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Conceptual Paper

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The productivity growth slowdown in advanced economies: causes and policy recommendations

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Abstract: The growth of total factor productivity (TFP) in advanced economies has slowed significantly after the 1970s. The global financial crisis (GFC) has resulted in the second productivity growth slowdown. This paper, on the basis of a broad literature review, identifies the structural forces and legacies of the financial crisis, explaining the productivity growth slowdown and providing possible policy solutions. The mismeasurement hypothesis is also discussed. The slowing pace of innovations, population aging, slowing human capital accumulation, limits of structural transformation, capital misallocation, and firm-level factors are identified as structural forces slowing TFP growth. Lack of capital deepening, financial frictions, and slowdown of international trade are the most important legacies of GFC affecting productivity growth.

Keywords: macroeconomics, productivity, TFP, productivity growth slowdown **JEL Classification:** D24, E01, E24, O47

1 Introduction

As Paul Krugman famously wrote, productivity is not everything, but in the long run, it is almost everything. Rising output per worker is crucial in improving living standards over time [Krugman, 1994]. Different productivity levels are significant in explaining why countries having similar amounts of production factors produce different amounts of output [Hall and Jones, 1999]. Total factor productivity (TFP) growth has been identified as the most important source of economic growth during the many decades of US history [Hulten, 2001], as a crucial source of industrial revolution in East Asia [Hsieh, 2002], and as a main or – in some countries – the second most important contributor to economic growth in Central Eastern European economies after the economic transition [Levenko et al., 2018]. Productivity growth is also a determinant of the success on the firm level [Syverson, 2011]. Due to its importance, productivity growth is one of the most important topics in macroeconomic research.

Between 1920 and 1970, the advanced economies of the world experienced high and stable growth of TFP; but, after 1970, TFP growth has slowed significantly. In the United States, in the late 1990s, TFP growth increased temporarily; however, after 2004, it slowed down again. If the post-2004 productivity growth slowdown had not happened, the US gross domestic product (GDP) in 2015 would have been \$3 trillion (17% of the US GDP in 2015) higher than it actually was. This value corresponds to an additional \$9,300 for every person or \$24,100 for every household in the United States [Syverson, 2017]. This estimate shows that productivity growth slowdown is an interesting research topic not only because

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of its theoretical importance, but also, foremost, due to the huge costs associated with it. It has immense consequences that affect all American citizens. Productivity growth slowdown is not constrained to the US economy. A broad sample of advanced economies showed similar productivity developments [Bergeuad et al., 2016].

This paper presents the explanations of this phenomenon that have been identified in economic literature and provides possible policy solutions. First, the recent developments in productivity growth are placed in the historical context and the mismeasurement hypothesis is discussed. Then, structural factors, such as the slowing pace of innovations, population aging, slowing human capital accumulation, slowing transition from low- to high-productivity sectors, capital misallocation, divergence among firms, and lack of business dynamism, are debated. Lack of capital deepening, presence of financial frictions, and slowdown of international trade are indicated as the important legacies of the financial crisis that affect productivity growth.

Section 2 presents how economists define and measure productivity growth. Section 3 contains data on productivity growth in selected advanced economies. Section 4 describes the ongoing debate between techno-optimists and techno-pessimists on the basis of influential books written by Gordon [2016] and Brynjolfsson and McAfee [2014] while also dealing with the mismeasurement hypothesis. Section 5 contains a review of the long-term forces explaining productivity growth slowdown, while Section 6 deals with the legacies of the financial crisis slowing productivity growth. Section 7 presents possible policy solutions that would enhance TFP growth. The last section concludes the paper.

2 Methodology and measurement

Productivity is commonly understood as the ratio between the volume of input and the volume of output factors. Economists have established production functions to represent the relationship between the amount of inputs and the amount of output that can be produced using existing technology. Among the many existing production functions, the Cobb–Douglas production function is the most widely used.

The Cobb–Douglas production function has the following form:

 $Q = AL^{\alpha}K^{\beta}$

where *Q* is the quantity of production, *L* is the quantity of labor, *K* is the quantity of capital, *A* is a positive constant representing the TFP, while α and β are constants between zero and one, representing the output elasticities of labor and capital. The Cobb–Douglas production function is homogeneous of degree one. The marginal products of each input are positive and declining.

Further, if: $\alpha + \beta = 1$, the production function has constant returns to scale. However, if $\alpha + \beta < 1$, returns to scale are decreasing, whereas if $\alpha + \beta > 1$, returns to scale are increasing. Assuming perfect competition, α and β can be shown to be the shares of the outputs in terms of labor and capital.

TFP (also called multifactor productivity) measures that growth of the output that cannot be explained by the growing volume of production inputs. It is often interpreted as the contribution of technological progress and better organizational techniques. Such a definition of TFP is very useful and intuitive, but it has an obvious limitation. We know that the TFP growth is "everything other than growth of inputs," but we do not know what it exactly is. If we try to understand why TFP growth has slowed, this constraint is especially significant because we have to identify the factors that affect a very broad phenomenon, which we have defined and measured only indirectly.

