Accelerating technological progress as part of manufacturing digitalization: macroeconomic and microeconomic dualism

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Abstract. The purpose of the paper is to study effects of digitalization for manufacturing and industrial enterprises focusing on the idea of dual nature of factors of technological progress’ acceleration. Based on a theoretical review and interviews with a focus group of 19 representatives of Russian companies responsible for business development, strategy, and digital transformation, the study suggests a summary of insights on microeconomic and macroeconomic factors of technological progress. A dual view is presented on the problem of patterns of technology introduction in order to accelerate technological progress in two subsections: from the point of view of a conglomerate of interpretations based on the microeconomic paradigm, and also from the point of view of the macroeconomic paradigm in an expanded sense, which includes mesoeconomic and ecosystem aspects of technological progress’ acceleration.

1 Introduction

At present, the problem of identifying patterns of introduction of new technologies in order to accelerate technological progress has acquired particular importance. Considering the aspects of digitalization of manufacturing through the prism of this problem allows to better understand how individual technologies and their major sets and complexes with a high degree of complementarity can not only be more quickly, but also more harmoniously and sustainably used in the manufacturing sector and adjacent industries.

Studies of this issue can be conducted from several major angles and perspectives.

Firstly, a separate direction of research is devoted to the issue of scaling one or more interconnected technologies, both in terms of their technical feasibility and commercialization. The problem of reducing the cost and the time of R&D is quite comprehensively developed. It is widely known that the introduction of new technologies is especially effective in terms of assembling prototypes and accelerating the release of new technologies.
products, including in various variations and modifications. The major studies in the field indicate that having industry leaders already adopting certain technologies or their sets and combinations has a positive effect on the further adoption of this technology by other market participants. In addition, the rate of adoption of new technologies by industrial companies can be influenced by such factors as: the size of the company, the growth rate of the industry [1], intercompany interaction [2], the level of competition in the industry [2], cost of implemented innovative technologies [3], as well as the availability of qualified specialists [4].

Secondly, the problem of the reverse influence of the acceleration of technological progress on the possibility of the emergence and implementation of individual technologies has acquired great scientific and practical interest. Here the main focus is on ecosystem effects, however, more particular phenomena in the framework of the innovative activities of industrial companies can also be considered in a broader sense within the framework of this rubric. For example, such a phenomenon as the reduction of unproductive costs in the implementation of innovative activities by companies. Here, as part of the expanding possibilities for customization and personalization, there is a natural niche for the introduction of proprietary technologies that allow industrial companies to respond even more sensitively and quickly to changes in customer tastes and preferences by switching to new or modified products and testing them faster [5].

The flexibility of production implies the technical and organizational ability to quickly change over equipment within the framework of new tasks, taking into account the requirements of customers and consumers of the final product [6].

Thirdly, it seems very promising and productive to consider the impact of introducing new technologies in order to accelerate technological progress in the broader context of analyzing the development of business models (including innovative ones) and the digital transformation of individual enterprises and industries, since the success of modifying business models and digital transformation projects of enterprises and industries are heavily dependent on the somewhat abstract category of “accelerating technological progress”. Within this framework one can specifically emphasize some epistemological one-sidedness which is inherently present in understanding the acceleration of technological progress as a certain predominantly abstract category within general social progress.

The pace of digitalization depends not only on the development of technologies themselves. L. Berg and colleagues pay attention to the aspect of cultural and social transformation [7], talking about the pyramidal structure of the digital economy, where the fundamental layer is a data-based culture, or data-driven culture, which is understood as a culture of willingness to create and transfer data along the entire value chain.

In no case can one deny the importance of the aggregated, macroeconomic nature of the acceleration of technological progress (including from the perspective of considering how such phenomena as technological progress and social transformation, technological progress and social change are interdependent). In this connection, a number of countries have developed and have already been implementing their policies of cyber-physical systems and digital production to accelerate technological production. Germany became the first country to implement a holistic strategy for the development of the fourth industrial revolution [8]. The initiative of Germany over the past decade has become generally accepted by almost all the leading economies of the world, to one degree or another. Many countries have followed a similar path, offering their programs, strategies and plans for the development of the sectors of the fourth industrial revolution. China announces its 2025 plan “Made in China 2025” and “Internet Plus” program to take the manufacturing industry to the next level [9, 10]. Countries have introduced similar policy initiatives and significant research efforts have been spent on the development and deployment of some of the
Industry 4.0 technologies: Industrial Internet Consortium (USA), Produktion 2030 (Sweden), Industria 4.0 (Italy), and Society 5.0 (Japan), as well as many others. It is also particularly interesting that just ten years after the introduction of Industry 4.0 in the European Union, the beginning of Industry 5.0 was announced. As part of the distinction between the two stages, Industry 4.0 is considered as predominantly technology-driven while Industry 5.0 is expected to be substantially value-driven. Industry 5.0 is understood as recognizing the capacity of industry to achieve social goals beyond jobs and growth as a sustainable source of prosperity, with a comprehensive understanding of the ecological boundaries of our planet and the overall well-being of the worker (Figure 1).

