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Direct and Indirect Impact of ICT on EU's Productivity Growth

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Abstract:

Purpose: *The aim of the research is to verify the hypothesis of a significant direct and indirect ICT impact on EU's productivity changes in 1997-2017.*
Design/Methodology/Approach: *A direct ICT contribution to productivity growth was captured at the macro level with the use of the growth accounting approach. A sector level study was conducted to assess the importance of both direct and indirect ICT transmission channels. The research was carried out with the use of the EUKLEMS 2019 database.*
Findings: *The results confirm the hypothesis about the direct and indirect impact of ICT on EU's productivity, which seems to be much more important for the old EU members. The indirect ICT transmission channel was found to be of key importance for the EU's productivity growth.*
Practical Implications: *The study identifies the cause of the decline in EU's productivity and the possibility of accelerating it by increasing the efficiency of the indirect ICT impact channel functioning.*
Originality/value: *The ICT impact analysis covering the old and new EU members in the period before, during and after the crisis shown in the paper has not been widely presented in the literature to date.*

Keywords: *ICT, productivity growth, ICT-producing sectors, ICT- using sectors.*

JEL classification: *O11, O33, O47, O52.*

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1. Introduction

Labour productivity growth is crucial to maintaining high level of wealth in the European Union in the long run. Since mid-1990s the EU has been experiencing a significant productivity slowdown with no certainty about the real root causes (van Ark *et al.,* 2008; Timmer *et al.,* 2010; Mas and Stehrer, 2012). This phenomenon has even exacerbated over the last decade, contrary to what would be expected in the recovery from the crisis. In the literature, among the reasons indicated, appears an argument that EU missed out on many of the productivity growth opportunities of the information and communication technology (ICT) revolution (Bauer *et al.,* 2020; van Welsum *et al.,* 2013).

Indeed, ICT is considered to be an "engine" of digital economy and its impact on labour productivity has a theoretical justification. ICT-driven productivity growth is the result of the appearance of certain transmission channels, direct and indirect ones. The direct impact of ICT, considered within the neoclassical theory framework, is connected both with the ICT production process and ICT regarded as capital input (Maggi *et al.,* 2007). In the first case, the production of ICT contributes directly to the total value added growth, because technological progress in ICT-producing sectors increases aggregate Total Factor Productivity (TFP) growth (Biagi, 2013). Secondly, improvement in ICT-producing sectors generates more demand for ICT capital in ICT-using sectors and productivity increases as a result of ICT capital deepening (Arendt, 2016).

However, the spread of ICT and production spillovers generated with time among firms lead to additional increase in productivity due to TFP growth in ICT-using sectors. This concept of an indirect transmission channel, derived from the new growth theory, treats ICT as a General Purpose Technology (GPT) which contributes to the innovation of the ICT-using sectors, enhancing the original benefits (Maggi *et al.,* 2007).

So far, in empirical studies the efficiency of the above transmission channels has been often demonstrated in the context of the EU-US productivity gap. The results showed a connection between ICT and EU's productivity (Schreyer, 2000; Van Welsum *et al.,* 2013) and the importance of both direct transmission channels (Timmer and van Ark, 2005; Oulton, 2010; Atkinson, 2018). Sector level studies also point to the difference in indirect channel functioning as a cause of the EU's lagging behind the US (Daveri, 2004; van Ark *et al.,* 2003, Timmer *et al.,* 2011).

UE-only macro and sector level studies have been rather scarce. Regardless of the methodological approach used, they prove, however, the importance of ICT capital deepening and TFP growth in ICT-producing sectors (direct channels) in shaping productivity dynamics, especially of the most developed EU economies (Karagiannis and Feridun, 2009; Spiezia, 2012; Hanclova *et al.,* 2015). Increasingly, research has focused on the contribution of TFP from ICT-using sectors to

productivity growth (indirect channel) and the diversity of EU countries in this regard (Pilat *et al.*, 2002; van Ark *et al.*, 2008). Initial evidence of the dominant role of ICT-using sectors in shaping TFP and productivity has also been obtained (Strauss and Samkharadze, 2011).

In literature there is a lack of comprehensive studies on the above issues for the period after 2007. The new EU members are also rarely included in analyses. The aim of the article is to fill that gap and verify the hypothesis of a significant ICT contribution to EU's productivity changes in 1997-2017. A macro and sector-level study, using the EU KLEMS growth and productivity accounts, pays attention to the role of both direct and indirect ICT transmission channels.