In the simple model, aggregate TFP growth is a result of two forces: within-firm productivity growth and allocation of resources across firms [Adler et al., 2017]. Within-firm TFP growth is based on innovations, as well as adoption of better technologies and management practices. It is important to underline that within-firm TFP growth is heterogeneous [Andrews et al., 2016]. Some firms actively innovate at the technology frontiers, while other firms lag behind and adopt existing innovation.

Empirical research presented in this paper suggests that increasing firm heterogeneity is one of the important sources of TFP growth slowdown.

If markets are competitive and function properly, resources move to firms that use capital and labor most productively at the margin. In this case, resource reallocation leads to TFP growth. Many markets are imperfect, and it is possible that production factors are misallocated due to real or financial frictions, market power, low mobility, or regulation [Gopinath et al., 2017]. A negative impact of the misallocation of production factors on TFP growth is a robust result in empirical research [Restuccia and Rogerson, 2017].

Although the concept of productivity is straightforward and intuitive, its measurement is challenging. An array of methodologies is available for researchers working on this issue. Discussion on the structure and the pros and cons of available methodologies can be a topic for a separate article [Del Gatto et al., 2011; Van Beveren, 2012] or a book [Grifell-Tatjé et al., 2018]. Therefore, we have decided to constrain ourselves to description of the methodology of productivity measurement contained in the Organisation for Economic Co-operation and Development (OECD) Productivity Manual [OECD, 2001], which is a canonical work on this issue used by statistical offices in OECD member states and researchers.

The OECD Manual adopt the index number approach. More advanced econometric approaches can also be used for the calculation of productivity growth, but their description is out of the scope of this paper. Moreover, they are usually challenging to implement at the level of statistical offices. Growth-accounting techniques examine the extent to which the observed change in output can be explained by the change in combined inputs. Therefore, growth accounting evaluates productivity growth residually. The OECD Productivity Manual is focused on the measurement of productivity on the sector level, which is the usual unit of analysis.

To develop the index of industry output, different outputs have to be weighted with their share in the total output. It should be remembered that price indexes for output can be difficult to measure, especially in the case of high-technology industries and advanced service sectors such as finance, health, or education. Moreover, measurement of output prices should be augmented by the inclusion of the quality change. Proper inclusion of rising quality is crucial in the context of the information and communications technology (ICT) revolution. Most of the ICT-intensive goods today have much better characteristics than 20 years ago, but also lower prices. If the prices of ICT-intensive goods used in the calculation of productivity growth do not reflect the quality gains of the produced output properly, our measure of productivity growth would be biased down.

Measurement of output can be based on the gross output or the value-added approach. In the first approach, output is equal to the sum of goods and services produced within a producer unit available for use outside the producer unit. In the value-added approach, purchases of intermediate inputs are deducted from the gross output. Therefore, we can interpret output in the value-added approach as a net measure.

To construct the index of combined inputs, different inputs have to be weighted with the factor income shares. Although the number of hours worked is the most important input in many sectors, this measurement can be challenging and requires the combining of information from many statistical sources. Usually, household-level and firm-level surveys are combined to summarize the household and the firm perspectives. To calculate the number of hours worked, first, salary-based employment and self-employment have to be combined. Thereafter, the number of persons employed should be converted to the number of normal hours worked. In the third step, the number of normal hours worked should be corrected by the overtime and work absences such as sick leave or vacation time. Sometimes, labor input is measured using the concept of full-time equivalent job, where the part-time employees are counted with smaller weights than for persons working full time. Moreover, measurement of the number of hours worked should be treating the hours of work of an experienced surgeon or software developer as being equal to the hours of work of a teenager in a grocery shop.

Capital input is measured by the flow of productive services from the cumulative stock of past investments. Service flows are usually not directly observable and have to be approximated by assuming that they are in proportion to the stock of assets. The price of capital services is measured by their rental price. In some cases, rental price is directly observed on the market. In other cases, productivity researchers have to approximate user costs, which represent the amount of rent that would be charged on a given asset. Measurement of capital inputs should be corrected by a depreciation on the basis of age–price profiles and by loss of efficiency over time on the basis of age–efficiency profiles.

Productivity is measured as a quantity index of output over a quantity index of inputs. Although many different index formulas are available, the Laspeyres and Paasche index, the Fisher index, and the Törnqvist index are most widely used. The choice of index should be based on a series of criteria or the economic theory. After the establishment of sector-level productivity, the indexes should be aggregated on the economy level. Simple aggregation, however, does not account for the link between sectors such as, for instance, the flow of intermediate inputs. If two connected sectors experienced productivity growth of 1% each, the combined productivity growth will be >1% because the productivity gains of the first sector combine with the productivity gains of the second sector as the first sector buys intermediate inputs from the second sector. To form an aggregate measure of productivity growth, the sectors are usually integrated into larger units, which thereafter are further integrated in increasingly larger units. In this process, intra-industry deliveries are netted out to obtain consistent higher-level productivity measures.

Investigating the causes of productivity growth slowdown, we should separate the structural forces from the cyclical factors. On the one hand, productivity growth slowdown began in the 1970s, while on the other, the global financial crisis resulted in the second productivity growth slowdown. The reasons for both of these could be connected, but they may also be different and may require distinct policy responses. Economists should carefully chose the econometric techniques used to achieve this aim.

