# EFFECTS OF AUTOMATION ON LABOUR MARKETS IN THE EMERGING COUNTRIES

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**Abstract.** *Europe and the Atlantic region have been the main attraction for the economic migration flowing all over the world. This migration results in a common fear and anxiety within the Western world, due to the high possibility of losing their jobs or working for fewer wages. However, the main factor that would shake the labour markets would be automation, rather than migration. Current developments in the automation field indicate that the peak point of automation could increase the employment problems of both local people and immigrants as well. As the machines gradually replace man-power (workers), this would result in massive unemployment scenarios. This concern existed during and after the Second World War, however, it gained speed with the introduction of the Fourth Industrial Revolution at the Hannover Fair in 2011. The purpose of this paper is to examine the effects of digitization and automation to the economy and especially to labour markets, in the period when the use of the physical and mental capacity of people is minimized and in the world where machines and systems such as "artificial intelligence", "Internet of Things", "new information technologies" are interconnected and intertwined. Countries that were mostly affected by the automation are the Far East countries, mainly China, due to the cheapest production, cheap labour and tax, and other conveniences. In this paper, through panel regression of data on the growth of investments in ICT and output per employed person, we examine and prove the impact of information and communication technologies (ICTs) on labour productivity on the example of several selected emerging markets in the period from 1990-2019.*

**Keywords:** *automation, digitization, the Fourth Industrial Revolution, emerging markets, labour markets.*

## 1. INTRODUCTION

Widespread academic papers suggest that the increasing acceptance of information and communication technologies (ICT), especially technologies that support the "new industrial revolution" (artificial intelligence, Internet of Things and advanced robotics) and transformative change that ICT can bring to organizations, is a key component in fixing lagging global productivity. ICT is a "General-Purpose Technology" that reshapes production and distribution systems, with far-reaching effects across national economies (Atkinson, 2018).

According to Brynjolfsson and McAfee (2014), finding powerful technologies is key to economic progress. Indeed, there is a broad consensus among economic thinkers that some technologies are significant enough to accelerate the normal course of economic progress. To do so, such technologies need to be spread across many, if not most; they cannot do that if they are represented in only one or a few sectors. The cotton gin was undoubtedly important in the textile sector in the early 19th century, but quite insignificant outside that sector. In contrast, steam engines and electricity quickly spread everywhere. The steam engine not only massively increased the amount of energy available to the factories but also freed them from the need to be near a stream or river to power the water wheel; it also revolutionized land travel by enabling railroads and sea travel. Electricity provided an additional boost to production by enabling machines to be individually powered. It has illuminated factories, office buildings, and warehouses and led to new innovations such as air conditioning, which has made work pleasant in the workplace.

Economists refer to these technologies as "General-Purpose Technologies" - GPTs and define them as "new ideas or techniques that have the potential to have a significant impact on many sectors of the economy". That is, in some way they have an impact on production as a result of the increase in output per employed person (productivity). Also, ICT (computer hardware, software, and telecommunications) meet all the criteria to be considered as general-purpose technologies, i.e. they are spread across many sectors of the economy, improve over time, and are a challenge for new innovations. So, it can be said that investments in ICT are starting a new "golden age" for innovation and growth.

The conference of the World Economic Forum in January 2016 announced the beginning of the new, i.e. the Fourth Industrial Revolution of global business leaders, heads of state, public intellectuals, and non-governmental organizations (Schwab, 2016). So, to speak, that year was the year of the announcement of the beginning of the new process of industrialization (Industry 4.0) as a replacement for the Third Industrial Revolution that appeared about four decades ago.

According to Um (2019), the use of the word "revolution" in combination with "industry" becomes part of our cultural heritage. Our industrial achievements are so monumental and numerous that their impact can hardly be estimated. We spend our daily lives using various appliances and instruments produced during the industrial revolutions, such as washing machines and vacuum cleaners, trains and cars, etc. The term "industrial revolution" refers to the change of technological economic and social systems in the industry.

