Macroeconomic Effects of Teleworking in EU27: Stochastic Frontier Approach

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MACROECONOMIC EFFECTS OF TELEWORKING IN EU27: STOCHASTIC FRONTIER APPROACH

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Abstract
The main aim of this paper is to investigate macroeconomic effects of teleworking during the COVID-19 pandemic, using an atypical approach. We apply stochastic frontier analysis to a Cobb-Douglas production function broadened with teleworkability variable, and analyse the level of (in)efficiency of EU27 countries in producing their GDPs. We find that increasing the percentage of jobs that can be done at home by 1 percentage point reduces the level of technical inefficiency by 3.5%. Additionally, we use a unique e-survey conducted in April and May of 2020, which provides the data on the share of people who started working from home as a results of a COVID-19 situation, and combine it with the teleworkability variable. Overall, our findings suggest that more developed EU countries have a higher share of teleworkable jobs, which in turn reduces their inefficiencies, and furthermore results in more people beginning to work from home in the pandemic.

Keywords: teleworking, production function, stochastic frontier analysis, EU, COVID-19
JEL classification: C21, O4, O33, O52

1. Introduction

The unanticipated spread of the global pandemic caused by COVID-19 has dramatically changed the classic workplace, forcing many organisations to shift to remote work. In such a specific situation, research on teleworking becomes increasingly important. As noted by ILO (2020), working from a distance and working at home are not new phenomena, but the relevance of measuring them has increased.

Admittedly, this sort of research has existed before, but the focus has been on its advantages and disadvantages (Baruch, 2000; Morgan, 2004), its impact on commuting (Kane and Tomer, 2015), improving organizational outcomes (Bloom et al., 2015, Martin and MacDonnell, 2012), productivity (Bloom et al., 2015); firm performance (Martínez Sánchez et al., 2007), local income (Gallardo and Whitacre, 2018), its psychological impact (Mann and Holdsworth, 2003), etc. The new situation caused by COVID-19 offers a unique opportunity to investigate the effects of teleworking, from a national – macroeconomic – perspective.

Teleworking can influence GDP – key macroeconomic indicator - through influencing productivity. Teleworking affects productivity via two main channels: worker efficiency and cost reduction. By enabling better work-life balance, less commuting and fewer distractions, teleworking may lead to more focused work and less absenteeism, thus resulting in worker satisfaction. The opposite happens when due to solitude, hidden overtime, fusing of private and work time, reduced number of in-person interactions, decreasing knowledge flows among employees and inappropriate working environment, telework results in worker dissatisfaction. On the cost reduction side, telework can lower capital costs by reducing office space and equipment required by the firm, by enlarging the pool of workers available to the firm as well as by increasing the skill supply and improving the match between jobs and hires. Additionally, hiring costs may decrease if higher worker satisfaction reduces voluntary quits and turnover. Overall, worker efficiency seems to improve with low levels of telework, but decrease as telework becomes the dominant mode of work (OECD, 2020).

This paper investigates the impact teleworking has on the reduction of inefficiencies in the production process. This issue is analysed from a macroeconomic i.e. national standpoint. A starting point is the classical Cobb-Douglas production function with two inputs: labour and capital. A stochastic frontier analysis is then applied, which relies on the estimation of technical efficiency measured as the ratio of observed output to the corresponding stochastic frontier output for each country. Additionally, we introduce an exogenous variable –

teleworkability - in the inefficiency model, which enables us to assess whether this helps to reduce the level of technical inefficiency.

Furthermore, we plot the data on the share of jobs that can be done at home against the share of people that started working from home as a result of COVID-19 situation, and observe whether the countries with higher share of teleworkable jobs have experienced correspondingly higher teleworking during the pandemic. For this, we use a unique e-survey conducted in April/May 2020 by the Eurofound (2020).