3 Data

Even in the case of advanced economies, the possibility of measurement of TFP growth in the long term is limited due to the availability and quality of macroeconomic data. The United States and the United Kingdom give us the best opportunity to analyze productivity growth over a period extending more than a century and to place TFP growth slowdown in a long-term perspective.

Figure 1 present the annualized growth of the output per person, output per hour and hours per person in the US in years 1870-2014. The past 150 years of the economic history of the United States can be divided into three periods. Between 1870 and 1920, the average growth rate of output per person equaled



Figure 1. Annualized Growth Rate of Output per Person, Output per Hour, and Hours per Person, United States 1870–2014. **Source:** Gordon [2016].

1.84% per year, while the average growth rate of output per hour stood at 1.79% per year. Number of hours worked per person increased on average by 0.05% per year. During the second period, the growth rates were significantly higher. Between 1920 and 1970, output per person rose on average by 2.41% yearly, while output per hour increased on average by 2.82% per year. High growth of output was accompanied by the decrease of working hours per person at the rate of 0.41% per year. In the third period spanning from 1970 to 2014, growth was remarkably slower than in the previous one. Output per person and output per hour grew on average only by 1.77% and 1.62% per year, respectively. Number of hours worked increased again by 0.15% per year. According to the Solow model, economic growth can be decomposed into (i) the growth in the amount of production factors available in the economy and (ii) the growth in TFP, which represent the technological progress and innovations leading to the more effective usage of production inputs. Contributions of education (representing the growing value of labor) and capital deepening were roughly the same in all periods. TFP growth in the 1920–1970 interval was three times higher than in the other two periods [Gordon, 2016].

Although different countries have their own unique economic history, sometimes, similar patterns can be observed. The Figure 2 presents the annualized TFP growt in the UK in years 1870-2014. In the United Kingdom, the TFP growth equaled 0.69% per year in the first period, increased to 1.95% per year in the second one, and decreased to 1.02% per year in the last one [author's own calculations on the basis of data from Bank of England, 2016]. A surge in the productivity growth resulting from the second industrial revolution has been also identified in the sample of 13 advanced economies [Bergeuad et al., 2016].

If we compare the precrisis and postcrisis TFP growth levels, we can identify the second productivity growth slowdown. During the last decade before the financial crisis, labor productivity grew on average by 1.1% in the euro area, while over the period 2008–2016, growth slowed significantly to 0.8% per year. This slowdown is even more significant if we consider only the period of economic recovery because, after 2013, the annual labor productivity growth equaled just 0.6%. This slowdown is evident regardless of how we measure productivity [European Central Bank (ECB), 2017]. The TFP growth slowdown following the global financial crisis is widespread and persistent across a broad sample of advanced, emerging, and low-income countries [Adler et al., 2017].

Productivity growth slowdown is even more surprising in the context of intellectual property statistics. According to the World Intellectual Property Organization [2017], the number of patents granted per year has been growing fast since the beginning of the statistics for 1980s. In 2016, 1,400,000 patents were granted worldwide, while in 1996, this number stood at <600,000. In 1983, only 397,530 patents were granted. The number of patents granted is, of course, not a perfect measurement of technical progress, but the fact



Figure 2. Annualized TFP growth in the United Kingdom, 1870–2014. **Source:** Own calculation on the basis of data from the Bank of England [2016].

that the "computer age," as famously quoted by Robert Solow (1987), can be seen everywhere, but in the productivity statistics, it is clear.

4 Impact of ICT on productivity growth and the issue of mismeasurement

Job automation and the broader impact of the ICT revolution on economy and society are today among the most important topics in public debate. Techno-pessimists usually place development of the digital technologies in the context of the Second Industrial Revolution and indicate that, in comparison with the latter, the impact of the ICT revolution on the economy is quite limited. Techno-optimists acknowledge that TFP growth is slowing, but according to many of them, it is only an artificial fact. They argue that modern macroeconomic statistics were developed after the Second Industrial Revolution, and their ability to measure the impact of digitalization on the macroeconomic aggregates is highly limited. Moreover, the ICT revolution is only at the beginning and we have not yet seen its whole impact. "*The Rise and Fall of American Growth*," written by Robert Gordon [2016], who is a Professor of the Social Sciences at Northwestern University, is a canonical book for the first group, while "*The Second Machine Age*," written by Brynjolfsson and McAfee [2014], who are both based at the Massachusetts Institute of Technology, states that ICT will wholly transform our lives in the coming decades. Both books gained the broad interest of scholars and policy makers, in addition to acquiring significant visibility in public debate. Therefore, we have decided to dedicate a part of this section to the description of their most important arguments, put forward the mismeasurement hypothesis, and further discuss the productivity growth slowdown sources in their context.

4.1 The ICT revolution in the context of the Second Industrial Revolution

The main axis of Gordon's [2016] book is a comparison between the impact of the Second Industrial Revolution, which according to the author completely transformed the US economy between 1920 and 1970, and the Third Industrial Revolution, which produced only a short acceleration in TFP growth in the 1990s. Gordon is pessimistic about the future of the US economy. In his view, productivity growth slowdown is not only a temporal phenomenon, but the new norm. He estimates that productivity growth in the 21st century will be much slower than during the past 100 years.

