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THE EFFECT OF ICT ON PRODUCTIVITY IN TRANSITION AND DEVELOPED EU MEMBERS

Abstract:

The aim of the paper was to investigate the effects of the share of value added of the ICT sector on productivity within the EU, and also to investigate any systematic differences in the effects between east (transition countries) and west (developed) EU members. To analyze the effect we used a fixed effects panel framework on a total of 23 EU countries (12 countries in “west” and 11 in “east” Europe) in a 25 year time period (1995-2020). Our main finding is that overall the share of ICT value added is a relevant and statistically significant predictor of labor productivity in the entire EU region. Furthermore, we find that the effect is twice as strong in west as opposed to east EU countries, implying a greater efficiency in translating new technology into more output per worker in developed countries. Additionally, we find that government share of GDP is a negative predictor of labor productivity in both sets of countries, giving credence to the often heard criticisms of the inefficient EU labor market due to excessive regulation which is further exacerbated by high corruption levels in east EU countries. Finally, we find that GDP per capita has a statistically significant negative relationship with productivity also in both sets of countries, implying that there is a significant catch-up effect at work both within west and east EU, with higher GDP per capita levels corresponding with lower productivity growth.

Keywords:

ICT, Productivity, Transition countries

JEL Classification: N10, O47, O57

1. Introduction[1]

There is a large literature on the effects of ICT on productivity. It started in the 1990's, largely due to two unexpected empirically observed phenomena. The first was that although the PC revolution was well underway in the 1980's and early 90's, there were no visible productivity gains in developed economies. This was named the "Solow's productivity paradox" on account of Robert Solow's famous 1987 quip that "You can see the computer age everywhere but in the productivity statistics". The second was that when productivity statistics started to show the ICT effect in the US (starting from around 1995), it was not visible in the EU, and the productivity gap between the US and EU which was shrinking up to that point, started to widen. Most of the research of the time concluded that the widening productivity gap was due to the fact that ICT diffusion was slower in Europe on account of inefficient regulation and rigid labor markets (Gust & Marquez, 2004). Today, 15 years after these conclusions were made, the US-EU productivity gap is still widening.

Further questions started to arise as to what long term effect the ICT revolution would have. Some authors thought it would entail a temporary one-off boost to productivity meaning that it would not rise to the level of a full blown GPT (*General Purpose Technology*) as had happened during the first and second industrial revolution. In fact some evidence of this was shown when productivity growth started to slow down around 2004 in the US.

The aim of this paper is to investigate the link between ICT and productivity in the EU, with a special focus on the performance differential between old and new (mostly transition countries) member states. We do this by used a fixed effects panel framework on a total of 23 EU countries (12 countries in "west" and 11 in "east" Europe) in a 25 year time period (1995-2020). This enables us to update the literature which mostly petered out by 2013 taking the time dimension up to 2020, and secondly to investigate more closely the differences between old (west) and new (east) EU members with regard to productivity determinants.

Our main finding is that overall the share of ICT value added is a relevant and statistically significant predictor of labor productivity in the entire EU region. Furthermore, we find that the effect is twice as strong in west as opposed to east EU countries, implying a greater efficiency in translating new technology into more output per worker in developed countries. This might be tied to our finding that the investment share of GDP (which we use as a proxy for capital deepening and overall non-ICT investments which contribute to labor productivity) is statistically insignificant in the case of west EU, but significant and positive for east EU countries. Taken together, these results point to a possible interpretation in which east EU which starts on a lower developmental level is still able to boost labor productivity with overall investment into infrastructure and other non ICT types of capital deepening, while the developed west EU countries are able to squeeze out more productivity exclusively through more ICT and technological development at which they are consequently more efficient.

We also get some interesting side-results from our set of control variables. Labor participation had a strong negative relationship with labor productivity in the early seminal research in the 1990's, which was thought to be a function of labor market reforms of the period. However we find that the relationship persists throughout the whole time period, pointing to something structural. A possible explanation is that more labor participation usually means more low-skilled workers which are less able to utilize modern technological advancements. Additionally, we find that government share of GDP is a negative predictor of labor productivity in both sets of countries, giving credence to the often heard criticisms of the inefficient EU labor market due to excessive regulation which is further exacerbated by high corruption levels in east EU countries. Finally, we find that GDP per capita has a

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statistically significant negative relationship with productivity also in both sets of countries, implying that there is a significant catch-up effect at work both within west and east EU, with higher GDP per capita levels corresponding with lower productivity growth. The paper is structured as follows. After the Introduction we present a brief Literature review where related research is briefly discussed. This is followed by a presentation of the selected model for analysis and relevant data sources in the Data and Methodology section. Finally we present our results in the Results section which is followed by our Conclusions.