The concept of "Industry 4.0" which was first used as a term in Germany at a fair in Hanover in 2011, in fact, describes the last phase of the industrial civilization that began to develop with the use of technologies that used water and steam, continued with electricity as the fruit of Industry 2.0 and through the digital / electronic phase in Industry 3.0. In this period of Industry 4.0 when the use of human physical and mental capacity is minimized, we experience a world where all vehicles, systems and machines are associated with the development of concepts such as, artificial intelligence, the Internet of Things - IoT . Establishing such systems that can decide on their own functioning with their minds means establishing a production environment that is free of human weaknesses and where the most rational choices are made (Aribogan, 2019).

In the new era there are simultaneous jumps in many areas; from sequencing whole genomes, nanotechnologies, renewable energies to quantum techniques. The main difference of this revolution from the previous three will be the possibility of merging these technologies and their interaction across physical, digital, and biological fields (Schwab & Davis, 2018). Quantum computer technologies, promising huge efficiency increases in many different areas, such as logistics and drug discovery, offer incredible advances in methods for modeling and optimizing complex systems. The use of blockchain technology, as was and still is the case with bitcoin and other types of digital money, significantly reduces the cost of coordination between different parties. This technology can become a driving force for the flow of huge amounts of value through digital products and services and make all markets accessible to anyone with an Internet connection, of course if it overcomes problems with the authorities and secures digital identities using the top encryption techniques. Virtual and augmented reality offers new channels to experience the world around us, it also speeds up and enriches the process of acquiring skills and applying them anytime, anywhere. Advanced materials can revolutionize the use of civilian and military drones, the supply of electricity to poor communities, and transportation systems.

But what matters is to think about what this would mean for emerging markets and developing countries. Given that even the last stages of the industrial revolution have not yet reached a large number of citizens in these countries (who still do not have access to electricity, water, tractors, and other machinery), many aspects of the Fourth Industrial Revolution characterize transformations in advanced economies, but this does not mean that one should not consider how that process will affect both emerging markets and developing countries.

One challenging scenario for developing countries and emerging markets is if digitalization and automation as part of the Fourth Industrial Revolution process lead to a significant return to production at home "reshoring", that is, in advanced economies back, something very likely if more access to low labour costs did not boost firm competitiveness. The ability to develop strong productive sectors that serve the global economy based on cost advantages is a good path for development, enabling these countries to accumulate capital, technology, and increase revenue. If this road is closed, many countries will have to rethink their industrialization models and strategies.

Another problem is the takeover of jobs in these countries through digitalization and automation. According to Egilmez (2018), Industrialization 4.0 is expected to highly utilize computerization in the manufacturing industry and aims to equip production with the highest technology. Here are three key pointers in moving forward: (1) Minimization of the human factor in production and elimination of man-made omissions in production; (2) Achieving a high level of flexibility in production and creating conditions for designing products that will meet the specific requirements of the consumer; (3) Intensification of the production process. With this in mind, no one can predict what the labour market will look like in 2050. According to an analysis by the World Economic Forum, the Fourth Industrial Revolution is expected to cause a loss of 5.1 million jobs in 15 countries, which make up 65% of the global workforce. If the socio-economic and demographic tendencies are added to the calculation, it becomes clear that the labour market in the coming periods will experience serious changes (Aribogan, 2019).

## 2. Productivity Paradox

Nobel laureate Paul Krugman is right when he says that "productivity is not everything, but in the long run it is almost everything". He is right because a country's ability to improve its standard of living over a long period of time depends almost entirely on its ability to increase output per employed person, that is, the number of hours of labour required to produce everything from pencils and paper, food and clothing for the military and police to tanks and submarines. Most countries do not have huge natural resources, oil reserves, or the like and therefore cannot get rich through their exports. So, the only sustainable way for countries to become richer, that is, to improve the living standards of their people is to provide more output with the same number of inputs, in other words, to produce more goods and services with the same number of people (Brynjolfsson & Hitt, 2000).

Productivity growth lays the foundation for improvements in living standards. Meanwhile, investments in information and communication technologies are considered a key driver of productivity growth. This relationship has been extensively studied for developed countries at the level of the firm, industry and national economy, with the majority of studies that show the effect of ICT on productivity as a positive and significant; but this has not been done in a sufficient manner for emerging markets, and developing countries. Perhaps this is due to the lack of high-quality micro and macro data sets for these countries.