The Second Industrial Revolution occurred between the final third of the 19th century and the beginning of the 20th century. Its most important inventions were electricity, telecommunication, and the internal combustion engine. They have been applied in all sectors of the US economy and have completely transformed the latter. During and shortly after the Second Industrial Revolution, households got networked owing to the rapid development of railroads and the invention of cars, which made traveling much faster and more comfortable. At the same time, new organizational techniques led to the better organization of production and commerce. After the Second Industrial Revolution, its impact could be seen everywhere, while the ICT revolution changed mainly the manner of entertainment.

In 1890, <30% of households had running water, while <15% had indoor flush toilets. In 1910, <20% of households used electricity as primary lighting, while central heating with adaptation rate <10% was even rarer. In 1940, all modern house conveniences were used in 50–70% of households, while in 1970, the adaptation rate reached nearly 100%. By 1940, 57% of Americans lived in cities, which means that urbanization doubled relative to 1870. During the Second Industrial Revolution, American housing stock was nearly completely replaced. Only 7.3% of dwellings existing in 1940 were built before 1880 [Gordon, 2016]. If we compare house conveniences broadly available in the United States in 2017 and 1977, the microwave oven will be the only difference.

After the Second Industrial Revolution, railroad and cars changed the way of traveling. The car was probably the fastest-implemented invention in the history of the United States. The ratio of motor vehicles to the number of American households reached 90% by 1929. Telephone, radio, and new printing

technologies revolutionized communication. Mass production and standardization of mechanical parts highly increased the productivity in manufacturing. Invention of department stores and supermarkets, which was possible due to the progress in transportation systems, decreased the costs of disposal, for both sellers and customers. New technologies, advantage of scale available due to the urbanization process, revolution in communication, and better organization and management techniques transformed the economy and highly increased the TFP.

The Third Industrial Revolution was born in the second half of the 20th century, while its full impact started in the 1980s. Electronics and ICT were the most important technological inventions of that period. Even though inventions of the Second Industrial Revolution are seen everywhere, ICT is responsible for only 7% of US GDP today. The Third Industrial Revolution produced short acceleration of productivity growth in the 1990s, but its impact is already utilized. Moreover, Moore's law, stating that each 2 years, the number of transistors that can be squeezed onto integrated circuit doubles, which highly increases the computing power of processors, does not hold anymore. The pace of the doubling power of computer chips has slowed from an interval of every 16 months to a period of 4–6 years since 2006 [Gordon, 2016].

4.2 Future of digitalization: Is the machine age still ahead of us?

Brynjolfsson and McAfee [2014] acknowledge that productivity growth, as measured by macroeconomic statisticians, is slower than in the past. They state, however, that the Third Industrial Revolution is just beginning and that we should wait to see its whole impact. They also argue that macroeconomic statistics ignores much of the impact of digitalization.

According to Brynjolfsson and McAfee [2014], our civilization is now at an inflection point – early achievements of the Third Industrial Revolution have been already implemented, but much more is still ahead of us. According to their forecasts, over the next 24 years, the increase in computer power will be over a thousand-fold. Moreover, the amount of data digitalized is growing faster than it was assumed in Moore's law. In their view, the creation of true machine intelligence and the connection of all people via a common digital network will transform world economy [Brynjolfsson and McAfee, 2014].

The first phase of the ICT revolution could have ended, but miniaturized products, artificial intelligence, robotics, self-driving cars, 3D printing, and cloud services and big data are still ahead of us. According to the OECD [2017a], the next production revolution will occur because of a confluence of technologies, which range from bioproduction and nanotechnology to 3D printing and digitalization.

Although the Second Industrial Revolution provided many visible and easy-to-commercialize inventions, much of the impact of the Third Industrial Revolution is indirect and hence missed in the calculation of TFP growth. The Internet makes purchase of goods much easier than before, and search machines have significantly reduced the time needed to find information. According to the experiment conducted by Varian [2013], by using Google, we can find an answer to a query four times faster than by using a traditional library, which corresponds to a gain of about \$500 per adult worker per year.

According to Brynjolfsson and McAfee [2014], macroeconomic statistics does not provide an accurate measurement of digitalization. Free content creation is a crucial characteristic of Web 2.0, but it is completely ignored by macroeconomic statistics. Furthermore, much of the commercial content is downloaded illegally, which is also missed by statisticians. We spend thousands of hours using social media, but we do not have to pay for them, which means that consumer surplus increases, while the GDP does not. Although the ICT revolution is silent, it has immense consequences.

4.3 Mismeasurement hypothesis

Are productivity statistics missing the impact of the ICT? This question is crucial for any research on productivity growth slowdown and, therefore, requires careful consideration. If the answer was positive, the productivity growth slowdown would be only an artificial phenomenon and, thus, not the fact. Syverson [2017] provides us with a reliable review of literature dealing with this issue. He compares the TFP growth in the United States

in two periods, namely, 1995–2004 and post-2004, and investigates whether the slower productivity growth in the second period could be an artificial phenomenon resulting from measurement problems.