The contributions of this paper are as follows. Firstly, the effects of telework from a macroeconomic perspective have so far been under investigated, so this paper attempts to fill in that gap. Additionally, we use an idiosyncratic database on the share of jobs that can be done at home (teleworkability), and combine this data with the standard macroeconomic production function, thus analysing whether teleworkability helps reduce inefficiencies in the production. This approach has not been used before, to the best of our knowledge. We, furthermore use another unique database, which provides the data on the percentage of people that started working from home with the start of the pandemic, and draw conclusions regarding the macroeconomic impact of the actual level of teleworking that took place in April/May of 2020.

This paper is organised as follows. Section 1 gives stylised facts regarding teleworking in Europe in the pre- and mid-COVID-19 period; Section 2 explains research methodology – stochastic frontier analysis and the data used in the empirical approach, while Section 3 discusses the Results and its implications. Conclusions are given in the final section.

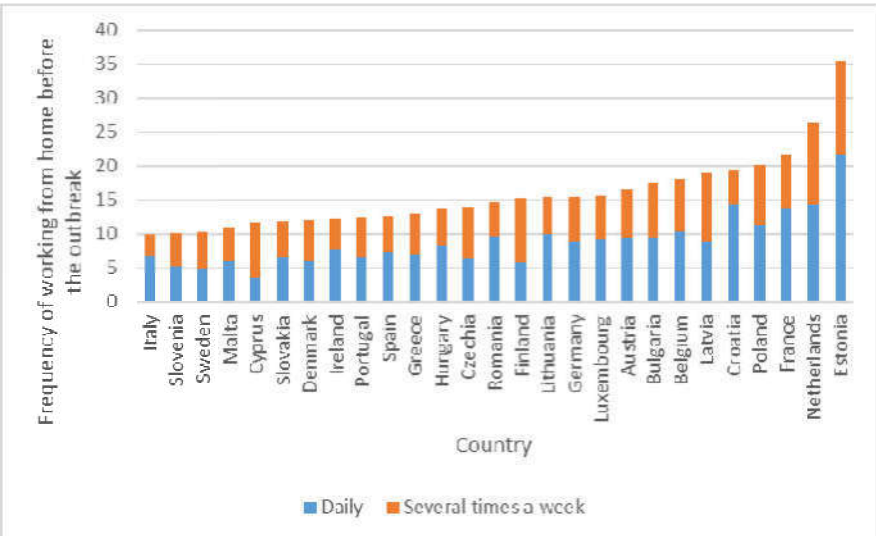
2. Stylised facts about teleworking in EU27

In this section, we look at some stylised facts in the pre- and mid-COVID-19 period, to observe changes that COVID pandemic induced in teleworking in Europe.

Macroeconomic effects of shocks such as pandemics are usually measured with aggregate time-series data, such as industrial production, GDP (growth) and/or unemployment rate. These datasets, however, are typically available with a time lag even in 'normal' times; moreover, the data from 2020 on any series is still unavailable, so the full impact of COVID-19 pandemic will have to be analysed in years to come.

What we can do is to use various sources that have managed to collect some real-time data, and observe the changes that pandemic has caused. One of these unique sources is Eurofound (2020), which conducted an e-survey called Living, working and COVID-19 , which provides a snapshot of the impact of the pandemic on certain aspects of people's lives.

Figure 1: Data on answers: 'daily' and 'several times a week' for respondents in the EU27 when asked: How frequently did you work from home before the outbreak of COVID-19?



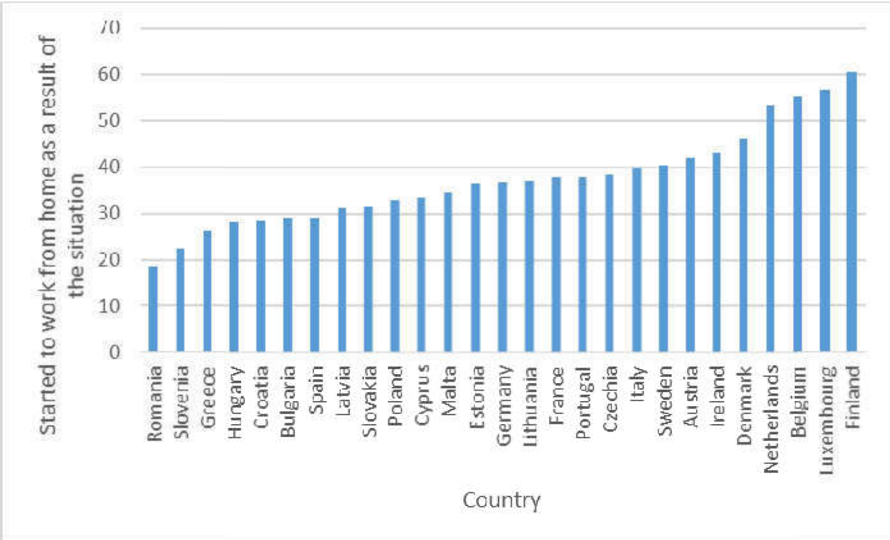
Source: Eurofound (2020) and author's calculations