But the problem is that in recent decades, the global world, including developed countries, has been facing a slowdown in productivity growth despite high investment in ICT. Following the introduction of technologies such as electricity, internal combustion engines and their implementation and adaptation in production systems in the mid-20th century, especially in the 1940s, 1950s, and 1960s, productivity growth was particularly rapid. However, by 1973 productivity growth had slowed.

In 1987, Robert Solow famously noted that the slowdown in productivity almost coincided with the early days of the computer revolution, arguing that "the computer age may be seen everywhere, but not in productivity statistics". Computers were still a small part of the economy, and in order for general-purpose technologies such as information technology to show their true impact on the economy, some complementary innovations had to be undertaken in organizations or institutions where those technologies are used. Recent research based on detailed data on productivity and the use of IT technologies suggests a significant and strong correlation between them. That is, firms that used IT or other general-purpose technologies and supported them with complementary innovations were more competitive than other firms that did not function that way.

So, despite the introduction and rapid development of computer technology at the time and other innovations that emerged from that computer revolution, productivity grew at a very slow pace. This is repeated today, especially in the period after the Great Recession of 2008. Brynjolfsson and McAfee (2014), have a rather interesting explanation for this phenomenon and argue that the slowdown in productivity in the 1970s and its acceleration after 20 years has an interesting precedent in the past. In the late 1890s, electricity was introduced into American factories. But the "productivity paradox" of that era was that for the next 20 years there was no increase in labour productivity. While the new technologies of the time were very different, many of the basic dynamics were quite similar. According to research, the main reason why the global economy could not reflect investments in ICT and digitalization in productivity statistics was "complementary investments", i.e. every dollar invested in computer hardware should be invested an additional $9 for software auditing, education, and institutional process.

Most likely, it is confirmed today. Despite the rapid growth of new technologies and innovations fueled by the Fourth Industrial Revolution, this is not reflected in productivity statistics as Nobel Laureate Solow put it in 1987. The benefits of these technologies on the the overall economy and labour productivity will be reflected in the statistics after additional and complementary investments are made, and this will take time.

In this paper, through panel regression of data on the growth of investments in ICT and output per employed person, we examine and prove exactly that problem of the "productivity paradox" on the example of several selected emerging markets in the period from 1990-2019.

## 3. LITERATURE REVIEW

### 3.1. Theoretical background

From a historical point of view, in the period after 1955 we can speak of four major and influential theories of economic growth: The non-Keynesian Harrod-Domar model of economic growth; Robert Solow's neoclassical model of economic growth; The endogenous model of the economic growth of Romer and Lukas and Institutionalist theories of economic growth. According to the Harrod-Domar model, economic growth is conditioned by savings and investments, according to Robert Solow by growth, i.e. investment in capital and labour, and the so-called total factor productivity, and according to Nobel laureate Paul Romer, growth is largely determined by technology - technological innovation. It actually integrates technological innovation into long-term economic growth and shows how and why knowledge and technological innovation are the most important factors for economic growth and development (Petreski, 2000).

As Paul Romer notes, the dominant growth theory of the late 1980s - Solow's growth model, who won the Nobel Prize in Economics in 1987 - can explain many features of economic growth, but not large and persistent differences in growth rates. Solow's model predicts that poorer countries should grow faster and reach the level of the richer fairly quickly. In Solow's model, the economy can grow by accumulating physical capital, for example, machinery, and infrastructure, but capital-driven growth must stagnate in the long run; for any given technology, adding more and more capital contributes to less and less output. To allow for steady long-term growth (and growth differences) in the model, the assumption should be that over time, the workforce becomes more productive due to technological progress, albeit at a different rate for each country. Solow's model does not explain these trends, because changes in technology in its modernity simply come exogenously from a "black box" (The Royal Swedish Academy of Sciences, 2018a).

Romer's greatest achievement was that he was able to open this black box and show how ideas for new goods and services - produced by new technologies - could be created in a market economy. He also showed how such endogenous technological changes can shape growth and what policies are necessary for this process to work well. Romer's contributions have had a major impact on the economy. His theoretical rationale laid the groundwork for the study of endogenous growth.

