Department of Economics

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Comparison of Economic Resilience Against Pandemics Among Countries: The Effect of Remote Work

Abstract

The impacts of Covid-19 resulted in a worldwide economic downturn across countries. This project attempts to use a standard Solow model to explain the differences in output reduction during the Covid-19 pandemic. The reduction in labour supply reduced investment in capital and economic output. The ability of labour to continue being used is assumed to be proportional to the digitalisation of the workforce. The study uses a standard OLS regression to compare output differences between European countries in 2020. The European Union's Digital Economy and Society Index (DESI) is used as a proxy for "digitalisation". Unfortunately, the analysis could not produce statistically significant results to show that the DESI influenced output. More data on "digitalisation" is needed to come to a more rigorous conclusion.

Contents

1. Introduction

The economic impact of COVID-19 has been felt far and wide, leaving millions of individuals and businesses grappling with the harsh realities of job losses, financial instability and an uncertain future. However, the impacts of Covid-19 have differed in intensity in different regions and nations. It is important for policy makers to know what factors contribute to the severity of economic impacts, since the pandemic posed unprecedented challenges that required careful analysis and strategic responses.

After the unfolding of the Covid-19 pandemic in early 2020, governments raced to implement containment and support measures. One of the most radical measures implemented across countries were lockdown measures, designed to reduce movement and social contact which would slow the transmission of the virus. Key components of a lockdown include stay at home orders, closure of non-essential businesses and schools, and travel restrictions.

The most important factor that this paper will discuss extensively is work from home arrangements. Telework and the implementation of other digital technologies were crucial factors in firms' and workers' ability to maintain production during the crisis (OECD a, 2021). Policy makers should ensure that factors enabling remote work are adopted to build resilient economies and firms.

The purpose of this study is to build a functional model that explains how a workforce's ability to adapt to the pandemic influences the severity of its economic impact. This will be laid out in three parts: a literature review explaining the most important factors in allowing a workforce to adapt and the political implications; a conceptual framework which will give a more detailed analysis of the problem and an OLS regression to back up the theory with some empirical work.

2. Literature Review

2.1. Defining Economic Resilience

The World Bank (Hallegatte, 2014) proposes that macro-economic resilience has two components: static resilience and dynamic resilience. Static resilience is the ability of an economy to limit the magnitude of immediate production losses for a given asset loss. Dynamic resilience is the ability of an economy to reconstruct and recover. Therefore, output will be the focus of this paper and the models that are constructed.

Policy makers use Gross Domestic Product as an indicator for the country's economic performance. GDP represents the total monetary value of all goods and services produced within a country's borders over a specific time period. GDP is used as a measure for output in this paper as GDP is the monetary value of output.

2.2. Differences Between Regions and Countries

There are several factors main factors that determine how well a country can adapt to new demands of the pandemic. These can be factors of a technical nature or related to cultural and social norms of a country.

A workforce's prior experience with remote work was a good indicator of how well the country can adapt. For example, the high levels of remote work experience in Nordic countries were a great estimator for success during the pandemic (OECD, 2021). This is likely because remote workers are more familiar with remote tools such as project management software, cloud-based document sharing platforms and video conferencing. Hence, employees could smoothly transition to remote work, since they were already confident using these tools. Companies that were familiar with remote work would also have established guidelines, protocols and policy, which would save managers from resource intensive tasks.

Connectivity is also another huge predictor of digital work success. Employees working remotely require an adequate level of broadband connections required to communicate. A paper by Andrews et al. (Andrews et al., 2018) states that the availability of high-speed broadband enables the use of remote tools, a few of which were mentioned in the paragraph above. An OECD report (OECD, 2021) suggest that while almost all firms in developed countries have access to broadband before the crisis, access to high-speed broadband is not as ubiquitous.