2. ICT and Productivity Growth- Methodological Issues

A direct ICT contribution to labour productivity growth can be captured at the macro level with the use of the growth accounting approach and derived from the neoclassical Solow-Swan model. Production (*Y)* in country (*i*) in time (*t)* is a function of aggregate factor inputs, labour (*L*), capital (*K*) and technological progress (*A*=*TFP*). Assuming the existence of the Cobb-Douglas production function:

$$Y_{it} = A_{it}(L_{it}^{\alpha} K_{it}^{1-\alpha}) \tag{1}$$

and after taking natural logs, the output (value added) change expressed in terms of capital, labour and technological progress growth rates can be obtained:

$$\Delta lnY_{it} = \Delta lnA_{it} + \alpha \Delta lnL_{it} + (1-\alpha)\Delta lnK_{it} \tag{2}$$

Following modification of equation (2) within KLEMS methodology, the labour input (*L*), human capital (*H*), ICT-capital and non ICT-capital can be extracted:

$$\Delta lnY_{it} = \Delta lnA_{it} + \alpha \Delta lnL_{it} + \beta \Delta lnH_{it} + \gamma \Delta lnK_{it}^{ICT} + (1-\alpha-\beta-\gamma)\Delta lnK_{it}^{nonICT} \tag{3}$$

Equation (3) can be rewritten as:

$$\Delta lny_{it} = \Delta lnA_{it} + \beta \Delta lnh_{it} + \gamma \Delta lnk_{it}^{ICT} + (1-\alpha-\beta-\gamma)\Delta lnk_{it}^{nonICT} \tag{4}$$

where $y_{it}=Y_{it}/L_{it}$, $h_{it}=H_{it}/L_{it}$, $k^{ICT}{}_{it}=K^{ICT}{}_{it}/L_{it}$ and $k^{nonICT}{}_{it}=K^{nonICT}{}_{it}/L_{it}$ represent, respectively, output, human capital, ICT and non ICT capital per hours worked.

Under the assumption of competitive factor market, input utilisation and constant returns to scale, the production elasticity with respect to particular inputs is equal to the shares of their compensation over total GDP (ϑ):

$$\Delta lny_{it} = \Delta lnTFP_{it} + \vartheta_{Lit}\,\Delta lnh_{it} + \vartheta_{ICTit}\Delta lnk_{it}^{ICT} + \vartheta_{nonICTit}\Delta lnk_{it}^{nonICT} \tag{5}$$

Equation (5) gives a clear interpretation of the relationship between labour productivity (LP) growth, TFP, ICT capital and other inputs (human and non-ICT capital) and is crucial in the context of direct transmission channels functioning (ICT capital deepening and TFP growth). However, capturing an indirect ICT impact requires a sectoral approach, within which contribution of ICT-using and ICT-producing sectors in aggregate TFP (productivity) growth can be estimated (Inklaar at. al, 2005).

In country *i* with *n* industries (*s*) in period *t*, aggregate labour productivity growth can be decomposed as (Strioh, 2002):

$$\Delta lny_{it} = \sum_{s=1}^{n} \rho_{its} \left(\Delta lnTFP_{its} + \vartheta_{Lits} \Delta lnh_{its} + \vartheta_{ICTits} \Delta lnk_{its}^{ICT} + \vartheta_{nonICTits} \Delta lnk_{its}^{nonICT} \right) + \mathrm{R} \quad (6)$$

where ρ_{its} is the share of industry *s* in aggregate value added and *R*- reallocation of hours[2].

Thus, the contribution of industries making up the ICT-producing/ICT-using sectors to aggregate TFP (productivity) growth can be calculated as:

$$\Delta lnTFP_{it} = \sum_{s=1}^{n} \rho_{its} \ \Delta \ln TFP_{its} \quad (7)$$

and is the weighted average of increases in TFP across industries, where the weights are the share of individual industries in the aggregate value added.