Romer notes three weaknesses of Solow's model: (1) Technological change is treated as an exogenous factor, because we are unable to understand the reasons that drive technological change; (2) Technology is treated as a public good - it is everywhere and anyone can use it; (3) The Law on Diminishing Returns in the Economy, i.e. if at a given level of technology you constantly invest in capital and labour, over time, the contributions of the additional invested units decrease.

Romer in his work seeks solutions to these problems. To explain this, we must first understand how technology and ideas differ from goods such as physical or human capital. Romer emphasizes two dimensions: (1) Physical and human capital are competitively good. If a particular machine is used or a trained engineer works in one factory, the same machine or engineer cannot be used at the same time in another factory. While new technologies and ideas, on the other hand, are non-competitive goods: one person or company that uses an idea or technology does not prevent other companies from using it; (2) These goods are not public goods and can be exclusive or partially exclusive if the institutions or regulations enable them to prevent someone from using them. If it is subject to private control it can be protected (for example, a patent right) and it can bring economic profit to the one who owns it. Romer's pioneering work has shown how the uncompetitiveness and exclusivity of new technologies and ideas determine economic growth and labour productivity (The Royal Swedish Academy of Sciences, 2018b).

### 3.2. Empirical studies

Productivity increases from a variety of factors, but the main factor is the use of more and better "tools" by manufacturers - in other words, the use of more and better machines, equipment, and software. Even in today's knowledge-based economy, the tools that are most present and most effective in increasing productivity are based on ICT. According to Thomas Niebel (2014), these digital tools are wider than just the Internet, although that in itself is driving growth. These include hardware, software, and telecommunications networks and tools that incorporate these components into them, such as IoT devices, artificial intelligence, and advanced robotics. Their impact is comprehensive as it is used in virtually every sector, from agriculture to manufacturing, from services to the functioning of governments, and so on.

Most macroeconomic and industrial studies are based on the growth accounting the framework, where it is assumed that the contribution of each input to production is proportional to the corresponding share in total input costs. The increase in output over input contributions is attributed to the growth of multi-factor productivity (MFP) or Solow total factor productivity (TFP), i.e. technological progress that is not expressed in production inputs. Jorgenson and Stiroh (2000), has applied the limit of production capacity to explain the increase in productivity growth in the United States since 1995. They found that computer hardware played a larger role as a source of economic growth and average labour productivity grew much faster between 1995 and 1999 as a result of capital deepening as a direct consequence of falling ICT prices and rising multi-factor productivity.

Oliner and Sichel (2000), obtain similar results, based on a growth accounting model similar to Solow's methodology. They find that the contribution of ICT capital increased between 1974-1995 and 1996-1999 and that MFP growth also increased by 40% between 1996-1999.

Colecchia and Schreyer (2002), extended the approach followed by Jorgenson and Stiroh (2000), and Oliner and Sichel (2000), to nine OECD countries by 2000. They found that in the previous two decades, ICT contributed between 0,2 and 0,5 percentage points per year to economic growth, depending on the country. During the second half of the 1990s, this contribution rose to 0,3 to 0,9 percentage points per year. The contribution of ICT investment to economic growth is highest in the United States, followed by Australia, Finland, and Canada. Of the nine countries analyzed, Germany, Italy, France, and Japan had the lowest ICT contributions to economic growth.

Similar country surveys have been conducted for the United Kingdom (Oulton, 2005), but have also been conducted in a comparative context (Inklaar, Timmer, & Van Ark, 2007). A recent study by Jorgenson and Timmer (2011), confirmed growth accounting as a well-established approach, providing new analysis of patterns and structural change in developed countries. The works of Draca et al. (2007), Cardona et al. (2013), prove the relationship between ICT and labour productivity as positive and significant in the case of developed countries using different methodologies.