Another vital factor in determining how effective an economy can adapt is the workers digital skills or "digital human capital". Worker's skills increase the effectiveness and efficiency of digital technologies used and how likely firms are to adopt these technologies (OECD, 2021)

It is also worth noting that the ability to uptake remote work also differs greatly between industries. The higher the share of ICT tasks that are required, the more there is a propensity for remote work (OECD, 2021) Also, certain workers did not have to work from home since their work was considered essential. For example, health care workers were not made to work from home since their work is considered essential and most of this work cannot be done remotely, therefore uptake for this industry would be less than the tech industry. This is another factor in a nations ability to adapt. Due to globalisation, many economies around the globe are highly specialised. This is largely due to comparative advantage, where countries produce goods and services where they have a lower opportunity cost compared to other countries, leading to gains from trade (Krugman and Obstfeld, 2018). This means that certain industries have a high proportional representation in some countries compared with other countries. For example, Saudi Arabia is highly specialised at producing oil, which accounts for a significant portion of its GDP.

Nations that boast robust and multifarious economies, such as China and Germany, have demonstrated a greater ability to withstand the economic effects of the pandemic, while smaller and more specialized economies, including those of numerous island nations and those dependent on the oil industry, have experienced a greater magnitude of economic impact.

We also must consider the social and cultural aspect of working from home. Attitudes towards working from home greatly influenced a countries propensity for it.

2.3. Political Implications of Covid-19 on the Labour Market

A countries fiscal and monetary response during the Covid-19 pandemic can not only have a huge impact on output and inflation but can also have political and cultural repercussions. An article by Cebula and Foley (2022) suggests that fiscal policy, such as furlough schemes, relaxed job security regulations, and reduced taxes on labour have effectively reduced the level of effort required for workers to achieve a certain level of income or well-being, which can help to incentivize workers to prioritize their own health and well-being over work, leading to labour shortages in certain industries. This supports the Keynesian viewpoint, that government stimulus can help an economy's recovery.

This is also supported by a paper by Gallant et al. (2020), who developed a search and matching model that considers temporary unemployment as separate from permanent employment. They observe that the Beveridge curve remains stable, even with the changes in the composition of the unemployed caused by the pandemic. The researchers then use the model to predict the path of unemployment over the next 18 months and find that their predictions of a more rapid recovery are higher than those from models that do not distinguish between temporary and permanent unemployment.

Although measures have caused labour shortages, this could have potential beneficial externalities. Unionization and labour activism have increased globally in response to the COVID-19 pandemic. Unionization can potentially help workers bargain for wage increases, better working conditions and better health conditions (McNicholas et al., 2020). Unionized workers (workers covered by a union contract) earn on average 11.2% more in wages than nonunionized peers (workers in the same industry and occupation with similar education and experience).

Policies had to be implemented by governments in response to economic and health crisis caused by the COVID-19 pandemic. The pandemic caused widespread job losses and economic disruption, leading governments to implement measures to support workers and households. These measures aimed to provide a safety net for those who were negatively impacted by the crisis. The policies were also likely implemented to stimulate consumer spending and support economic growth, as increased government benefits and reduced taxes on labour can provide a boost to consumer spending.

Initial crisis responses between different countries share many similarities. The following paragraph takes ideas from a paper by Eichhorst et al. (2020). Many countries have used a short-term work scheme to keep workers in their jobs and maintain low unemployment. These schemes are most justified when there is a sharp demand slump followed by a quick recovery of output. Certain countries, such as Austria, introduced new temporary short term work schemes that are more generous than previous versions. Other countries, such as Sweden, introduced a completely new short-term work scheme. Spain, France and Italy included additional sectors into their schemes and the idea to include more vulnerable types of workers was pursued even more heavily in Switzerland. This paper also provides support for the idea that low-skilled workers and migrants suffered from difficulties adjusting to pandemic restrictions, which seems to be a pattern across countries.