2. Literature Review

The empirical literature on the effect of ICT on productivity can be classified to two main groups based on methodological differences: research based on growth accounting techniques and on econometric techniques.

The early literature focused on growth accounting (Biagi & others, 2013). One of the first tasks was to find the reason for the productivity uptick in the US starting in the mid 1990's after several decades of slowdown. This early research pretty much unanimously agreed that the major cause was to be found in ICT technology (Gordon, 2000; Jorgenson et al., 2002; Jorgenson & Stiroh, 1999). The first results seem to indicate a weak link between ICT capital deepening and productivity in the period up to 1992 (Oliner et al., 1994). However things rapidly change after 1995 when the full effects of ICT production become visible (Jorgenson & Stiroh, 1999; Sichel & Oliner, 2002). There were two seminal "retrospective" works which are considered for all intents and purposes authoritative on the matter of US productivity growth (Jorgenson et al., 2008) and the US vs EU productivity gap (Van Ark et al., 2008).

Jorgenson et al. (2008) concludes that in fact ICT had a substantial effect on US productivity after 1995. Furthermore the concluded that Information technology emerged as the driving force behind the acceleration of labor productivity growth that began in the mid-1990s, while capital deepening and total factor productivity growth outside of information technology increased in relative importance after 2000. Van Ark et al. (2008) confirm this view, and starts to try to find out the reason for lagging EU ICT adoption. They find the reasons in the small share of technology producing industries in Europe, slower advances in technology and innovation coupled with high level product and labor market regulation in the EU. Finally a more recent retrospective (Gordon, 2013) casts doubt on the long term effects of the ICT revolution, claiming that after 2004 the productivity growth levels have fallen back to pre '90s levels.

Concerning the US vs EU productivity difference, the first papers used growth accounting to asses the contributions of various sectors of the economy to productivity growth (Daveri, 2004; Van Ark et al., 2008) but over time econometric methods became preferred in most cases on account of their higher levels of versatility compared to the strict neoclassical growth accounting methodology.

Moving on to the use of econometrics in trying to address the productivity paradox, one of the earlier attempts is by Gust and Marquez (2004). The authors use a panel of 13 countries in the period from 1992 to 1999 to attempt to ascertain to what degree ICT production and ICT adoption can explain the observed productivity differences between the US and other European developed countries. Since they find a significant and positive effect of both variables (IT production and adoption/diffusion) they further attempt to isolate the factors responsible for the observed differences in IT adoption. Their final results therefore constitute two panel regressions. One with proxy variables for ICT production and adoption (with relevant control variables) on the right side with labor productivity on the left side of the equation, and the other with ICT adoption as the dependent, and various proxy variables measuring regulatory practices with a special reference to labor market rigidities. They conclude that there is a significant role of ICT adoption in explaining the difference in productivity between EU countries and the US, which in turn are to a large degree connected to labor market inefficiencies. Furthermore they judge that in the future the EU will need substantial labor market reforms in order to "reap the full benefits of information technology".

O'Mahony and Vecchi (2005) attack the problem of quantifying the impact of ICT on output growth with several eceonometric approaches, including traditional panel analysis and dynamic panel data estimation. They start of with traditional panel methods, but do not register a significant impact of ICT on output, which they attribute to heterogeneity across industries especially across time. To deal with issues of industry heterogeneity, nonstationarity and cointegration they use a pooled mean group estimator (PMG) which applies, as the authors succinctly explain: "an error correction modelling framework to the panel dimension by imposing homogeneity restrictions on the long-run parameters and deriving the error correction coefficient and the other short-run parameters of the model by averaging across groups." They conclude that in line with expectations that ICT growth has a significant and positive effect on output growth, with the results being robust in the case of the US, but less so in the case of the UK. Additionally they hypothesize that the effect is larger than what work done using purely growth accounting methods implies.