So, we can conclude that technology has incredible power to stimulate economic growth, improve people's lives, and create opportunities, both for individuals and for companies and countries. As we have seen, this relationship has been extensively studied in developed countries at the firm, industry, and country levels, with the majority of studies showing the effect of ICT on productivity as positive and significant. However, there is rather weak and ambiguous empirical evidence of the contribution of ICT investment to economic growth for emerging markets and developing countries. However, the World Bank (2012), is optimistic, stating that ICT is very promising and will reduce poverty, increase productivity, increase economic growth, and so on. Perhaps the weak and ambiguous empirical studies on the impact of ICT on developing countries and emerging markets are driven by the lack of high-quality micro and macro data sets for these countries.

There are also valid reasons why the impact of ICT on growth in developing countries and emerging markets is different than in developed countries. According to Niebel (2014), there are two reasons that explain this phenomenon: (1) Developing countries may not have absorption capacity such as an adequate level of human capital or other complementarity factors such as R&D costs and therefore receive less ICT investment compared to developed countries; (2) On the other hand, ICT can help emerging markets and developing countries to "skip" the traditional methods of increasing productivity mentioned by Steinmueller (2001). Additional productivity gains can be triggered by “ICT-related overflows or network effects” as ICT can reduce transaction costs and speed up the knowledge creation process. But these network effects can be more pronounced when many companies in a region or industry use similar levels or types of ICT.

Only recently Niebel (2018), based on available data from The Conference Board Total Economy database, analyzed 59 developing countries, emerging markets, and developed countries in the period 1995-2010 and showed that the percentage output elasticity of ICT is greater than the part for compensation of the ICT factor that indicates the return of the ICT capital. The results show that developing countries and emerging markets receive no more ICT investment from developed economies.

## 4. Analysis of the Impact of ICT on Labour Productivity in the Case of Selected Emerging Markets

### 4.1. Research data and methodology

In this paper we analyze the impact of information and communication technologies have had on labour productivity per person employed in several emerging markets (Brazil, China, India, Indonesia, Mexico, Russia, South Africa and Turkey) selected based on the classification that stands for at the productivity brief for 2019 of the company "The Conference Board", in the period 1990-2019. Empirical analysis is made using the panel approach through fixed and random-effects techniques, where the dependent variable is the growth of labour productivity per person employed, and as independent variables we include the growth of investments in ICT and the growth of multi-factor productivity, using EViews econometric software. The data are provided from The Conference Board Total Economy database and are taken as annual labour productivity growth and MFP growth as annual growth rates. Only the data on the growth of investments in ICT are obtained as the first difference from the natural logarithm of the absolute values of ICT investments by years and they are presented as growth rates. In order to obtain stationary series and a more normal distribution of the residuals, we divide the time period from 1990-2019 into two subperiods, one from 1990-2006 and the other from 2007-2019; This division also helps us to compare the impact of ICT investments on labour productivity before and after the Great Recession of 2008, i.e. it allows us to determine whether after the World Economic Crisis there is a further decline in labour productivity despite the new industrial revolution and new technologies that are increasingly involved in creating added value in the economy.

Econometrically, the general model we use for estimation when using panel data can be described as (Brooks, 2014):

$$\gamma_{it} = \alpha + \beta x_{it} + u_{it}, \ (1)$$

where $\gamma_{it}$ is a dependent variable, $\alpha$ is the intercept term, $\beta$ is a $k \times 1$ vector of the parameters of the explanatory variables to be estimated and $x_{it}$ is a $1 \times k$ vector of observations of the explanatory variables, $t = 1, \dots, T; i = 1, \dots, N$.

The simplest way to analyze panel data is by estimating aggregate regression, which involves estimating one equation for all data, so that the $\gamma$ database is arranged in a single column containing all cross-member observations and time series, and similarly, all observations of each explanatory variable are arranged in single columns in the matrix x. In that case, this equation is estimated in the usual way using the ordinary least squares (MLS) method.

Although this is a really simple way to proceed, and requires an assessment of as few parameters as possible, the procedure has some serious limitations. Most importantly, the aggregation of data in this way implicitly assumes that the average values of the variables and the relationships between them are constant over time and across all the cross-members in the sample. We could, of course, estimate individual time series regressions for each member or country, but this would probably be a sub-optimal way to proceed as this approach would not take into account any common structure present in the time series. Alternatively, we could estimate individual cross-regressions for each particular time period, but again this may not be wise if there are some common variations in the series over time (Brooks, 2014).