The mismeasurement hypothesis could take two forms. It is possible that today, prices are a worse indicator of the utility provided by products than in the past because the most popular technologies used by consumers (smartphones, social networks, and media) are monetarily relatively cheap, but they are highly time-expensive. If it is true, GDP will not provide as good a measurement of total surplus as before. The second option is that the price deflator of new technology products is rising too fast or falling too slowly and, therefore, the price indexes used to calculate the value of output do not reflect the output value as reliably as in the past.

If the TFP growth post-2004 had been the same as that between 1995 and 2004, the US GDP in 2015 would have been \$3 trillion (17% of US GDP in 2015) higher than it actually was. This value corresponds to \$9,300 for every person or \$24,100 for every household in the United States. If the mismeasurement hypothesis is true, we should be able to identify the growth of the total surplus equal to nearly 20% of the American GDP, which is ignored by macroeconomics statistics. Moreover, the fact that the extent of TFP growth is slowing in each sector of the economy, not only in the ICT-intensive sectors, ought to be taken into account. Furthermore, the scope of TFP growth slowdown among countries is unrelated to the share of ICT in the GDP of any given country.

Greenstein and McDevitt [2009] estimate that consumer surplus created by the replacement of dial-up Internet access by broadband connection totaled \$4.8–6.7 billion, while in 2015, the total US broadband revenues are estimated to be \$55 billion. If we update the estimation of Greenstein and McDevitt to 2015 data, we reach \$17–26 billion, which is two orders of magnitude smaller than the missing \$3 trillion [Syverson, 2017]. Even the highest estimation of surplus created by broadband [Nevo et al., 2016] is equal to <5% of the \$3 trillion in missing GDP. Time-use valuation approaches provide higher estimates of the surplus created by the Internet, but even the highest of these estimates [Goolsbee and Klenow, 2006] equals only a third of the missing output.

Syverson [2017] estimates an upper bound of the lost output that can be explained by the mismeasurement hypothesis on the basis of those sectors of the economy in which mismeasurement is most likely because they are ICT intensive. Value added by the chosen industries stood at \$813 billion in 2004 and \$1,384 billion in 2015; therefore, these industries experienced real value-added growth of \$571 billion between 2004 and 2015. If the mismeasurement hypothesis is true, the incremental consumer surplus that these industries would have created will need to be more than their measured incremental value-addition by more than six times. This is an enormous and highly improbable amount of mismeasurement.

It should be noted that productivity measurement is based on the formal economy. Development of platforms, such as Uber or AirBnb, switches a part of the services from the formal to the informal economy [Goldin et al., 2018]. Although both firms have high capitalization, they are still too small to be responsible for a significant part of the gap in productivity growth. Ahmad et al. [2017] estimate that in the UK, total investment would increase by only 0.04% if Uber drivers' cars were accounted for as investment. Similarly, growing profit shifting and tax evasion of multinational corporations pose additional challenges for productivity measurement. Empirical research shows that growing profit shifting virtually lowers the output of the US economy. Its impact is, however, too small to explain a significant part of the post-2004 productivity growth slowdown [Guvenen et al., 2018].

If the mismeasurement hypothesis would be true, the TFP growth should be slower in ICT-intensive states. Analysis of TFP development across the US states shows that this is not true. TFP growth slowdown is a widespread phenomenon, and it is not stronger in this group of states [Cardarelli and Lusinyan, 2015].

Although it is possible that mismeasurement partially explains the gap in TFP growth, there is no full explanation due to the fact that the gains of consumer surplus left that need to be identified are extremely big. The mere fact that GDP is an imperfect measure of welfare is insufficient as an evidence for the mismeasurement hypothesis. Therefore, supporters of the mismeasurement hypothesis have to prove that the relation between GDP and total surplus changed significantly around 2004.

5 Long-term forces slowing TFP growth

5.1 Slowing pace of innovation

In the United States, the TFP growth in ICT-intensive sectors slowed significantly in the early 2000s after the temporary surge in the late 1990s. The pace of innovation in other sectors may have slowed earlier and remained more stable, but it is still a subject of debate. Productivity growth slowdown is more pronounced in the sectors in which ICT is produced or intensively used [Cette et al., 2016].

Analysis using TFP growth rates at the country–industry level for a group of advanced economies over the period 1970–2010 shows TFP shocks in the United States produce important spillovers for the whole group. A 1% drop in TFP at the technological frontier in each industry lowers the TFP by about 0.2% on average across all advanced economies overt the medium term. Intra-sector and inter-sector levels are responsible for one-half of this slowdown each. The identified impact is significantly higher in countries with high exposure to the technological frontier through international trade [Adler et al., 2017].

The slowing pace of innovation can serve as an explanation for the TFP growth slowdown in the United States, which experienced a boost in productivity in the 1990s. It can, however, not explain the slowdown in the euro area, which experienced much less surge in productivity growth in the 1990s. Even if the impact of ICT on productivity has run its course in the United States, it could not have simply missed Europe.