Becchetti and Adriani (2005) offer an interesting take on ICT in which they propose to define it almost exclusively in software terms as "weightless, implementable and infinitely reproducible knowledge products". The search for these non-material ICT productivity benefits are essential in their view in order to fully explain economic growth in the 21st century. Since they posit that the ICT revolution mainly consists of intangibles, theoretically there should be almost instant diffusion across countries, industries and firms. Since this is not supported by the data, the authors assume that there are several infrastructure-related "bottlenecks" in play which go a long way in explaining productivity growth differences across countries. According to the authors these bottlenecks include: the quality of telephone lines, number of personal computers, mobile phones and internet hosts. Using cross-section and panel analysis, they conclude that ICT diffusion is a significant predictor of rates and levels of productivity when the aforementioned bottlenecks are taken into consideration. Furthermore, the results point to the conclusion that income differences between countries are less structural than was previously supposed, and are to a large measure of a transitory character depending on the spread of telecommunications infrastructure.

Venturini (2009) chime in on the debate of the long term effects of ICT on output growth. More specifically, by using panel cointegration analysis within a production function framework, they analyze output elasticities of ICT. The analyzed dataset is comprised of EU-15 countries and the US in the period 1980-2004. The goal was to see if the ICT revolution could be a significant long term growth factor instead of a simple temporary "boost". Their results show that ICT indeed is a long term stable predictor of income, with estimated returns from 0.08 to 0.14 depending on the specification and control variables used. Furthermore, they find that the ICT sector punches above it's weight, i.e. the elasticity of output with respect to ICT is more than the share of ICT in the economy which implies long run positive externalities. These results go against the grain of the established opinion of the time, which was that ICT technology would comprise of a temporary boost which would end with the proliferation of PC's, the Internet and mobile phones to the majority of the population.

Conway et al. (2007) investigate the link between product market regulation and ICT proliferation, and it's consequent impact on productivity growth. They find that anti-competitive product market regulation, especially in non-manufacturing sectors. This, they authors argue can go a long way in explaining the observed productivity divergence in OECD countries (mostly in the contrast with US vs EU) starting in the mid 90's. Furthermore they find that the negative effect of anti-competitive regulations is especially strong in sectors that are heavily involved with ICT (either in production or adoption). As a quantitative approximation, they find that when there is a worldwide upward movement in the productivity frontier (due to for example technology shocks brought about by the ICT revolution), countries with strong anti-competitive regulatory frameworks can develop a productivity gap of 40% relative to more liberal countries.

Regarding the link between productivity and ICT in the EU, as well as the differences in the relationship between east and west EU, a relatively small amount of work was done. The primary source is the already heavily cited Bart van Ark and co-authors (Van Ark et al., 2013, 2018; Van Ark & Jäger, 2017; Van Ark & Piatkowski, 2004) with sporadic contributions from other authors over the decades (Dahl et al., 2011; Relich, 2017)

One of the first papers to explore the role of the ICT sector in the productivity gap between east and west Europe is the paper done by Van Ark and Piatkowski (2004). The authors use a growth accounting framework to analyze the difference in productivity between EU-15 countries and CEE (Central and Eastern Europe) countries in the 1990's to see if there is convergence or divergence and why. They conclude that labor intensity has been a substantial source of convergence. Moreover, their findings imply that CEE investments in ICT brought about the same productivity growth as ICT investments in EU-15, and that most of this effect can be traced to ICT investments in manufacturing. They conclude that although ICT can be an important source of long term growth in the future for CEE countries, it is probably a temporary source of convergence since most of the ICT revolution benefits are expected to come from its diffusion in the service sector which will probably be hampered by inefficient institutions.

Dahl et al. (2011) revisit the problem of ICT led productivity growth in Europe in the 1990's. The authors disagree with the established opinion up to that point, which was that the EU divergence and slowdown after 1995 of productivity growth compared to the US is mostly due to an under-performing ICT sector. Instead they posit an alternative hypothesis, that the lagging European productivity has more to do with negative macroeconomic shocks of the period. They use panel analysis on a multi-country dataset to try to argue that ICT had a strong impact on European productivity growth but this effect is dampened by macroeconomic shocks unrelated to ICT which was not the case in the US. As far as the authors can determine, this constitutes a minority view.