To solve this problem, we choose between two classes of panel evaluation approaches that can be used in such research: fixed-effects models and random-effects models. The simplest types of fixed-effect models allow the intercept in the regression model to differ between the cross-members, but not overtime, while all estimated slope coefficients are fixed both cross-sectionally and temporally.

The fixed-effects model can be estimated using the following equation (Brooks, 2014):

$$\gamma_{it} = \alpha + \beta x_{it} + \mu_{it} + v_{it}, \ (2)$$

where the error member $u_{it}$, decomposes into an individual specific effect, $\mu_i$, and the "remainder disturbance", $v_{it}$, which varies with time and terms (including everything that remains unexplained for $\gamma_{it}$). We can count on $\mu_i$ as covering all variables which affect $\gamma_{it}$ cross-over, but do not differ over time, as in our model countries belonging to a certain group of countries according to the amount of per capita income.

An alternative to the fixed effects model described above is the random-effects model. As with the fixed effects model, the random effects approach proposes different intercept terms for each member, and again these intercept terms are constant over time, assuming that the relationships between the explanatory and explained variables are the same both crosswise and temporally.

However, the difference is that according to the random-effects model, it is assumed that the intercepts for each cross-member derive from a common intercept $\alpha$ (which is the same for all cross members, over time), plus a random variable $\epsilon_i$, which varies through cross members but is constant over time. $\epsilon_i$ measures the random deviation of each entity's intercept term from the "global" intercept term $\alpha$. We can write the panel model with random effects as follows (Brooks, 2014):

$$\gamma_{it} = \alpha + \beta x_{it} + \omega_{it}, \ \omega_{it} = \epsilon_i + v_{it}, \ (3)$$

where $x_{it}$, is still a $1 \times k$ vector of explanatory variables, but unlike fixed effects, there are no dummy variables here to capture heterogeneity (variation) in the cross-sectional dimension. Instead, it happens through members $\epsilon_i$. It should be borne in mind that this framework assumes that the new error cross member $\epsilon_i$ has zero mean, is independent of the individual error member $v_{it}$, has a constant variance $\sigma_\epsilon^2$, and is independent of the explanatory variables $x_{it}$. Finally, we run the Hausman test in order to see which of the models in our analysis is recommended and display the results.

### 4.2. Results of the Empirical Analysis

*4.2.1. The impact of ICT on labour productivity in emerging markets in the period 1990-2006*

This section provides a panel regression on the impacts of ICT investments on labour productivity per person employed in the case of emerging markets in the period 1990-2006. The results of the conducted LLC-test (Levin, Lin, and Chu) for the integrative characteristics of the examined variables in the model, we can conclude that according to the stated test, the series of productivity per person employed is not stationary at the level. Therefore, we need to consult other tests to examine the (non) stationarity of the series. The p-value of Im, Pesaran and Shin W-statistics is 0,0048, which means that the series is stationary in level, at a level of significance of 0,05; The p-value of ADF - Fisher Chi-square is 0,0083, which also means that the series is stationary in the level, at the significance level of 0,05 and the p-value of PP - Fisher Chi-square is 0,0000, which means that the series has no single root at the level even at the significance level of 0,01. Finally, according to the majority of tests, we conclude that the series of output per employed person does not have a single root in the level. The MFP data series according to the LLC test is stationary at the level of significance of 0,1; while, according to other tests, it is stationary even at a significance level of 0,05. The ICT data series, on the other hand, shows a level of stability, at a significance level of 0,05 according to the majority of tests.

Then, we evaluate the fixed effects model in order to see what information the "likelihood ratio" gives us from the “Redundant Fixed Effects Tests”. The results of this test indicate that in this model it is permissible to impose fixed or random-effects on the cross-members, and not on the period. So, it is advisable to work with a model with fixed or random-effects, rather than a pooled regression where all data is considered to belong to one entity without paying attention to the different characteristics between entities / cross-member entities. Next we perform the Hausman test in order to decide which technique should be used in our model. The p-value of the Chi-square statistic is 0,6717, i.e. it has a higher value of 0,05 or 0,1; which means that we cannot reject the null hypothesis and find that in our case the random effects model is recommended.