**Fig. 1.** Core values of the concept of Industry 5.0. Based on [11].

Within the framework of the main values of Industry 5.0, a human-centric approach puts basic human needs and interests at the heart of the production process, moving from technological progress to a fully human-and-society-centric approach. One of the central priorities of Industry 5.0 is that industrial workers must continue to upskill and reskill to improve career opportunities and work-life balance (and there is a growing realization, a proper improvement in work-life balance is needed after all preceding broken promises).
For an industry to respect planetary boundaries, it must be sustainable. Resilience primarily implies the need to increase the resilience of industrial production, better protect it from disruptions of any kind and level, and ensure its ability to provide and maintain critical infrastructure during times of crisis, including political tensions and nature disasters.

2 Methods

The study is interdisciplinary economics, management theory, decision theory and industrial digitalization were used as a theoretical foundation. Other theoretical methods of research (abstraction, analysis and synthesis, induction and deduction) were also used. The empirical part of the study is based conducting semi-structured interviews with a focus group of Russian manufacturing and industrial companies’ managers, who are responsible for business development, strategy, and digital transformation in order to produce a comprehensive summary of insights on macroeconomic and macroeconomic factors of technological progress.

3 Results

According to the empirical part of the study based on semi-structured interviews with the focus group the main insights on macroeconomic and macroeconomic factors of technological progress are as follows. At the current stage, the technological structure of Industry 5.0 is not entirely clear. Even Industry 4.0 is still faced as a separate concept with some criticism regarding the completeness and consistency of the overall technological framework (platform). Although the initial sharp criticism and skepticism about Industry 4.0 has faded away in recent years, as the outcomes of the fourth industrial revolution has become systemic and irreversible.

Reasoning about Industry 5.0 in the current versions, declaring, first of all, the maximum humanization of the economy at the microeconomic level, may seem somewhat speculative. Undoubtedly, technological progress acts as a great facilitator of frugality, environmental friendliness, but the dynamics of sustainability and resilience of industries and sectors of the economy, depending on technologies, is characterized by inconsistency, ambiguity, and non-linearity of processes. Regarding technologies, there is no fundamentally new one that is not already at least partially present in the interpretations of Industry 4.0. That is why it is a big challenge to sufficiently differentiate Industry 5.0 from Industry 4.0.

The main technological framework (platform) of Industry 5.0, is quite similar to Industry 4.0 mix of technologies, albeit it is just somewhat more advanced and ambitious, with a more distant time horizon: biotechnologies and intelligent materials that allow the use of materials with embedded sensors and advanced features, while being recyclable; artificial intelligence to detect cause-and-effect relationships in complex dynamic systems, which leads to the formation of a more “effective” intelligence (actionable intelligence).

The Boston Consulting Group has identified nine key assistive technologies for Industry 4.0, while the EU has identified six enabling technologies for Industry 5.0. Both technology pools clearly overlap. Why such a technological shift, which is not obvious in terms of scale (besides, the degree of its significance and achievability in the foreseeable future is debatable) should lead to some new business philosophy, a sharp breakthrough in the humanization, resilience of industries – this is not entirely clear. So far, this is more like a kind of declarative techno-optimism, i.e., such an ideological position, within which there are inflated expectations from scientific and technological progress despite actual systemic contradictions, difficulties and problems in the course of social development.
In addition, the thesis of the humanization of production in the most expansive interpretation can be criticized in terms of general socio-economic trends over the past two decades. It would seem that the fourth industrial revolution should have been accompanied by an improvement in the indicators of overall socio-economic dynamics. But in the advanced economies of the world, despite a general progressive transformational trend in industries, there has been a deterioration in socio-economic well-being both at the level of local communities and at the national level. The new technological order in industries has so far contributed little to solving the growing problems: the long-term stagnation of real wages, the deprivation of territories, and the decrease in housing affordability. At the same time, research appears to have long lacked a more microeconomic interpretation of accelerating technological change as the sum of individual instances of change in business models and digital transformation projects. Undoubtedly, such an approach can be too reductionist if there is a complete denial of qualitative changes at the level of aggregation of economic entities at the level of industries, industry complexes, regions and the country. However, a major research task should be to fill the traditional gap in the comprehensiveness of understanding how the introduction of technologies within individual business leads the general acceleration of technological progress. The emergence of new and powerful digital technologies, digital platforms and digital infrastructures has fundamentally changed innovation and entrepreneurship. Beyond simply opening up new opportunities for innovators and entrepreneurs, digital technologies have a broader meaning for creating and capturing value [12].