Has technological progress really slowed? The answer to this question is highly controversial. It is possible to decompose TFP growth into technical progress and efficiency components. According to this decomposition, technological progress has not slowed in the United States in the years 1961–2014 [Diewert and Fox, 2018]. The expenditure on research and development (R&D) and the number of high-technology patents remain high by historical standards [ECB, 2017]. Moreover, as indicated earlier, some researchers argue that the full impact of the ICT revolution has not yet been attained [Brynjolfsson and McAfee, 2014]. Although growing social economic inequalities can weaken innovation according to some post-Keynesian theoretical models [Neto and Ribeiro, 2019], this hypothesis is not confirmed by empirical research [Aghion et al., 2019].

5.2 Population aging

It is clear that workers' productivity varies over their working life, but the economic theory provides no clear insight about the impact of population aging on TFP growth. On the one hand, accumulation of experience leads to higher productivity, whereas on the other, depreciation of knowledge and age-related reduction of physical and mental capabilities result in lower productivity. The former effect is probably more important in the first decades of a worker's career, while the latter dominates in the preretirement period.

Empirical analysis shows that the relationship between changes in the age structure of the working population and TFP growth is significant. Aging may have slowed TFP gains from the 1990s through the 2000s by as much as 0.2–0.5% points per year on average across the advanced economies and by about 0.1% point on average across the emerging and developing economies [Adler et al., 2017].

The negative impact of the aging of the population on productivity growth been also confirmed by other empirical papers [Feyrer, 2007; Aiyar et al., 2016]. On the other hand, recent research by Acemoglu and Restrepo [2017] does not find any negative impact of population aging on economic growth, indicating the faster adoption of labor-saving technologies in rapid-aging societies as the reason for this contradictory outcome.

5.3 Slowing human capital accumulation

Human capital accumulation leads to increased productivity and wages. Returns from schooling are high for individuals, while for the society, they may be even higher due to positive externalities. Better quality of human labor is crucial for economic development.

Human capital accumulation has slowed across the broad sample of economies [Barro and Lee, 2013; Morrisson and Murtin, 2013]. Calculation based on social returns to education established in the literature suggests that, in the average advanced and emerging economies, about 0.3% points per year of the slowing labor productivity during the 2000s can be attributed to the slowing human capital accumulation. Contribution of human capital to labor productivity growth in the 2000s was twice as small as in the 1980s [Adler et al., 2017].

5.4 Limits of structural transformation and growing importance of services

Migration of the workforce from low-productivity sectors, such as agriculture, to high-productivity sectors increases productivity. This effect is especially important for emerging market economies and low-income countries due to the big share of agriculture in total employment.

The growth in the share of people living in cities in the whole-world population has slowed significantly. In 2016, >54% of the world population already lived in cities [World Bank, 2018]. There is strong evidence that the growth of cities supports productivity growth in developing countries [Duranton, 2008]. The possibilities for transferring workers from agriculture to manufacturing and services have been already exhausted in advanced economies. Additionally, many emerging countries have also already made the easiest and most significant part of the transition.

Advanced economies have already experienced the second wave of structural transformation. Today, in the average OECD country, 70% of the employed population works in services. On average, TFP growth in services is weaker than in manufacturing because of the lower level of standardization than in the case of goods, lower level of competition, and the fact that services have to be delivered in person Therefore, the growing importance of services weakens the overall TFP growth [Sorbe et al., 2018].

5.5 Capital misallocation

Since the early 1990s, countries in southern Europe have experienced low level of productivity growth, accompanied by declining real interest rates. Using a large and representative sample of Spanish manufacturing firms, Gopinath et al. [2017] identify an important increase in the dispersion of the return to capital across firms, leading to productivity losses from capital misallocation over time. They develop a model consisting of heterogeneous firms, financial frictions that depend on firm size, and capital adjustment costs. The authors show that decline in real interest rates resulted in an increase in the dispersion of the return to capital and lower TFP.

According to the developed model, when financial markets are imperfect and underdeveloped, capital flows to the firms that have the highest net worth but not necessarily the highest productivity. As the next step, Gopinath et al. [2017] extend their sample and find that capital misallocation resulting in slower TFP growth is observed also in Italy and Portugal, but not in Germany, France, and Norway.

Restuccia and Rogerson [2017] provide us with a review of research on the link between the impact factor misallocation and productivity growth. Misallocation of production factors has also been identified as an important factor decreasing the TFP level in China and India [Hsieh and Klenow, 2009]. In the United Kingdom, one-third of the postcrisis productivity growth slowdown can be explained by the slower reallocation of resources [Barnett et al., 2014]. Although there is consensus that the weaker contribution of resource reallocation to TFP growth after the financial crisis is a significant factor explaining the productivity growth slowdown in the United Kingdom, some researchers are skeptical toward the possibility of exact measurement of the explanatory power of this factor [Riley et al., 2015].

5.6 Firm-level factors: zombies, heterogeneity, and lack of business dynamism

Old firms that have persistent problems meeting their interest payments are known among economists as "zombies." The impact of zombie firms on economic growth and productivity has been investigated for

the first time in the case of Japan after the experience of the Lost Decade [Caballero et al., 2008]. Existence of zombie firms lowers the TFP growth by decreasing the productivity at the industry level and deters the potential entry of young firms, which could increase productivity growth. Zombie firms hinder the reallocation of resources across industries. They inflate wages relative to productivity and lower the market prices as well as the value of (also nonzombie) market shares.