Van Ark et al. (2013) look at productivity growth in the 2000's. The paint a relatively bleak picture of EU productivity in the decade, especially when taking into account data from the Great Recession of 2008. Using a growth accounting methodology, they come to the conclusion that the main weakness of EU productivity in the first decade of the 21st century is TFP growth, which is negative in the period 2006-2011 for the EU-15 except for Germany, Netherlands and Austria. They find the situation in the new (east) EU countries to be slightly better, there TFP growth for the main part stayed positive (except in Bulgaria, Slovenia and Hungary), but very low in the case of the Baltic states. They attribute this weak performance not only to ICT or technological progress and innovation in general (which can explain low growth rates but not negative ones) but also to inefficient allocation and reallocation due to underperforming labor and capital markets, causing resources to be allocated to less productive parts of the economy. These findings were largely confirmed again in Van Ark and Jäger (2017) where the dataset was enlarged to encompass years up to 2015. The authors conclude that the Great Recession (08/09) and the Euro Area recession (11/12) have "significantly damaged the growth potential of European economies across the board", with very low productivity rates expanding from the service sector to the goods producing and manufacturing sectors.

In the last of the published papers related to the Gronigen publications, Van Ark et al. (2018) report the final snapshot of EU GDP and productivity growth before the COVID-19 pandemic. They report that while GDP growth returned to pre crisis levels at the tail-end of their dataset, structural (i.e. productivity) statistics are still lagging behind substantially. More specifically, they find that labor productivity growth rates are about 50% of what they were in the 90's and 00's before the Great Recession, and roughly a third of what they were in the 70's and 80's. Additionally, they find that the TFP situation is even worse, wtih overall EU TFP growth rates at around 0.1%. An interesting additional fact emerges from their analysis, which is that even these relatively weak growth rates are primarily due to CEE countries closing the productivity gap with developed EU countries, but even taking this into account CEE countries are currently at about 50% of the productivity level of developed EU countries, meaning that even with the current productivity growth differential, it will still take decades for the gap to close.

Finally, a recent study on the effect of ICT on labor productivity in "old" and "new" Europe (Relich, 2017) first approximate ICT with related sub-variables: ERP software, e-commerce and CRM software, and number of ICT specialists. Their find that several variables have a positive and significant effect on labor productivity, chief among them being the number of ICT specialists. Additionally, they find that when comparing CEE with EU-15 economies the impact of the various ICT proxy variables is invariably greater in the CEE region, especially in the use of ERP and CRM technology diffusion, where they find almost a two times greater effect in transition countries.

3. Data and Methodology

Since the aim of the paper is to analyze the impact of ICT on labor productivity in transition and developed EU countries, we divide the EU into "east" and "west", roughly corresponding to what is usually termed CEE (Central and East Europe) and EU-15 countries, with minor alterations due to data limitations. Following this logic our set of "west" EU countries includes 12 EU-15 countries: Belgium, Denmark, Germany, Greece, Spain, France, Italy, Netherlands, Austria, Finland, Sweden and Portugal, while our set consisting of "east" EU includes 11 countries: Bulgaria, Czechia, Estonia, Croatia, Latvia, Lithuania, Hungary, Poland, Romania, Slovakia and Slovenia. The data is gathered from various Eurostat datasets. Data acquisition, management and visualization was done using the *tidyverse*, *lubridate* and *eurostat* (Grolemund & Wickham, 2011; Lahti et al., 2017; Wickham et al., 2019) group of packages in the R statistical software.

The main limiting factor in these types of analyses is ICT data. Official definitions of the ICT sector are very fine grained, going to 4 digit NACE classifications, which makes the data very hard to obtain, usually inclining researchers to opt for some sort of rougher approximation (Gust and Marquez, 2004) which will still capture the vast majority of the ICT effect on the economy. Following this reasoning, we define ICT as NACE rev. 2 categories C26 (*Manufacture of computer, electronic and optical products*) and section J (Information and communication) which notably includes J61 (*Telecommunications*) and J62-J63 (*Computer programming, consultancy, and information service activities*).