The next step is to estimate the model, i.e. to determine the coefficients of the independent variables by imposing random effects on the cross-members in the model, and it is estimated by the following equation:

$$output\_per\_employed\_person\_growth_{1990-2006} = \alpha + \beta_1 \Delta\ln(ict)_{1990-2006} + \beta_2 mfp\_growth_{1990-2006} + (\mu + \epsilon_{1990-2006}). \quad (4)$$

The table below shows the results of the estimated model based on Equation 4. The coefficient of determination $R^2$ has a value of 88,52% which indicates that most of the variations in the model are explained by the included variables. The p-value of the F-statistics of the estimated model is 0%, i.e. lower than 5%, which means that we accept the hypothesis that the explanatory variables together have a significant influence on the movement of the dependent variable. In order to examine the multicollinearity, we present the growth in MFP as a function of the growth of investments in ICT. The VIF result obtained from that model is about 1; and it is generally accepted that multicollinearity should be treated as a problem in case the VIF is greater than 5. Also, many consider the absolute value of the simple correlation coefficients (r) higher than 0,80; is already a sign of strong multicollinearity. In our case, we can say that multicollinearity according to both criteria should not be treated as a problem. In order to examine whether the residuals follow a normal distribution, the Jarque-Bera test was performed. In our model, the p-value of the test statistics is 12,68%, i.e. it has a higher value of 5%; in that case we cannot reject the null hypothesis that residuals follow a normal distribution.

**Table 1.** Results for the estimated coefficients based on the model with random effects in the model for the emerging markets in the period 1990-2006

| Explanatory variables | Coefficient | t-statistics | p-value |
|---|---|---|---|
| **Δln(ict)** | 0,054021 | 4,425895 | 0,0000 |
| **mfp_gowth** | 0,987210 | 29,44819 | 0,0000 |
| **α** | 0,895867 | 1,333721 | 0,1846 |
| **$R^2$** | 0,885195 | | |
| **F-statistics** | 512,7415 | | |
| **p-value (F-stat)** | 0,000000 | | |

| Specification of effects | | |
|---|---|---|
| | S.D. | Rho |
| **Cross-members random** | 1,694057 | 0,5769 |
| **Characteristic-random** | 1,450653 | 0,4231 |

Source: Authors' own calculations using EViews.

After these diagnostic tests, we can proceed to the interpretation of the estimated coefficients of the explanatory variables. From the obtained results in table 1, it follows that the growth of ICT investments in selected emerging markets in the period 1990-2006 had a positive and significant impact on the output growth per employee (p-value of t-statistics is 0%). The growth of investments in ICT by 1% slightly increases the productivity per person employed by 0,05%. Also, the growth of MFP in emerging markets in the same period had a positive and significant effect on productivity per person employed, but with greater intensity, increasing productivity per person employed almost unit, i.e. 0,99% (p-value of t-statistics is 0 %).

#### *4.2.2. The impact of ICT on labour productivity in emerging markets in the period 2007-2019*

In this section, we analyze the impacts of ICT on labour productivity in the case of emerging markets, but in the period 2007-2019. From the results for the integrative characteristics of the used variables from the conducted LLC-test in the model on the emerging markets in the period 2007-2019, it is obvious that all data sets of the used variables are stationary in the level I (0), i.e. the p-values of their LLC-statistics for all three variables are below 5%.

The results of the Redundant Fixed Effects Tests, suggest that we can impose fixed or random-effects only on the cross-sections, and not on the periods. Then, we perform the

Hausman test in order to decide which technique should be used in our model. The p-value of the Chi-square statistic is 0,0029, i.e. it has a lower value of 0,05 or 0,01; which means that we can reject the null hypothesis and find that in our case the fixed-effects model is recommended.

The next step is to estimate the model, i.e. to determine the coefficients of the independent variables by imposing fixed-effects on the cross-section in the model, which, as with the random-effects model, proposes different intercepts for all cross-sections, and it is estimated by the following equation:

$$output\_per\_employed\_person\_growth_{2007-2019} = \alpha + \beta_1 \Delta\ln(ict)_{2007-2019} + \beta_2 mfp\_growth_{2007-2019} + \mu + v_{2007-2019}. \quad (5)$$

The table below shows the results of the estimated model based on Equation 5.