Today, zombie firms are an important phenomenon also in the European Union. The share of capital sunk in zombie firms in 2013 ranges between less than 5% in Slovenia to nearly 20% in the case of Italy. The share of zombie firms increased between 2007 and 2013 in the nine OECD countries with enough data for intertemporal comparisons. Had the zombie share not risen from the precrisis levels, the contribution of capital reallocation to TFP would have been around 0.7–1% higher in Italy and Spain. In other countries, reducing zombie congestion to the lowest level observed within each industry could increase TFP by about 0.5%. The business investment by the typical nonzombie firm would have been on average 2% higher in 2013 had the zombie share not risen from its 2007 level. The econometric specification using the fixed-effect structure and a number of robustness tests confirm that these effects are not influenced by the impact of the financial crisis [McGowan et al., 2017]. The negative impact of zombie firms on productivity growth in OECD countries has been confirmed by other empirical research too [Gouveia and Osterhold, 2018].

Productivity growth slowdown is a heterogeneous phenomenon. In OECD countries, labor productivity is still rising fast at the technological frontier, but the productivity divergence between the frontier and laggard firms is increasing. The divergence is significantly higher in sectors in which pro-competitive product market reforms were least extensive. It is important also that the productivity of most elite firms (the top 2%) has risen relative to that of other frontier firms (the top 5%). TFP growth was significantly weaker in those industries in which TFP divergence was more pronounced [Andrews et al., 2016].

Among the firm-level sources of productivity growth slowdown, lack of diffusion of technologies is probably the most important one. The slowing diffusion could have two reasons. The first one is the growing complexity of technologies, which increases the amount of investment required for the successful adoption of new technology. It is also possible that new technologies are held by the few early adopters who are learning while everyone is still lagging behind. Stagnation of TFP growth of laggard firms may also be related to rising barriers to entry, rising market power of frontier firms, and decline in competitiveness of markets.

A growing body of literature demonstrates the secular decline in a variety of measures of business dynamism in the United States in the past few decades, particularly the post-2000s. Declining business dynamism is evident in data on formation of new firms, job creation as well as destruction, and worker flows. Many important innovations, especially in ICT, have been developed in start-ups, so the slowdown of business dynamism may mean that there are fewer new innovative firms to replace old laggard firms [Decker et al., 2016]. The share of young shareholders has also declined, which could lead to higher risk aversion of firms, subsequently slowing the growth in number of shares traded daily at the New York Stock Exchange and probably resulting in worse capital allocation. Decline of net private business investments also reduces productivity growth [Gordon, 2016]. Slowdown of business dynamism has been documented in the EU also [ECB, 2017]. Since the 1980s, the average markups in the United States have more than tripled across the majority of industries, which reflects a rise in market power. Distribution of markups has widened substantially [De Loecker and Eeckhout, 2017]. The rise of markups is especially significant in sectors that intensively use intangible capital [Haskel and Westlake, 2017]. Rising market power, which by definition means lower competition, can decrease the pressure on productivity improvements.

6 Legacies of the Great Recession

6.1 Lack of capital deepening

Increasing the amount of capital per unit of labor is one of the basic ways to increase both labor productivity and economic growth. During the financial crisis, the capital–labor ratio experienced "artificial" deepening

because the reduction in employment was bigger than the reduction in net investments. After the financial crisis, capital deepening in the euro area and in the United States stagnated. Much of this stagnation can be explained by the accelerator response of investments to weak demand, resulting in the decrease of total output via hysteresis-like effects [Ollivaud et al., 2016]. Economic recovery began in 2013, but net investments in the United States halved from the precrisis rates and fell much more in the euro area. On the other hand, growing employment reduced the capital–labor ratio [ECB, 2017].

Capital deepening is one of the crucial factors affecting the productivity, economic growth and living standards. Three postcrisis years is, however, too short a period to be sure that lack of capital deepening is or will be an important problem in advanced economies. Nevertheless, more research on this issue should be encouraged.

6.2 Financial frictions

Duval et al. [2017] studied the role of financial frictions as an explanation for the post-financial crisis productivity growth slowdown. They used cross-country firm-level data showing that the combination of financial fragilities and tightening credit conditions was an important reason for the slowdown.

Firms that had a more fragile balance sheet before the crisis experienced a decline in TFP growth relative to their financially robust counterparts. The identified difference was higher in countries in which credit conditions deteriorated more. Financially fragile firms reduced intangible capital investments, which led to slower TFP growth.

According to recent empirical research, financial frictions account for between one-quarter and onethird of the productivity growth slowdown during a financial crisis [Besley et al., 2016]. Economic theory and empirical research indicate that financial frictions resulting from crises are especially important for TFP growth in emerging countries [Queralto, 2010].

6.3 Slowdown of international trade

Growth of the international trade has slowed significantly after the financial crisis. World export, measured in terms of the current United States dollar (US\$), increased from 19.68 trillion in 2008 to 20.819 trillion in 2016. Growth of the international trade after the financial crisis was slower than the growth of GDP on average, leading to a decline of the value of world exports – from 30.87% of world GDP in 2008 to 28.56% of world GDP in 2016 [World Bank, 2018].