3. Conceptual Framework

3.1. Comparative Statics

3.1.1. Labour Market Supply and Demand

The economic framework behind this analysis is taken from the standard neoclassical labour market and the aggregate supply and demand curves (Manfred Gärtner, 2013, pp.159, 217). The labour demand curve is equal to the marginal product of labour. In perfect competition, the firm demands an amount of labour where marginal revenue is equal to marginal cost. This condition is met when the profit function of a firm is maximised subject to labour:

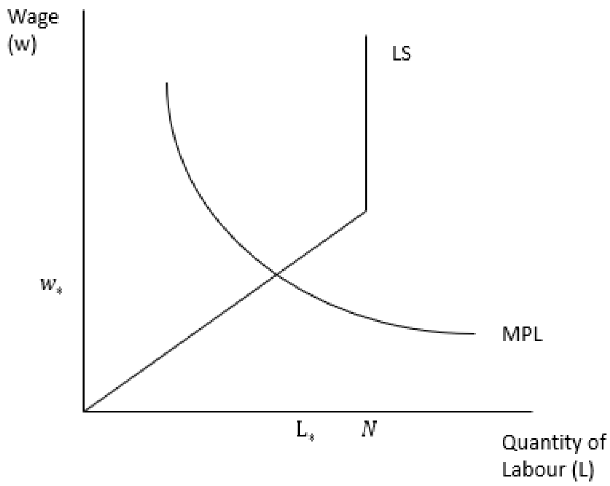
$$max\ \Pi\ = Y(K, L) - wL - rK$$

$$\frac{\partial \Pi}{\partial L} = \frac{\partial Y(K, L)}{\partial L} - w = 0$$

$$w = \frac{\partial Y(K, L)}{\partial L} = MPL$$

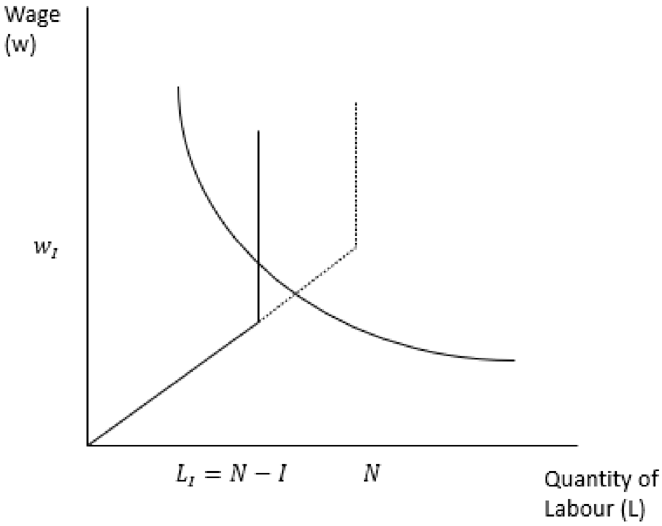
For simplicity of the model, the productivity of a regular worker is assumed to be equal to the productivity of a teleworker. The literature supports this as Bloom et al. (2013) suggests that workers from home are more productive than in person workers.

For the labour supply curve, the willingness of people to work depends on how much they are paid, therefore as the wage increases the labour supply increases. The labour supply curve is upward sloping. However, regardless of how high the wage is, there will always be a proportion of the population that is unable to work because they are too young, too old or unable for other reasons. This means that a point is reached on the labour supply curve where the labour supply curve is vertical. Increasing the wage does not increase the quantity of labour supplied. Only the active population N can work. The graph below shows labour supply and demand curves, intersecting at equilibrium:

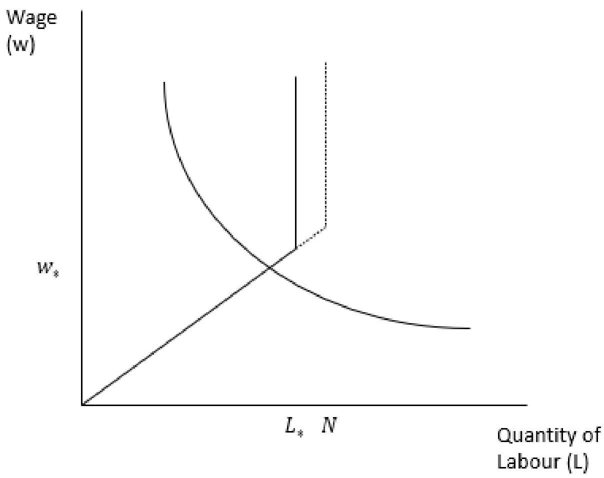


However, in pandemic conditions, restrictions are imposed on workers. Only essential and teleworkers are allowed to work in these circumstances, hence the active population reduces to $N - I$. I can be considered the number of inflexible workers in an economy. Inflexible workers are those that cannot adapt to the digital working environment. They may not be able to adapt because of poor or non-existent internet connection, a lack of digital infrastructure of firms or because of a lack of digital skills. Another factor increasing the number of inflexible workers, are attitudes towards social distancing.