Figure no. 1 gives the data on frequency of people who worked from home before the pandemic. On average, 15.7% of all respondents in EU27 worked from home on daily or weekly basis. This percentage was the highest in the Estonia (35.4%), followed by

Netherlands (26.4%) and France (21.7%). Italy and Slovenia, on the other hand, had the lowest percentage – only 10 percent of people working regularly from home.

Figure no. 2 shows what happened after the pandemic, where, on average, 37.28% of EU27 residents started working from home in this new situation. Finland, Luxembourg and Belgium exhibited highest percentages of teleworkers and these were 60.5%, 56.6% and 55.1%, respectively. In Romania and Slovenia, on the other hand, the number of people that started working from home during the initial stages of pandemic was below 25%.

Figure 2: Data on answers 'Yes' for respondents in the EU27 when asked: Have you started to work from home as a result of the COVID-19 situation?

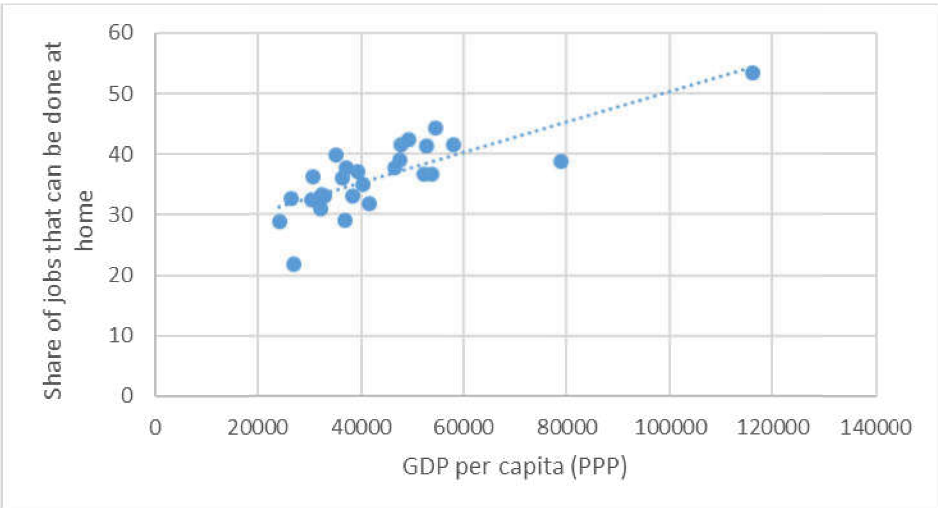


Source: Eurofound (2020) and author's calculations

Overall, the pandemic, expectedly, seems to have contributed to a large increase in teleworking. It should be stressed, however, that not all jobs are teleworkable. Some jobs simply cannot be done remotely. Most low- and middle- skilled occupations, for example, are not teleworkable. Another unique database which turns out to be very useful in current situation is the one constructed by Dingel and Neiman (2020), which lists the percentage of jobs in each country that can be done at home, or teleworkable jobs (teleworkability). In Section 2 we use this variable as an input into the quantitative analysis investigating the (in)efficiency of production in EU27 countries.

Figure no. 3 plots this idiosyncratic variable - the share of jobs that can be done at home - against GDP per capita for each of the EU27 countries.