In this article, following Pilat *at al.* (2002) and Strauss and Samkharadze (2011) and using the EUKLEMS 2019 data[3], ICT-producing sectors are represented by computer, electronic, optical manufacturing (C26), electrical equipment and information (C27) and communication services (J). ICT-using sectors (van Ark *et al.*, 2003; Inklaar *et al.*, 2005) group the industries with the highest volume of investment in ICT, i.e., wood and paper products, printing and reproduction of recorded media (C16-18), machinery and equipment (C28), other manufacturing, repair and installation of machinery equipment (C31-33), whole trade and retail trade (G), financial and insurance activities (K) and professional, scientific, technical, administrative and support services activities (M-N).

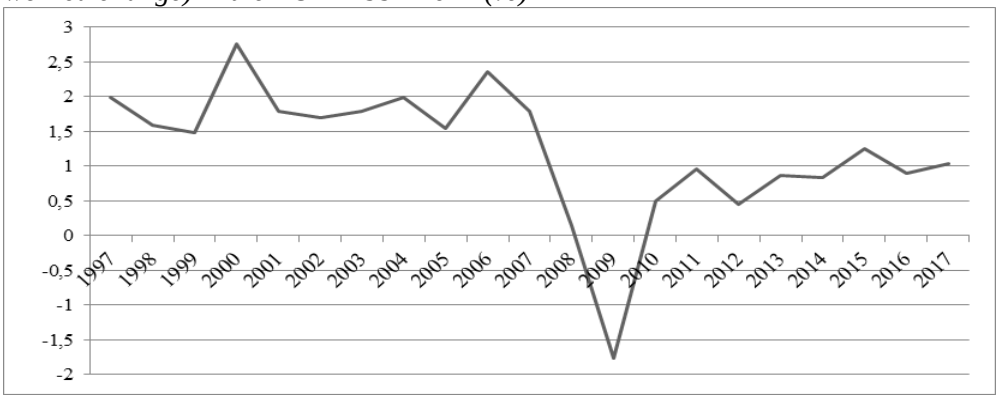
3. Productivity Dynamics in the EU in 1997- 2017

In general, in the period 1997-2017, a gradual decline in the productivity growth rate of EU countries was observed. Nevertheless, three sub-periods differing in terms of productivity dynamics can be distinguished.

[2] *R reflects differences in the share of industry s in aggregate value added and its share in aggregate hours worked.*

[3] *The industry classification in EUKLEMS 2019 is aligned with NACE Rev. 2/ISIC Rev. 4.*

Figure 1. *Labour productivity (LP) dynamics (average annual value added per hour worked change) in the EU in 1997-2017 (%)*



Note: *The average annual value added per hour worked growth calculated for Austria, Belgium (since 2000), Bulgaria, Cyprus, the Czech Republic, Germany, Denmark, Ireland, Greece, Spain, Finland, France, Hungary.*
Source: *Own calculations, EUKLEMS database.*

The pre-crisis period 1997-2007 was characterised by a relatively high increase in labour productivity, i.e., between 1.7% and 3.7% per year. The financial crisis started in 2007 and its consequences in the following years are undoubtedly associated with the drop in EU's productivity. In 2008-2012, the average annual productivity change ranged from -1.8% to 1%. A bit higher annual labour productivity growth rate in the EU after 2013 was observed. In 2013-2017 the average EU productivity growth ranged from 1.2% to 2% per year, which means that EU member states did not achieve the pre-crisis growth rate. Given the above changes in EU's productivity dynamics, it seems advisable to track a direct and indirect ICT impact in these aforementioned sub-periods.

4. Direct ICT Impact on EU' Productivity – Macro Level Study

A direct ICT impact on EU members' labour productivity growth can be estimated using equation (5), where gross value added (per hour worked) growth is decomposed into the contribution of ICT capital, TFP growth and non-ICT inputs. Detailed results of the study conducted with the use of the EUKLEMS 2019 database is included in Table 1.

After analysing ICT capital deepening as a direct channel of ICT impact, it can be stated that in 1997-2007 ICT investments accelerated (to a small extent) productivity growth of EU countries (by 8% in the EU-11 and 3% in the UE-2). In the pre-crisis period, TFP growth accounted for about 50% of EU's productivity change. A particularly high positive contribution was observed in the new EU countries (70%), in Finland, France and Germany. Only Italy and Spain experienced a decline in TFP.