4 Discussion

At the same time, technological progress can dematerialize the economy, facilitating the supply of digital goods and services, which are an increasingly large part of the economy and exports; the increasing importance of digitally delivered services reduces the movement of economic actors and their associated emissions. A deeper change in consumption is expected with the development of the product as a service (PaaS) model, which allows comparing the desired result from using a product without buying it. New technologies are leading to a more integral, sustainable and strategic integration of service components into the overall product shell. As an illustration, Mobility as a Service (MaaS) uses this model to bring transport services from public and private providers together through a single gateway that creates and manages trips. This reduces carbon emissions and optimizes the space occupied by vehicles, helping to move towards greener cities. At the same time, new business models, such as the gig economy, are optimizing the use of existing resources, increasing the opportunities for capital use thus drastically improving the efficiency of operations and providing the most companies in the new sectors and subsectors with high margins.

Digitization also eliminates intermediaries, reducing transaction costs and links in value chains, with consequent savings in energy and resources. At the same time, the cognitive landscape of the sectors of the "new economy" is so complex that interpretive aspects in decision-making come to the fore. A certain increase in the efficiency of perceptions and interpretations (primarily due to the realism of ideas about the true potential of companies' business models and the probability distribution of various business development scenarios) for industry stakeholders is the most difficult interdisciplinary scientific and practical task. According to estimates by some research organizations, intangible assets have reached almost 90% of the S&P500 capitalization definition, and the share of tangible assets in capitalization determination has decreased to 10%, which is half as much as 20 years ago. Whether it is possible to say that the situation with such a high importance of intangible assets for determining the value of a business has...
now gone too far, or, on the contrary, that this is just a normal situation (“new normal”) in
the modern innovative and transformational landscape of the economy is a very debatable
question.

The noted aspects are important both for the competitiveness of Russian industrial
enterprises and in the context of achieving a more stable and resilient margin
for their business. New technologies offer a significantly greater variety of segments and niches for
building new business models. An example here is the ability to use monthly subscription
services instead of directly selling machinery and equipment. This is especially important
because, on average, the service components of business models have been shown to be
more cost-effective over the past decade. What attracts investors, and the companies
themselves have an internal resource for accelerated development.

According to many researchers, practitioners and analysts, the central aspects from the
point of view of the microeconomic paradigm of accelerating technological progress
through the introduction of new technologies are the integration of the culture of
accelerating technological change into the overall change management and leadership in
industrial companies. After all, the fourth industrial revolution and the introduction of new
technologies are all about productivity, flexibility and competitiveness. New technologies
help manufacturers reduce production costs; increase the potential for the development and
creation of new products; adapt to changing customer requirements; grow at a much higher
rates in comparison to the industrial average level.

The central microeconomic factor that positively influences the adoption of new
technologies by industrial companies is the experience in implementing such projects.
Industry 4.0 technologies are usually complex, which requires the project manager to have
in-depth knowledge in this area. In addition, the readiness of industrial companies and their
existing infrastructure to integrate new equipment is crucial. This factor, associated with
successful cases, allows an organization to improve the accuracy of its planning regarding
the implementation of the technology, the approximate period of return on investment, and
evaluate the positive and negative aspects of the implementation of the technology.

The macroeconomic paradigm of the introduction of new technologies implies, first of
all, a better understanding of the ecosystem and multiplier effects from the introduction of
new technologies for the entire economy, including in terms of certain positive externalities
associated with the acceleration of technological progress. A good and relevant example
here is the recent strong growth in the market for high-tech industrial equipment and
semiconductor electronics, which has led to a shortage of component base for many
industries, including the automotive industry. This growth is accompanied by both the
development of relevant technologies and the overcoming of various barriers that hinder t
the development of relevant industries, as well as the acceleration of scientific and
technological development not only in leading industries, but also in related ones.

5 Conclusions

A dual view is presented on the problem of patterns of technology introduction in order to
accelerate technological progress in two subsections: from the point of view of a
conglomerate of interpretations based on the microeconomic paradigm, and also from the
point of view of a conglomerate of interpretations based on the macroeconomic paradigm in
an expanded sense, which includes mesoeconomic and ecosystem aspects of technological
acceleration.

The designated dual research principle makes it possible to better understand at least
some of the patterns of technology implementation. Because digitalization matters at
different levels of analysis (individual, organizational, ecosystem/community, regional/public). For example, consider privacy and data security. Clearly, new digital
infrastructures and platforms such as social media, mobile computing, and cloud computing raise serious privacy and security concerns for individual users or consumers; however, importantly, these concerns also create ripple effects that spill over to firm-level issues (e.g., firm-customer relationships, firm reputation) and social issues (e.g., social media as a surveillance tool, distrust to the media and democratic institutions) [12].

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