Figure 3: Share of jobs that can be done at home versus GDP per capita, 2018, in EU27



Source: Dingel and Neiman (2020) and author's calculations

A clear positive relationship is visible between income levels and teleworkable jobs, meaning that in more developed countries the share of teleworkable jobs is higher. It is possible, therefore, that the higher share of teleworkable jobs "greases the wheels" of an economy, by helping it become more efficient in its production. We investigate next this issue in more detail.

3. Methodological approach and data

As indicated in the Introduction, teleworking influences GDP via influencing productivity, and this impact takes place through two main channels: worker efficiency and cost reduction.

Productivity and efficiency are often used interchangeably, although they refer to somewhat different notions. Namely, productivity is the ratio of output to input(s), while efficiency refers to the achieved level of output, in relation to the maximum that can be produced, given the inputs, various restrictions and existing technology. Efficiency, therefore, takes into account constraints that prevent increases in productivity. To the extent that efficiency is a more comprehensive concept than productivity, in this paper we investigate technical efficiency of countries in achieving their respective GDPs, accounting for the impact of teleworking.

Farrell (1957) was the first one to lay foundations of the theory of efficiency and its measurement, where he differentiated between three key measures of efficiency: overall, technical and price efficiency. Technical efficiency, which we focus on in this paper, can be defined as the ability of a unit (be it firm, country or something else) to achieve maximum output from a given set of inputs. Put differently, technical inefficiency exists when a higher level of output can technically be attainable from the given inputs. This is a so-called output oriented measure of technical inefficiency. In this case, inefficient units are located below the production frontier (Kumbhakar et al., 2015).

There are nowadays two dominant approaches to estimating technical efficiency and these are Data envelopment analysis (DEA) and Stochastic frontier analysis (SFA). Both approaches rely on the estimation of a frontier whereby the efficiency in the production of output is measured relative to a frontier (potential or maximum output) for each unit/country. This efficient frontier is not some absolute standard; rather it is derived from the best practices contained in the sample under consideration. Therefore, all the (in)efficiencies are only relative (in)efficiencies, given the observed data. Since the true frontier is unknown, an empirical approximation is needed, which is frequently labelled a "best practice" frontier.

Two main differences exist between these two approaches: while DEA is a non-parametric approach, SFA is a parametric approach. This means that many a priori assumptions about the structure of the production possibility set and the data generating process have to be made in SFA. Even though this seems to be a rather large drawback of SFA, its advantage stems from the fact that it allows us to assume a stochastic relationship between inputs and outputs, i.e. to assume that deviations from the frontier reflect not only inefficiencies but also noise in the data.

Our model is a standard Cobb-Douglas production function with two inputs: labour and capital, and one output – production (GDP). A general formulation of the simple multi-input single-output stochastic frontier model for cross-sectional data is given as:

$$y_i = \alpha + x_i'\beta + \varepsilon_i, \quad i = 2, \dots, N \tag{1}$$
$$\varepsilon_i = \upsilon_i - u_i$$
$$\upsilon_i \sim \mathcal{N}(0, \sigma_\upsilon^2)$$
$$u_i \sim \mathcal{N}^+(\mu, \sigma_u^2)$$
$$\mu_i = z_i'\psi$$

where y_i is the logarithm of GDP of the i-th unit (country in our case), x_i is a vector of inputs (labour and capital) and β is the vector of technology parameters. The composed error term, ε_i, is the difference between a normally distributed disturbance, υ_i, representing measurement and specification error, and a one-side disturbance, u_i, representing inefficiency, z_i is a vector of exogenous variables (including a constant term), and ψ is the vector of unknown parameters to be estimated (the so-called inefficiency effects). In addition, u_i, and υ_i are assumed to be independent of each other and independently and identically distributed across observations. In this approach, distribution has to be assumed, and frequent choices include half-normal, exponential, or truncated normal distribution (Belotti et al., 2013). We use the latter, whereby the notation $\mathcal{N}^+(\mu,\sigma_v^2)$ indicates a truncation of the normal distribution at 0 from above, with μ representing the pre-truncation mean parameter. Maximum likelihood (ML) technique is used for estimation (Kumbhakar et al., 2015).