The graph below shows an economy with a high degree of inflexibility:



The point of intersection of the labour demand and supply curves during a pandemic could potentially reduce equilibrium unemployment if the curves intersect at $N - I$. Countries with more digitalisations could increase the value of $N - I$ by reducing the number of inflexible workers, resulting in a higher pandemic equilibrium employment. If a country is sufficiently digitalised, equilibrium output may not change from pre-pandemic levels. The graph below shows an economy with a low level of inflexible workers.

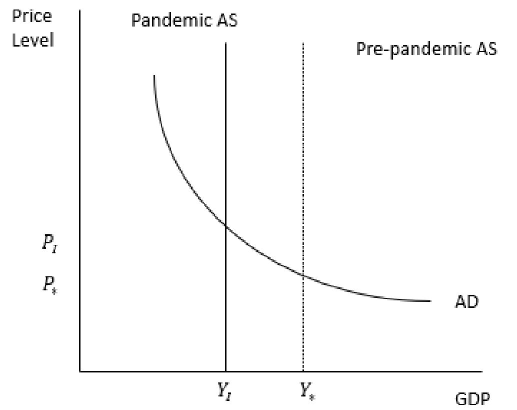


Looking at the impact of Covid-19 on Japanese firms suggests that, although the average firm's economic activity reduced due to a reduction in the population's mobility, the adoption of working from home before the pandemic mitigated the negative impact of Covid-19. The effect of Covid-19 in terms of sales was mitigated by 55% and the negative impact in terms of hours worked was mitigated by 35%. (Kawaguchi, Kitao and Nose, 2021). Another way to say this is that 55% of the sales that would've been lost to the pandemic were saved because of remote work. Likewise, 35% of working hours that would've been lost because of the pandemic were saved by remote work. 100% mitigation would mean that no effect occurred.

3.1.2. Aggregate Supply and Aggregate Demand

These effects on the labour market will influence total output that firms in the economy will produce, or in other words the aggregate supply (AS) in an economy. Aggregate supply will be modelled by a neoclassical production function. Aggregate supply is determined by total labour and capital in the economy and does not change because of the price level. If the number of inflexible workers is sufficient such that $L_I < L_*$, the labour supply curve will shift to the left and intersect with the demand curve at a point where GDP is lower, and the price level is higher. Having a larger flexible workforce could reduce the GDP shock or eliminate it entirely.

$$Y_I = F(K, L_I) < Y_* = F(K, L_*)$$



The aggregate supply curve intersects with the aggregate demand (AD) curve at an equilibrium level of output and price level. Aggregate demand is defined as the total spending on domestic goods and services in the economy. The AD curve is downward sloping for three reasons. Firstly, the wealth effect states that because as the price level increases, people's savings diminish. Since an increasing price level makes people less wealthy, consumption decreases. Secondly, the interest rate effect states that as outputs rise, there will be a higher demand for credit, pushing interest rates up. Finally, the foreign price effect explains that if prices rise in a domestic country but remain the same globally, then goods in the domestic country will be relatively more expensive compared to goods in the rest of the world. Therefore, the exports of the domestic country will fall, and imports will rise. Consequently, net export expenditures will reduce, causing output to fall.

Research suggests that aggregate demand decreased during the Covid-19 pandemic (Kollmann, 2021), since people are less inclined to spend in times of uncertainty, coupled with the fact that workers around the globe were temporarily laid off. For now, let's assume that the AD curve does not shift, so that the effect of the AS curve, or the supply side of the economy, can be analysed individually. This paper also proposes that supply shifts is the dominant force driving GDP contraction.

