a warehouse of a large e-commerce provider in Eastern Germany that I visited in 2016, about half of the workforce of 3.000 employees left the company each year (Butollo et al., 2018). While such rates of turnover used to be manageable in the context of mass unemployment, the labour market does not support such constant high demand any more. In Germany, labour shortages in the area of unskilled work are commonplace and the companies have started to poach each other's workers.

Automation is increasingly seen as a means to counter labour shortages and, in fact, there are strong efforts to implement automated guided vehicles, pick robots, automated sorting facilities and other devices. At the same time, digital assistance systems are introduced that lower the requirements with regard to skills and even language requirements so that people without prior knowledge can be hired (Butollo et al., 2018; Krzywdzinski, 2022).

Contrary to the expectations nourished in the media, the introduction of automation in logistics is progressing slowly (Koepp, 2023; Moody, 2018). Logistics is a highly cost-sensitive sector with low margins, which makes it difficult to fund complex automation arrangements (Gutelius & Theodore, 2019; Pulignano et al., 2022). What is more, there are high requirements of flexibility both in terms of the objects that are handled in warehouses and in terms of capacity utilization that differs significantly between seasons (Dörflinger et al., 2020; Jaehrling et al., 2018). Many companies engage in efforts to automate, but moves back and forth and progresses by trial and error, as my colleague Robert Koepp has shown in the case of warehouse automation at a major logistics provider (Koepp, 2023).

With the rise of e-commerce, the total turnover of goods that are processed in logistics operations has constantly increased, and so have in labour-intensive logistics operations. While large logistics providers like Amazon or DHL therefore try to rationalize their operations, their total number of employees has increased, not declined.[2] Constant absolute growth of demand represents the most obvious rebound of automation in this industry.

The case of logistics warehouses in Germany hence shows that automation is partly motivated by severe labour shortages that do not only concern skilled workers, but also workers without specific qualifications related to logistics. Yet it also shows that automation progresses slowly and is ill-equipped to counter these labour shortages in a meaningful way. German companies in logistics therefore increasingly resort to organized efforts to recruit workers abroad. But experts in the industry admit that this has become more difficult in the recent past. Some companies also started to offer slightly improved conditions and to build back fixed-term employment and dispatch labour in order to reduce labour turnover. This situation implies a significant alteration in power relations and could provide favourable conditions for trade unions.

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1 This synopsis is based on discussions and qualitative empirical data on automation in the German logistics industry I conducted with Robert Koepp in the context of the research group "Working in highly-automated, digital-hybrid processes" at the Weizenbaum Institute for the networked society.

2 According to interview data from 2020, the demand for labour in Amazon's so-called "robotic fulfilment centres" is about one sixth lower than in conventional ones. Since 2021, the company has invested in six new fulfilment centres in Germany, increasing their total number to 20 (https://www.aboutamazon.de/news/logistik-und-zustellung/fakten-ueber-die-amazon-logistikzentren).

b) Skilled work in industry[3]

A single case study of a company in the German mechanical engineering industry reveals a similar relationship between labour shortages and technology. The company in a Bavarian small town experiences, like many peers, a difficult situation in terms of the availability of skilled staff. In the coming years, many experienced workers will retire and the company not only risks losing their formal skills, but also the experiential and tacit knowledge that was built up during decades of constant employment in the firm. Management also complains about severe problems with recruiting new workers and complains about the shift of values attitudes among young candidates who rather want to work in service functions in urban areas and enjoy the benefits to travel and work remotely, than to accept a life-long occupation in industry that requires physical presence in a provincial town.

The ambitious automation strategy of the company takes account of these difficulties. It is justified not only with view to general efficiency gains, but as a means to liberate skilled labour from basic routine elements so that they can dedicate more time to demanding tasks. Digital assistance systems in the assembly department can be operated in a "beginner" or "expert" mode, acknowledging that it won't be able to always mobilised skilled workers for the task, but also guaranteeing that, if skilled workers are available, they won't be bothered by too detailed work instructions. In the quality control department, an automated scanning software fulfils time-consuming functions in fault detection that are currently taken on by skilled workers. According to the management, the implementation of the software would make skilled workers available for more sophisticated tasks in other fields.

All in all, implementation of technology at this industrial company is shaped by the difficult labour market context. This is evident in terms of the narratives that surround it, and it most likely also corresponds to the motivation of management to make investment decisions.[4] While the introduction of assistance systems and automation software can contribute to allocating the scarce resource of skilled labour in a more suitable way, the substitution effects are limited. The production manager of the company acknowledges that automation will only marginally resolve the problem of labour shortages which are rooted in demographic change and a change in the values and preferences of labour market entrants. Management is particularly concerned about the latter question. While many complaints about the preferences of young graduates are voiced, it is also acknowledged that jobs at the factory need to feature more possibilities for self-fulfilment and career development than in the past in order to attract new workers, for instance by offering mobility and educational options or schemes for better work-life-balance.