***Table 1**. ICT capital, TFP and other inputs contribution to average annual productivity growth of EU economies in 1997-2017*

	1997-2007				2008- 2012				2013-2017			
Country/group	LP (%)	ICT capital (p.p)	TFP (p.p)	other inputs (p.p)	LP (%)	ICT capital (p.p)	TFP (p.p)	other inputs (p.p)	LP (%)	ICT capital (p.p)	TFP (p.p)	other inputs (p.p)
Austria	1,93	0,10	1,08	0,74	0,69	0,05	-0,02	0,67	0,73	0,07	0,28	0,38
Belgium	1,31	0,09	0,70	0,52	0,53	0,01	0,09	0,43	0,50	0,03	0,15	0,32
Germany	1,88	0,05	1,40	0,42	0,46	-0,02	-0,02	0,50	0,87	0,02	0,82	0,03
Denmark	1,07	0,15	0,88	0,03	0,93	0,09	-0,43	1,27	1,14	0,10	0,86	0,18
Spain	0,22	0,20	-0,38	0,40	2,02	0,22	-0,55	2,36	0,70	0,13	0,06	0,51
Finland	2,62	0,10	2,16	0,36	-0,11	0,07	-1,02	0,84	0,47	0,04	0,05	0,37
France	1,55	0,08	1,23	0,25	0,17	0,05	-0,34	0,46	0,81	0,08	0,04	0,68
Italy	0,44	0,06	-0,14	0,52	0,04	0,01	-0,89	0,93	0,28	0,03	0,06	0,19
Netherlands	1,63	0,21	0,95	0,47	0,48	0,12	-0,10	0,47	0,61	0,13	0,27	0,21
Sweden	2,66	0,22	0,41	2,04	0,15	0,11	-1,05	1,09	1,02	0,34	0,37	0,31
United Kingdom	2,12	0,19	1,12	0,81	0,19	0,05	-0,23	0,38	0,32	-0,03	0,42	-0,07
Czech Republic	3,66	0,15	1,87	1,64	0,80	0,09	-0,72	1,43	1,41	0,06	0,92	0,43
Slovakia	5,32	0,09	4,45	0,77	2,19	0,09	0,92	1,19	2,18	0,08	1,31	0,79
Bulgaria	n/a	n/a	n/a	n/a	4,50	0,13	1,27	3,10	1,93	-0,06	0,84	1,16
Estonia	n/a	n/a	n/a	n/a	1,43	0,16	-1,50	2,77	0,98	0,07	0,37	0,55
Hungary	n/a	n/a	n/a	n/a	-1,08	0,01	-2,36	1,28	0,07	-0,02	0,56	-0,47
Lithuania	n/a	n/a	n/a	n/a	2,79	0,31	-1,48	3,96	0,94	0,03	0,48	0,43
Latvia	n/a	n/a	n/a	n/a	4,05	0,15	0,43	3,47	1,60	-0,08	1,44	0,23
Slovenia	n/a	n/a	n/a	n/a	0,09	-0,02	-1,74	1,85	1,50	-0,03	1,03	0,51
UE-11	1,58	0,13	0,86	0,60	0,51	0,07	-0,42	0,85	0,68	0,09	0,31	0,28
UE-2/ EU-8	4,49	0,12	3,16	1,21	1,85	0,11	-0,65	2,38	1,33	0,01	0,87	0,45

***Note:** LP- labour productivity growth, TFP- total factor productivity growth , ICT capital- contribution of ICT investment (p.p.), other inputs-contribution of labour (LC) and other capital investment (non-ICT capital). According to equation (5): LP=TFP+ICT capital+ LC+ non-ICT capital.*

***Source:** Own calculations, EUKLEMS database.*

In 2008-2012 productivity growth of the old EU countries in about 13% resulted from the accumulation of ICT capital. In the new EU members this contribution was much lower (0.11 pp. from 1.6% productivity growth). The positive ICT capital contribution was, however, too timid to compensate for the sharp drop in TFP experienced by the EU-11 group (except Belgium) and most of the new EU countries (except Latvia, Bulgaria and Slovakia). Countries that experienced a decline in TFP showed only a slight increase or drop in productivity. Therefore, in the crisis period and in the years immediately following, the negative contribution of TFP can be considered the key cause of EU's productivity slowdown. Countries with relatively high contribution of non-ICT inputs (new EU members and Spain) had an advantage in productivity growth.