Table 1. Data sources and definitions

Variable	Indicator(s)	Source
y	Output-side real GDP at chained PPPs (in mil. 2017US$)	Feenstra, Inklaar and Timmer (2015)
k	Capital stock at constant 2017 national prices (in mil. 2017US$)	Feenstra, Inklaar and Timmer (2015)
l	Number of persons engaged (in millions)	Feenstra, Inklaar and Timmer (2015)
telework	Share of jobs that can be done at home – teleworkability (in %)	Dingel and Neiman (2020)

4. Results and discussion

We use cross-sectional data since the data on teleworkability is available only for one period i.e. year, namely 2018. All variables (except telework) are in logarithms. Countries under investigation comprise of EU27.

An important issue in this sort of analysis is the insertion of exogenous variables in the model, which are supposed to affect the distribution of inefficiency. This is also one of the reasons we opted for truncated normal distribution, as this option is available only under such an assumption. These variables are typically neither inputs nor outputs; rather they are factors that affect the unit/country performance (Belotti et al., 2013). We use our variable on teleworkability (telework) as this exogenous variable.

Table no. 2 gives the results of the truncated-normal model as given by equation no. 1, with exogenous determinants in μ (*mu*) and σ_u^2 (*Usigma*). Following Wang (2002), μ and σ_u^2 are parametrised by the same vector of variables, in our case teleworkability (*telework*). This parametrisation of *mu* means that the mean of the truncated normal distribution is a linear function of *telework*, while *Usigma* specifies that the technical inefficiency component is heteroskedastic, with the variance expressed as a function of *telework.*

Table 2 Results of SFA for Cobb-Douglas production function with truncated-normal distribution for inefficiency term

	(1) **lny**	**(2)** **lny**
Frontier		
lnl	0.777^{***}	0.825^{***}
	(0.115)	(0.0839)
lnk	0.292^{***}	0.261^{***}
	(0.0997)	(0.0712)
_cons	7.968^{***}	8.614^{***}
	(1.395)	(0.958)
Mu		
telework	-0.0277^{***}	-0.0385^{***}
	(0.00860)	(0.00935)
_cons	1.558^{***}	2.220^{***}
	(0.459)	(0.350)
Usigma		
telework	0.0152	0.158^{*}
	(0.133)	(0.0877)
_cons	-4.889	-9.385^{***}
	(5.137)	(3.228)
Vsigma		
_cons	-3.934^{***}	-31.06
	(1.036)	(708.2)
N	27	26

Standard errors in parentheses

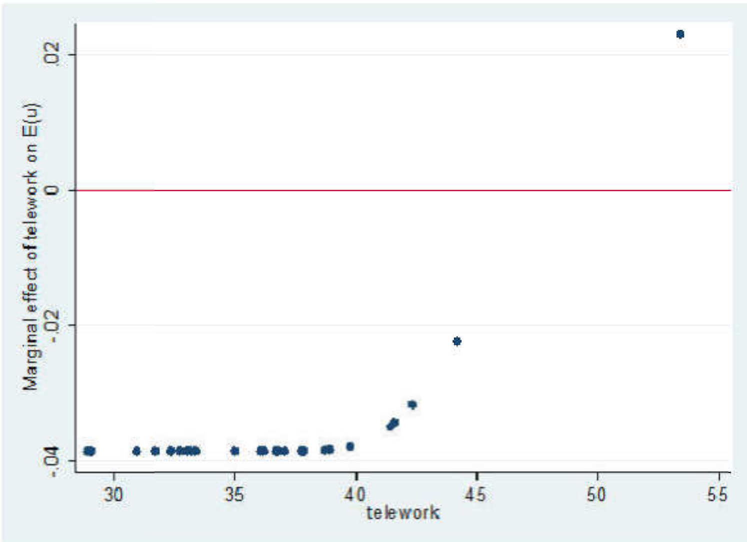
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Model given in column (1) presents the results for the full sample (EU27), while the results in column (2) exclude Romania. Namely, the results in column (1) - insignificance of the coefficient of telework for Usigma - urged us to undertake sensitivity analysis by excluding extreme observations. Romania was chosen as it had the lowest value of telework in the sample. At the other extreme was Luxembourg with the largest value of telework, an issue that is discussed lower in the text. The log-likelihood value of models (1) and (2) are 7.96 and 9.97, respectively, which is higher than log-likelihood value of the half-normal specification (not reported, but available upon request) of 2.44. The LR test, therefore, clearly supports the truncated-normal specification with determinants of inefficiency, over the half-normal specification. Additionally, larger LR value, and the significance of the coefficient of telework for Usigma both speak in favour of model (2). We, hence, proceed with this model.