To study the effect of of ICT on productivity in EU countries we opt for entity fixed effects panel analysis. The regression equations are of the basic form:

$$LP = \beta_i + \beta_1 ICT_{i,t} + \beta_2 X_{i,t} + u_{i,t}$$

where $i = 1, 2 \ldots$ to n (number of countries depending on the group of countries in question), t = 1995, 1996, ... , 2020; ICT is the share of the previously defined ICT sector in total value added, and X stands for selected control variables (labor participation, gdp per capita etc.). We estimate six variations of this basic equation using different combinations of control variables in order to ascertain the robustness of the results. We use country fixed effects (also known as the *within* method) which is commonly used in the literature.

This method allows for systematic differences between countries as regards the intercept term β_i, meaning that we attempt to account for effects which are different for each country but invariant across time. This seems like a plausible assumption given that each country will have different regulations and different starting sizes of the ICT sector. Furthermore we use the so called *HAC* (*heteroscedasticity and autocorrelation consistent standard errors*) to account for both heteroscedasticity and autocorrelation within countries.

4. Results

The results for west EU are given in Table 1 and for east EU in Table 2. In each table, the results of six different regression outputs are summarized, beginning with (1) which represents a simple one variable regression measuring the effect of the percentage change in value added ("ict_va_change") to the percentage change in labor productivity. From there in equations (2) - (6) control variables are added one by one. We take (4) as the "baseline" specification in Table 1, and specification (5) in Table 2.

Table 1: West EU panel regressions

	(1)	(2)	(3)	(4)	(5)	(6)
ict_va_change	0.025	0.173***	0.155***	0.136***	0.136***	0.141***
	(0.020)	(0.012)	(0.010)	(0.010)	(0.011)	(0.012)
lag(emp_change)		−0.350*	−0.518***	−0.527***	−0.527***	−0.540***
		(0.140)	(0.144)	(0.154)	(0.149)	(0.146)
gov_share_gdp			−0.225***	−0.232***	−0.230***	−0.238***
			(0.052)	(0.045)	(0.042)	(0.046)
log(gdp_pc)				−1.781**	−1.779**	−0.851
				(0.635)	(0.639)	(0.849)
investment_share_gdp					0.003	−0.023
					(0.055)	(0.050)
rd_share_gdp						−0.856+
						(0.453)
Num.Obs.	296	288	288	288	288	281
R2	0.043	0.299	0.396	0.423	0.423	0.449
R2 Adj.	0.002	0.266	0.365	0.391	0.388	0.414
AIC	1197.0	1079.9	1038.8	1028.1	1030.0	995.0
BIC	1198.7	1079.6	1036.4	1023.7	1023.7	986.6
RMSE	1.82	1.56	1.45	1.42	1.42	1.39
Std.Errors	HC1	HC1	HC1	HC1	HC1	HC1

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Overall we find a significant and positive relationship between the share of the ICT sector and labor productivity in both groups of countries. This is an interesting find in itself since it does not support a commonly argued position in the early literature that the ICT revolution is going to be a temporary productivity boost and not a source of long-run growth. Additionally the size of the coefficient is roughly twice the size for west EU countries as opposed to east EU implying a greater efficiency in translating new technology into more output per worker in developed countries.

The variable "lag(emp_change)" is the lagged share of employed persons in total population (older than

15) i.e. the labor participation rate. Gust and Marquez (2004) find this to be a negative and significant predictor of labor productivity change, as is the case in our results. The argument is that countries with a higher labor force growth will be less able to fully absorb new technologies. Their research was done for the 1990's where there was an additional argument that advanced EU countries in that period made a series of labor market reforms which brought low skilled workers back in to the labor force. Since the results are so robust and we are dealing with a much broader timeframe the first argument seems more likely, but whatever the reason it is interesting to see that even when expanding the dataset 20 more years this negative relationship still holds true both for east (as we can see from Table 2 and west EU).

The variable "gov_share_gdp" measures the percentage size of government spending in total GDP to proxy for the magnitude of government intervention in the economy. We find that in both groups of countries this coefficient is significant and negative, implying inefficient government spending and regulatory framework, giving corroboration to the often heard argument that EU countries in general have too much government which is mainly responsible for the EU vs US productivity gap.