In 2013-2017 in Western Europe, 12% of the increase in productivity was due to investment in ICT. In the EU-8 group ICT capital contribution was lower (only 0.005 pp. from 1.6% productivity growth), in some countries even negative (e.g., Bulgaria, Hungary). After 2013, TFP growth largely contributed to EU's productivity dynamics (about 45% in the EU-15 and 50% in the EU-8).

5. Direct and Indirect ICT Impact on EU's Productivity Growth – Sector Level Study

In the above macro-level study, despite having evidence of the key role of TFP in shaping productivity of EU economies, it is not possible, to clarify which part of TFP change came from ICT-producing sectors (direct channel) and which from ICT-using industries (indirect channel). Using the previously discussed equation (7) and sector-level data, a more detailed study aimed at disaggregating TFP growth was conducted. The study concerns 13 EU members for which sector-level productivity accounts in the EUKLEMS 2019 database were available. The results of the study are summarised in Table 2.

Table 2. *Contribution of ICT-producing and ICT-using sectors to average TFP growth of EU countries in 1997-2017*

	1997-2007			2008- 2012			2013-2017		
Country/group	TFP growth (%)	in ICT producing sectors (p.p)	in ICT using sectors (p.p)	TFP growth (%)	in ICT producing sectors (p.p)	in ICT using sectors (p.p)	TFP growth (%)	in ICT producing sectors (p.p)	in ICT using sectors (p.p)
Austria	1,08	0,14	0,57	-0,02	0,01	0,38	0,28	0,04	0,15
Belgium	0,70	0,16	0,20	0,09	0,05	0,12	0,15	0,08	0,03
Germany	1,40	0,42	0,21	-0,02	0,27	-0,54	0,82	0,14	0,22
Denmark	0,88	0,24	0,40	-0,43	0,21	-0,35	0,86	0,25	0,21
Spain	-0,38	0,03	0,06	-0,55	0,01	-0,33	0,06	0,07	0,01
Finland	2,16	0,94	0,87	-1,02	-0,15	-0,05	0,05	0,35	0,17
France	1,23	0,24	0,20	-0,34	0,03	-0,22	0,04	0,06	-0,02
Italy	-0,14	0,10	-0,17	-0,89	0,03	-0,19	0,06	-0,02	0,25
Netherlands	0,95	0,32	0,56	-0,10	-0,01	0,26	0,27	0,06	0,22
Sweden	0,41	0,60	0,48	-1,05	0,34	-0,06	0,37	0,12	0,66
United Kingdom	1,12	0,30	0,53	-0,23	0,03	-0,04	0,42	0,18	0,24
Czech Republic	1,87	0,26	1,11	-0,72	0,17	0,12	0,92	0,20	0,76
Slovakia	4,45	0,31	1,47	0,92	0,68	0,16	1,31	0,16	-0,22
UE-11	0,86	0,32	0,36	-0,41	0,07	-0,09	0,31	0,12	0,19
UE-2	3,16	0,29	1,29	0,10	0,43	0,14	1,12	0,18	0,27

Source: *Own calculations EUKLEMS database.*

In 1997-2017, a positive contribution of TFP from ICT-producing sectors to aggregate TFP was observed in most EU countries. However, the changes in TFP from ICT-using sectors turned out to be more significant. In the pre-crisis period, the contribution of these sectors to aggregate TFP was generally positive and quite high. On average, in the EU-11 it amounted to 0.36 pp. of 0.8% TFP growth rate, in the EU-2 it was 1.3 pp. of 3.2% increase in TFP.

In 2008-2012, a negative contribution of TFP from ICT-using sectors (0.1 pp. on average) was the cause of the aggregate TFP drop (0.4% per year) in most old EU countries. In turn, a low TFP growth rate in the Czech Republic and Slovakia was the result of the negative contribution of TFP from non-ICT sectors. In the period after 2013, a much higher contribution of TFP from ICT-using sectors (0.2 pp. in the EU-11 and 0.3 pp. in the EU-2) resulted in higher aggregate TFP growth (0.3% in EU-11 and 1.1% in EU-2 on average).

Based on the above study results (Tables 1 and 2), direct and indirect channels of ICT impact on EU's productivity in 1997- 2017 can be estimated (Table 3).