The coefficients on capital and labour are both positive and statistically significant, in line with expectations. The significant coefficient on telework in mu implies that the inclusion of telework in this model is supported by the data. The negative sign on telework means that increasing the percentage of teleworkability i.e. of teleworkable jobs in an economy, reduces, on average, the level of technical inefficiency. The estimated coefficients on telework on mu and Usigma in table no. 2 are not directly interpretable due to the non-linearity of the model; hence marginal effects of the technical inefficiency should be computed. Average marginal effect of -0.035 in our sample suggests that an increase in the share of jobs that can be done at home (teleworkability) by 1 percentage point reduces the level of technical inefficiency by 3.5%.

As noted by Kumbhakar et al. (2015), an advantage of Wang (2002) model, applied here, is the accommodation of nonmonotonic efficiency effects, which means that the marginal effect of telework on inefficiency can alternate in terms of the sign, depending on the value or the percentage of telework (and the values of other variables). To check for this we draw a scatterplot (figure no. 4) of marginal effects against values of telework.

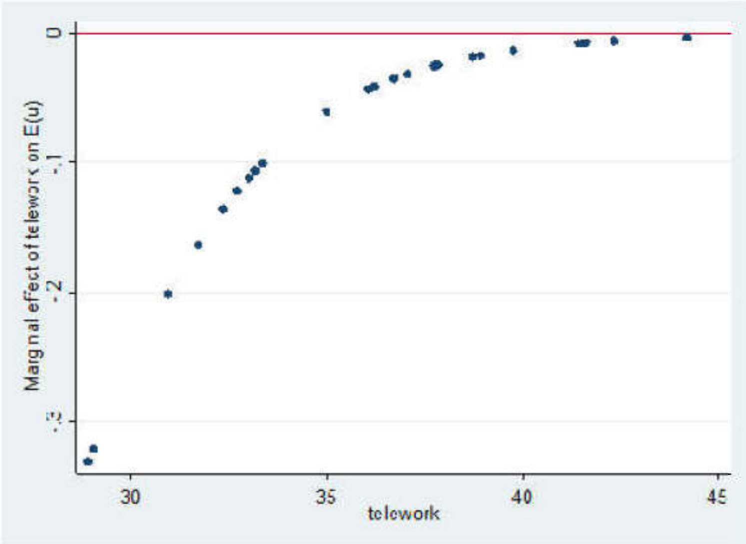
Figure 4: Marginal effect of telework on inefficiency in EU26



Source: author's calculations

The graph given in figure no. 4 indicates that for majority of observations the marginal effect is negative, and that the size of the negative effect is larger when the value of telework is smaller. As the percentage of jobs that are teleworkable rises, the marginal effect moves towards zero, and eventually becomes positive. This result indicates that there exists an optimal level of teleworkability in an economy with regard to technical efficiency improvement. In our data, that optimal percentage is around 48.5%. Expanding the share of teleworkability above this does not improve technical efficiency. The one positive value pertains to Luxembourg, which seems to be an outlier in the sample. As a robustness check we, therefore, repeat the procedure just described, leaving out Luxembourg this time, in which case the scattergram of marginal effects exerts the shape given in figure no. 5

Figure 5: Marginal effect of telework on inefficiency in EU25



Source: author's calculations

Figure no. 5 indicates, again, that the marginal effects are negative, but approaching zero, and optimum seems to be somewhere above 45% of telework, which is in line with our previous conclusions.