Table 2: Transition country panel regressions

	(1)	(2)	(3)	(4)	(5)	(6)
ict_va_change	0.090***	0.113***	0.105***	0.077**	0.065***	0.064***
	(0.019)	(0.022)	(0.022)	(0.024)	(0.016)	(0.015)
lag(emp_change)		−0.178+	−0.298***	−0.231**	−0.361***	−0.367***
		(0.094)	(0.080)	(0.075)	(0.099)	(0.101)
gov_share_gdp			−0.317***	−0.347***	−0.312***	−0.311***
			(0.074)	(0.068)	(0.060)	(0.062)
log(gdp_pc)				−1.887*	−1.390*	−1.245
				(0.742)	(0.685)	(0.770)
investment_share_gdp					0.234***	0.243***
					(0.062)	(0.059)
rd_share_gdp						0.208
						(0.799)
Num.Obs.	272	254	254	254	254	248
R2	0.110	0.175	0.252	0.316	0.385	0.377
R2 Adj.	0.072	0.134	0.212	0.276	0.346	0.334
AIC	1397.1	1270.5	1247.7	1227.0	1202.0	1172.2
BIC	1398.7	1270.1	1245.3	1222.5	1195.6	1163.8
RMSE	3.13	2.92	2.78	2.66	2.52	2.50
Std.Errors	HC1	HC1	HC1	HC1	HC1	HC1

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

We also measure GDP per capita ("log(gdp_pc)") which is here to see if initial levels of development are important. As we saw in the literature review some researchers argue that if there is a "catchup" mechanism in play the coefficient should be negative and significant, which it is in both analyzed cases (east and west EU), giving evidence that the labor productivity gap within both groups is shrinking.

To proxy for capital deepening, and overall non-ICT investments which contribute to labor productivity, we include the investment share in GDP ("investment_share_gdp"). It is interesting to note that this variable is insignificant in the case of west EU countries, but significant in east EU countries. This is perhaps a result of west EU countries now primarily basing their productivity growth on ICT related industries, while the less developed east EU countries still being able to boost productivity with general investments in infrastructure etc. Finally to proxy for investments into new technology we include the share of R&D expenditure in GDP which turns out to be insignificant at the 5% level in every specification for both groups.

5. Conclusion

The aim of the paper was to investigate the effects of the share of value added of the ICT sector on productivity within the EU, and also to investigate any systematic differences in the effects between east (transition countries) and west (developed) EU members. To analyze the effect we used a fixed effects panel framework on a total of 23 EU countries (12 countries in "west" and 11 in "east" Europe) in a 25 year time period (1995-2020).

Our main finding is that overall the share of ICT value added is a relevant and statistically significant predictor of labor productivity in the entire EU region. This casts doubt on a frequent hypothesis in earlier work which surmised that the ICT revolution which started in the 90's would be a temporary, not a long term boost to productivity growth. Furthermore, we find that the effect is twice as strong in west as opposed to east EU countries, implying a greater efficiency in translating new technology into more output per worker in developed countries. This might be tied to our finding that the investment share of GDP (which we use as a proxy for capital deepening and overall non-ICT investments which contribute to labor productivity) is statistically insignificant in the case of west EU, but significant and positive for east EU countries. Taken together, these results point to a possible interpretation in which east EU which starts on a lower developmental level is still able to boost labor productivity with overall investment into infrastructure and other non ICT types of capital deepening, while the developed west EU countries are able to squeeze out more productivity exclusively through more ICT and technological development at which they are consequently more efficient.

We also get some interesting side-results from our set of control variables. Labor participation had a strong negative relationship with labor productivity in the early seminal research in the 1990's, which was thought to be a function of labor market reforms of the period. However we find that the relationship persists throughout the whole time period, pointing to something structural. A possible explanation is that more labor participation usually means more low-skilled workers which are less able to utilize modern technological advancements. Additionally, we find that government share of GDP is a negative predictor of labor productivity in both sets of countries, giving credence to the often heard criticisms of the inefficient EU labor market due to excessive regulation which is further exacerbated by high corruption levels in east EU countries. Finally, we find that GDP per capita has a statistically significant negative relationship with productivity also in boths sets of countries, implying that there is a significant catch-up effect at work both within west and east EU, with higher GDP per capita levels corresponding with lower productivity growth.

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