A positive impact of international trade on productivity is a robust result in economic research [Choudhri and Hakura, 2000; Alcala and Ciccone, 2004; Caliendo and Rossi-Hansberg, 2012]. Trade with China alone may have produced as much as 10% of the TFP growth in median-advanced economies over the period 1995–2007 [Adler et al., 2017]. Greater foreign competition increases pressure on domestic firms to produce more efficiently and to innovate. Imported inputs enhance the variety and quality of intermediate goods available for domestic firms. The learning effects are also important. Slowing growth of the international trade should reduce productivity growth, while new trade restrictions in advanced economies would reverse some of the earlier gains.

7 Public policy recommendations

The productivity growth slowdown does not win much attention in the public debate due to its complexity. Its importance and immense consequences make it, however, one of the most discussed issues among policy makers. Many international institutions, such as the International Monetary Fund, the OECD, the World Bank, the International Labor Organization, the European Commission, and the European Central Bank, have issued publications on this topic. The European Council [2016] published a recommendation calling on the Eurozone member states to establish national productivity boards to analyze developments and policies that can affect productivity and competitiveness. Although pro-productivity institutions are

not a panacea, they improve the policy process and political debate, in addition to providing an important input to evidence-based policy making [Renda and Dougherty, 2017].

Economic theory indicates clearly that higher competition leads to higher productivity growth due to bankruptcies of ineffective firms and changes in resource allocation. Andrews et al. [2016] identify that TFP divergence is much more extreme in sectors in which pro-competitive product market reforms were least extensive. They estimate that if the reforms in the retail trade and professional services had been equivalent to those in the best service sectors, the extent of TFP divergence may have been up to 50% smaller. Andrews et al. [2016] recommend introducing pro-competitive product market reforms that will strengthen the incentives for laggard firms to adopt frontier technologies. The positive impact of pro-competitive reforms on resource allocation is also confirmed by empirical research [Andrews and Cingano, 2014].

Adler et al. [2017] advise to develop better migration policies and encourage workforce migration. They find that a 1% point increase in the share of migrants in an adult population raises the labor productivity of the host economy up to 3% in the long term through higher human capital and improved TFP. Peri [2012] finds that in the United States, immigration has a strong positive association with TFP growth. On the other hand, however, a good migration policy of the receiving country can decrease the TFP growth in the sending country due to the resulting brain drain. Although Adler et al. [2017] also recommend to further liberalize international trade, currently, such recommendation probably will not win much democratic legitimacy and have low chances of being implemented.

We should modernize our education systems by teaching our children how to use the benefits of the digitalization age, while ensuring and enhancing equality of opportunities [World Bank, 2019]. Digitalization has already changed many workplaces, which will probably continue. We have to encourage lifelong learning because there are many indicators that we will have to learn new competencies and skills more often than in the past. It will be beneficial to further support science, technology, engineering, and mathematics (STEM) education, especially among disadvantaged groups.

We ought to introduce reforms inhibiting the impact of population aging. On the one hand, governments should use active labor market policy tools while, on the other, increase the implementation of good migration policies. Governments have to increase the sustainability of pension systems and modernize health care to control its growing costs.

Public policy should also consider the role of weak aggregate demand [Bughin et al., 2018]. Weak demand holds back investments, which counteracts capital deepening and innovations. Governments ought to invest more in sustainable infrastructure and renewable energy sources, as well as increase public support for R&D. In the past decades, many critical innovations – from ICT and biotechnology to green technologies – have been developed on the base of state support. The state can not only fix existing markets but also actively shape and create new markets [Mazzucato, 2013].

8 Conclusions

The productivity growth slowdown is one of the most important macroeconomic problems of our times because, in the long term, TFP growth is a crucial factor in increasing living standards. It has not only a huge theoretical importance but also immense consequences. If the post-2004 productivity growth slowdown had not happened, The US GDP in 2015 would have been 17% higher than it actually was [Syverson, 2017]. Although it is often argued that macroeconomic statistic does not measure the impact of ICT properly, such a hypothesis cannot explain the productivity growth slowdown, which is simply too big to result only from measurement problems.

Growth in TFP is measured as everything else except the growth of inputs. This term has an extremely broad meaning, which makes investigation of the reasons of productivity growth slowdown very difficult. The slowing pace of innovation is often indicated as the reason, but this approach is highly controversial. Among the structural factors, we could – with high level of confidence – identify population aging, slowing human capital accumulation, capital misallocation, divergence among firms, and lack of business dynamism. After the financial crisis, financial frictions and slowdown of international trade have further

reduced TFP growth. Although some researchers state that lack of capital deepening is one of the sources of slow productivity growth in the euro area after the financial crisis, it is too early to be sure that developments in terms of capital–labor ratio are not artificial.

Attacking the productivity growth slowdown requires public policy response. States have to modernize education systems and encourage lifelong learning. Product market reforms should be introduced and international trade should be further encouraged, while taking care of the distributional impact of those policies. Policies that reduce the consequences of population aging ought to be implemented. Governments should increase aggregate demand and support innovation.

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