It should be stressed at this point that the data on the percentage of people that occasionally teleworked before the pandemic (as presented in figure no. 1) differs from the data of the scope of jobs that can be done via telework (as given in figure no. 3 and used in the empirical part of the paper). Namely, jobs that tolerate doing some tasks from home may not be apt to be done completely from home. As an example consider Sweden, where 57.2% people in 2015 reported that they did some telework at home, while only 30.7% of jobs could actually be done completely remotely after the outbreak of the crisis (OECD, 2020). Our finding that the optimal share of teleworkable jobs in an economy is below 50%, speaks in favour of this argument.

Finally, one of the key reasons for applying SFA is to obtain the technical efficiency, i.e. the ratio of observed output to the corresponding stochastic frontier output. This measure takes a value between zero and one hundred and measures the output of the i-th country relative to the output that could be produced by a fully-efficient country using the same input vector. In our sample the average technical efficiency is 46.33%. Individual technical efficiencies are given in table no. 3.

Table no. 1 Technical efficiency scores for individual countries

Country	Technical efficiency	Rank
Austria	51.4	6
Belgium	49.5	8
Bulgaria	32.5	25
Croatia	36.4	21
Cyprus	46.5	10
Czech Republic	38.2	19
Denmark	53.8	4
Estonia	44.2	11
Finland	51.1	7
France	43.1	12
Germany	41.9	15
Greece	33.3	24
Hungary	34.6	23
Ireland	100.0	1

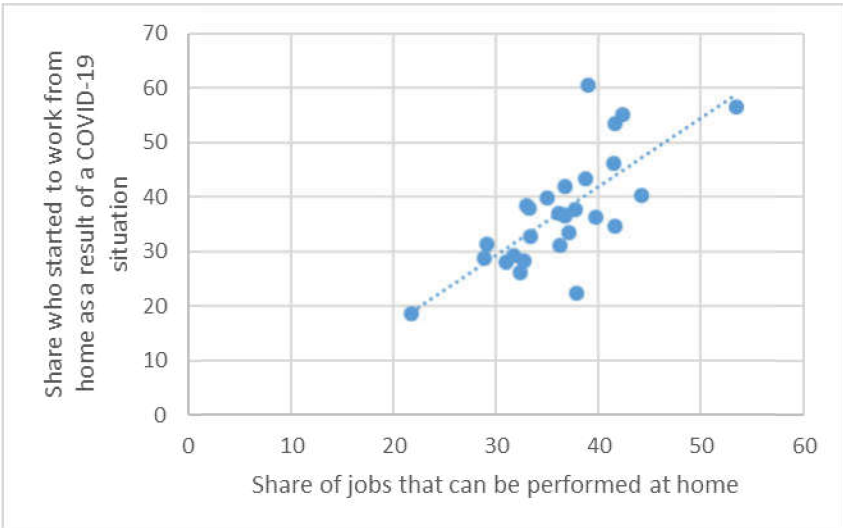
Italy	39.2	18
Latvia	36.3	22
Lithuania	42.5	14
Luxembourg	72.4	2
Malta	62.6	3
Netherlands	49.2	9
Poland	43.0	13
Portugal	31.9	26
Slovakia	37.1	20
Slovenia	40.6	17
Spain	41.6	16
Sweden	52.1	5

As can be seen from table no. 3, Ireland is the most efficient country in the sample, followed by Luxembourg and Malta. At the other side of the spectrum, the most inefficient countries are Greece, Bulgaria, and Portugal, technical efficiency of Portugal being only 31%. There is, therefore, room for improvement in majority of countries, with inefficiencies reaching above 50%.

After having established that the pre-COVID data (year 2018) suggests that increasing the percentage of teleworkable jobs in an economy helps reduce the level of technical inefficiency, i.e. that those countries that have a larger percentage of teleworkable jobs have higher GDPs, we next look at the connection between teleworkability and the actual level of teleworking that took place in April/May of 2020.

Figure no. 6 compares the share of jobs that can be done at home and the share of people that started working from home as a result of the pandemic.