**Table 2.** Results for the estimated coefficients based on the model with random effects in the model for the emerging markets in the period 2007-2019

| Explanatory variables | Coefficient | t-statistics | p-value |
|---|---|---|---|
| **Δln(ict)** | 0,029181 | 2,570757 | 0,0117 |
| **mfp_growth** | 0,861042 | 29,22879 | 0,0000 |
| **α** | 2,050874 | 10,20794 | 0,0000 |
| **$R^2$** | 0,987715 | | |
| **F-statistics** | 839,7624 | | |
| **p-value (F-stat)** | 0,000000 | | |

Source: Authors' own calculations using EViews.

The coefficient of determination $R^2$ has a value of 98,77% which indicates that most of the variations in productivity per person employed came from variations in investments in new technologies. The p-value of the F-statistics of the estimated model is 0%, i.e. lower than 5%, which means that we accept the hypothesis that the explanatory variables together have a significant influence on the movement of the dependent variable. To examine multicollinearity, we present the growth in MFP as a function of the growth in investments in ICT. The VIF result obtained from that model is about 1,05; and it is generally accepted that multicollinearity should be treated as a problem if the VIF is greater than 5. Also, many consider the absolute value of the simple correlation coefficients (r) to be higher than 0,80; is already a sign of strong multicollinearity. In our case, we can say that multicollinearity according to both criteria should not be treated as a problem. To examine whether the residuals follow a normal distribution, the Jarque-Bera test was performed. In our model, the p-value of the test statistics is 14,04%, i.e. it has a higher value of 5%; in that case, we cannot reject the null hypothesis that residuals follow a normal distribution.

After these diagnostic tests, we can proceed to the interpretation of the estimated coefficients of the explanatory variables. From the obtained results in table 2, it follows that the growth of ICT investments in the selected emerging markets in the period 2007-2019 had a positive and significant effect on the output per employed person growth (p-value of t-statistics is 1,17%). 1% increase in investments in ICT increases the output per employed person by a minor 0,03%. While the growth of MFP in developed countries in the same period has a positive and significant effect on productivity per person employed (p-value of t-statistic is 0%). 1% growth in MFP leads to 0,86% growth in output per employed person in the emerging markets in the analyzed period.

## 5. CONCLUSION

In the previous sections we examined in detail the impact of ICT investments on labour productivity in the example of 8 emerging markets (Brazil, China, India, Indonesia, Mexico, Russia, South Africa and Turkey) using the panel regression method and the techniques of fixed or random effects. The analysis covered the period from 1990-2019, but in order to get better results for the stability of the series and the normality of the residuals, and to better see the impact of the Great Recession, we divided that period into two sub-periods, one from 1990-2006 and the other from 2007-2019.

The basic question is whether the benefits of ICT are different between developed countries and emerging markets and whether there is a difference in the impact of ICT investments in the two periods. As we can conclude we see that the impact of ICT investments on labour productivity in the period before the Great Recession and in the post-crisis period remain minor and contribute to a very small part of labour productivity growth, and this is in favor of the "productivity paradox" by Solow that "the age of computers may be seen everywhere, but not in productivity statistics". But, as we said before, the slowdown in productivity in the 1970s and its acceleration after 20 years had an interesting precedent in the past. In the late 1890s, electricity was introduced into American factories. But the "productivity paradox" of that era was that for the next 20 years there was no increase in labour productivity. While the new technologies of the time were very different, many of the basic dynamics were quite similar. We had an interesting conclusion, and we will use it now, that in order for these "general-purpose technologies" and other ICT investments of the Fourth Industrial Revolution to be reflected in productivity statistics, they will need additional complementary innovations, and that will take time. Therefore, in 2016, developed countries opened the topic of the Fourth Industrial Revolution in order to quickly reconcile the circumstances of that revolution, and perhaps for the next so that they can reflect the benefits of them in statistics.

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