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3 This synopsis is based on empirical data I gathered with my colleagues Mario Ottaiano, Leon Hellbach and Jordi Ziour in November 2022.

4 This is reported by various management representatives. The details of the actual decision-making process that led to these investments are not covered by the empirical material, however. The explanations of my interview partners could also constitute a simplification and a rationalization of their actions ex post.

c) Care robotics[5]

The third case study concerns the occupation of elderly care. There are severe labour shortages since many years, while demand is constantly rising due to demographic change. The excessive work burden due to understaffing threatens the stability of employment in this fields. According to a recent survey among caretakers in Germany, 35 percent consider to quit their job each year because of their excessive work burden (Auffenberg et al., 2022).

The political strategies to deal with labour shortages in this field heavily rely on the expectation of a partial relief through digitalization. This expectation is the dominant legitimation for investment in technology in Germany (Krings & Weinberger, 2018). One point in case is care robotics. However, there is a huge gap between such expectation and the actual returns through care robotic, more so than in the priorly discussed fields of logistics and industry. Most care robotics applications are not ready for implementation and where they exist, they have little to do with a substitution of work or a substantial relief of work burden of care takers (Maibaum et al., 2022; Schulz-Schaeffer et al., 2023).

A study on the subject therefore points out a "self-perpetuation of the promise of care robots" (Schulz-Schaeffer et al., 2023). Even though most expectations about the effects of this technology are not realistic, the narrative is constantly revitalized, mainly because there is a convergence of interests and shared sensemaking between technology providers, politicians, and practitioners that all would benefit if these expectations would be met (ibid). The actual effects in terms of reducing the work overload in the health sector by implementing digital technologies seem to be marginal. Work intensity of care workers in highly-digitalized "connected clinics" is not much lower than in clinics that operate with a low degree of digital equipment, according to a recent empirical study (Bringmann, 2023).

It seems therefore futile to hope for a technological solution for one of the major societal problems in our aging societies. There seems to be no alternative to massively improve the conditions in care professions to counter labour shortages. As this requires to systematically hire more staff, the employment strategies in elderly care are caught in a catch-22 dilemma. As the study on German caretakers' preferences concludes: "more staff is required, to attract more staff" (Auffenberg et al., 2022: 78). The care crisis in Germany is a particularly strong example for the insufficiency of technological solutions for countering labour shortages. In absence of a technological solution, there is growing tension and conflict about the workload in hospitals and care facilities that has been the subject of labour struggles in the recent past.

5 This synopsis is based on the quoted secondary data.

Conclusion

The starting point of this contribution was the paradox of rising employment figures despite continuous automation. An interpretation of rising complexity of capitalist development was introduced and three kind of rebound effects of automation identified that lead to continuous demand for labour despite automation: rising complexity of value creation, work related to the introduction of automation, and work needed to mitigate the societal consequences of capitalist development. By way of short case studies on work in logistics, industry and care it was illustrated that the implementation of digital technology is partly motivated by the labour market situation: automation technologies are introduced in order to mitigate labour shortages. The case studies illustrated as well, however, that there are exuberant expectations about the effects of digitalization in this respect. While the narratives about and legitimations for the introduction of digital technologies are heavily shaped by the motivation to combat labour shortages, the actual technologies are barely equipped to do so. They may contribute to liberate skilled labour from unnecessary repetitive tasks, but they are ill-equipped to mitigate the consequences of a major structural shift in the labour markets of most advanced economies.

Hence it seems probable that the question of work burden will play a more prominent role in industrial relations of the future. There is a strong conflict of interests as enterprises need to mobilise more work from fewer people whereas many workers' main interest is to limit excessive work burden and to achieve a better work-life-balance. The ecological and social transformation of our societies indeed are linked because the success of the ecological transformation crucially depends on how work is allocated: for the sake of achieving societal transformation and enabling the ecological turnaround or in the form of "bullshit jobs" (Graeber, 2018) that engender the acceleration and consolidation of the self-consumption of resources.

Similar as in the case of the ecological transition and the rebound effects we experience in this field, the dynamics of self-perpetuating growth, acceleration and rising complexity need to be addressed if sustainable development is to be achieved.[6]

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[6] At hospitals in various regions, workers for the first time achieved collective contracts that contain stipulations about minimum staffing at facilities and a build up of employment.

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