Figure 6: Share of people who started working from home as a result of COVID-19 situation versus share of jobs that can be done at home in EU27



Source: Eurofound (2020) and Dingel and Neiman (2020) and author's calculations

The two observed variables show a very close correspondence, the slope of the trend line being 1.26. This result suggests that in those countries with the higher share of jobs that are teleworkable, a larger number of people started working from home as a result of COVID-19 situation. Overall, our results indicate that the structure of the economies of the more advanced countries is such that they have more teleworkable jobs, and furthermore in these economies more people started working from home after the pandemic started, thus adjusting better to the new situation. Less developed EU27 countries, therefore, might face more challenges than more developed ones in continuing to work remotely.

Furthermore, dividing the results according to sex and age (not reported but available upon request), enables us to reach the following conclusions:

The share of males who started working from home as a result of the pandemic is positively related to the share of jobs that can be done at home, and the slope of the trend line is even steeper in this case, amounting to 1.91;

The share of females who started working from home as a result of the pandemic is positively related to the share of jobs that can be done at home, but with the slighter slope of the trend line of 0.98, suggesting that this relationship is somewhat weaker for women than men;

As for the division by age groups, in all three groups analysed (18-34, 35-49, and over 50 years of age), share of people who started working from home as a result of the pandemic is positively related to the share of jobs that can be done at home. The slope of the trend line is 0.71, 1.26 and 0.34, respectively. This suggests that, expectedly, this relationship is the weakest for the age group of those above 50 years of age, as the adjustment to new technologies and trends is more challenging for this group. The relationship is the strongest for those aged 35-49.

5. Conclusion

The main aim of this paper is to investigate macroeconomic effects of teleworking during the COVID-19 pandemic. Since the pandemic is still ongoing and macroeconomic data is published with a delay, it is practically impossible to undertake a standard panel data approach to analysing the effects of the pandemic on key macroeconomic variables. The approach we adopt, therefore, is somewhat atypical. Firstly, we make use of the data published by Dingel and Neiman (2020) on the share of jobs that can be performed at home, i.e. that are teleworkable. Dingel and Neiman (2020) is a sole source of such data, and they have provided the data for 2018 only, so our first part of the analysis is restricted to this year. We apply stochastic frontier analysis to a typical Cobb-Douglas production function, and analyse the level of (in)efficiency of EU27 countries in producing their GDPs. A specificity of our approach lies in the fact that we broaden the model by including the teleworkability variable, which, we hypothesise, affects the distribution of found inefficiencies. Indeed, our results indicate that increasing the percentage of jobs that can be done at home reduces the level of technical inefficiency by 3.5%. Moreover, we find that the optimal percentage of teleworkable jobs in an economy is just below 50%. This result, which refers to year 2018, thus establishes the situation in the pre-COVID-19 period. In the next step, we make use of a unique e-survey conducted in April and May of 2020, which provides the data on the share of people who started working from home as a results of a COVID-19 situation, and combine it with aforementioned teleworkability variable. Overall, our findings suggest that more developed EU-27 countries have an edge in the pandemic on the less developed ones. In other words, their economies have a higher share of teleworkable jobs, which in turn, reduces their inefficiencies, and furthermore results in more people beginning to work from home in the pandemic. Additionally, we find this relationship to be stronger for men than women and for the age group of 35-49, compared to those younger than 35 and older than 49 years.

Admittedly, a drawback of our research refers to the fact that we investigate a cross-section of countries during only one year (2018), due to data unavailability for other years. One of potential extensions of our research, therefore, would be the inclusion of more years in the future, as the data on teleworkability becomes available. Additionally, the data on the share of people who started working from home with the start of the pandemic was available only for the period April/May 2020, so future research could benefit from a longer series on this variable and panel-type investigation of the macroeconomic effects of the pandemic. Finally, it should be emphasised that we have assessed relative, not absolute efficiencies, meaning that they refer only to the countries in our sample. On the other hand, since all EU27 countries are included in the analysis, population can be considered to be sampled exhaustively, so the fact that we cannot extend our conclusions outside our sample becomes irrelevant.

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