Table 3. *Direct and indirect channel of ICT impact on productivity growth in the EU in 1997- 2017*

	1997-2007			2008- 2012			2013-2017		
Country/group	LP (%)	Direct ICT impact (p.p)	Indirect ICT impact (p.p)	LP (%)	Direct ICT impact (p.p)	Indirect ICT impact (p.p)	LP (%)	Direct ICT impact (p.p)	Indirect ICT impact (p.p)
Austria	1,93	0,24	0,57	0,69	0,06	0,38	0,73	0,11	0,15
Belgium	1,31	0,25	0,20	0,53	0,06	0,12	0,50	0,11	0,03
Germany	1,88	0,47	0,21	0,46	0,25	-0,54	0,87	0,16	0,22
Denmark	1,07	0,39	0,40	0,93	0,30	-0,35	1,14	0,35	0,21
Spain	0,22	0,23	0,06	2,02	0,23	-0,33	0,70	0,20	0,01
Finland	2,62	1,04	0,87	-0,11	-0,08	-0,05	0,47	0,39	0,17
France	1,55	0,32	0,20	0,17	0,08	-0,22	0,81	0,14	-0,02
Italy	0,44	0,16	-0,17	0,04	0,04	-0,19	0,28	0,01	0,25
Netherlands	1,63	0,53	0,56	0,48	0,11	0,26	0,61	0,19	0,22
Sweden	2,66	0,82	0,48	0,15	0,45	-0,06	1,02	0,46	0,66
United Kingdom	2,12	0,49	0,53	0,19	0,08	-0,04	0,32	0,15	0,24
Czech Republic	3,66	0,41	1,11	0,80	0,26	0,12	1,41	0,26	0,76
Slovakia	5,32	0,40	1,47	2,19	0,77	0,16	2,18	0,24	-0,22
UE-11	1,58	0,45	0,36	0,51	0,14	-0,09	0,68	0,21	0,19
UE-2	4,49	0,41	1,29	1,50	0,51	0,14	1,79	0,25	0,27

Source: *Own calculations EUKLEMS database.*

In all the subperiods, the majority of EU countries experienced a positive, direct impact of ICT on productivity (due to ICT capital deepening and TFP growth in ICT-producing sectors). A negative impact was observed only in Finland during the crisis. Greater importance of this direct channel was observed in the old EU members than in the EU-2.

In 1997-2017 EU's labour productivity (LP) growth was strongly connected with the indirect channel of ICT impact, i.e., with TFP dynamics in ICT-using sectors. In the pre-crisis period, TFP growth in these sectors had a positive impact on productivity in the EU (except Italy). In the old EU members its contribution was on average 0.4 pp. of 1.6% growth in LP and in the EU-2 about 0.3 pp. of 4.5% increase in LP. Much higher importance of the indirect channel than the direct one was observed in Austria, the Netherlands, UK, Czech Republic and Slovakia.

During the crisis most EU countries (except Austria, Belgium, the Netherlands, the Czech Republic and Slovakia) recorded a negative impact of the indirect channel and, consequently, a productivity drop. After 2013, in the EU-11 group (except France) a significant and positive impact of the indirect channel (contribution was 0.22 pp. of 0.7% LP growth on average) was observed, especially in Austria, Germany, the Netherlands, Sweden and Italy. A significant positive impact was

recorded in the Czech Republic (0.7 pp. of 1.4% LP growth), but a negative one in Slovakia.

6. Conclusions

The results of the conducted study confirm the hypothesis of the direct and indirect impact of ICT on EU's productivity, but it seems to be much more important for the old EU members. The productivity dynamics of the new EU countries depended more on traditional inputs than ICT, and were more stable, especially during the crisis.

In 1997-2017, a positive (but rather small) direct ICT impact on EU' productivity related to the acceleration of ICT capital deepening, especially in the old EU members, was observed. In all economies, productivity growth was primarily related to the changes in TFP. In general, TFP in ICT-producing sectors increased, having a positive impact on productivity (direct channel). It turns out that the indirect channel was, however, of key importance for the EU's productivity growth. TFP changes in the ICT-using sectors had the greatest impact on the productivity dynamics, especially during the crisis.

Therefore, to accelerate EU's productivity in the future, it is necessary to use this channel more efficiently than ever before. Achieving benefits from ICT in the form of additional TFP growth (generating spillover effects) requires, however, not only greater investment in ICT, but also institutional changes aimed at, among others, market deregulation, support for reorganization processes in companies and technology diffusion.

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