This model makes the neoclassical assumption that wages and employment adjust instantaneously which further implies that money is neutral. The equilibrium employment level instantaneously changes L_* to L_I when the pandemic restrictions commence and therefore the shift in aggregate supply is also instantaneous. Also, markets are perfectly competitive, and agents choose to operate in a way which is rational and self-interested. Neo-classical theorists believed that prices in the economy do not affect aggregate quantity supplied, and therefore the Aggregate supply curve is vertical, even in the short term. This implies that only a shift in the AS curve can change output in the economy. Aggregate supply could be assumed to have input factors of labour and capital. In the example above, a decreased labour input leads to a lower output, if aggregate demand remains constant. Hence, if aggregate demand in the economy falls, the price level charged by firms will fall, so GDP remains at the same level. The government cannot influence GDP by increasing aggregate demand through fiscal policy.

Keynesian theorists (Keynes, 1936) would disagree that a short run AS curve is vertical. They would say that the supply curve used above is a long run aggregate supply curve. A short run aggregate supply curve would be upward sloping. When the price level is low, producers are less motivated to produce and sell goods because their profit is less, therefore a short-run aggregate supply curve is upward sloping. The lower the price level the lower the quantity of aggregate supply. When the price level is greater, the greater the quantity of aggregate supply.

The different conclusions come because Keynesians assume that prices and wages are "sticky". There are times when market forces will not reach equilibrium price levels by themselves quickly. This means that Keynesian theorists argue that the government should intervene to stimulate the economy. Boosting AD will cause GDP to increase. Conversely, classical theorists would argue that the government should not intervene, stimulating the economy with fiscal policy would only lead to an increase in the price level. For simplicity, this paper has used classical assumptions.

The Covid-19 pandemic is somewhat unique since it caused both aggregate supply and aggregate demand to fall (Kollmann, 2021). The supply shock was caused because a large portion of economy had to stay at home (mitigated by digital technology as seen above). The demand shock was caused because households cut back on spending (saving due to uncertainty). Businesses also cut back on investment.

3.2 Augmented Solow-Growth Model

3.2.1. Set up

The comparative statics used above are useful, but to analyse the effects of Covid-19 over time, a dynamic equation is needed. The Solow model (Solow, 1956) is perfect to analyse this problem as it allows us to analyse the reduction in labour supply and subsequent effects on investment and capital. Other models, such as the Overlapping

Generations (OLG) model analyse the economy over a time horizon which is too long. Models such as the Schumpeterian growth model, include aspects of the economy that are irrelevant. We are not interested in R+D expenditure or technological progress. One of the drawbacks of the Solow model is that it cannot explain long-run growth, but in this project, we are more interested in using the model to explain the shock caused by Covid-19.

First, there is a production function in the form:

$$Y_t = K_t^{\alpha} H_t^{\beta} (A_t L_t)^{1-\alpha-\beta}$$

In each time period (years), Where output (Y_t) is a function of physical capital (K_t), human capital (H_t), productivity (A_t) and labour (L_t). All capital input factors exhibit diminishing marginal returns, so an additional unit of any factor increases output by less than the previous unit. This holds when $\alpha + \beta < 1$v
Alpha < 1

For simplicity, we assume that labour and productivity do not change over time. That is, there is no technological change or growth of the labour force. We are also more concerned with the shock to the labour force, rather than its growth over time. In other words, productivity and labour are made exogenous.

$$L_t = \bar{L}$$
$$A_t = \bar{A}$$

This means our production function is a constant return to scale Cobb-Douglas production function:

$$Y_t = K_t^{\alpha} (\bar{L}\bar{A})^{1-\alpha}$$

Next, the total output in the economy is either used as consumption or investment. Therefore, the relationship is:

$$Y_t = C_t + I_t$$

We also assume that agents have a constant saving rate. Hence, one minus this savings rate is equal to consumption. We will also say that savings are equal to investment:

$$S_t = sY_t$$
$$C_t = (1-s)Y_t$$
$$S_t = I_t$$

Investment is directed into replacing old capital or generating new capital inputs. Old capital must be replaced because capital depreciates at a rate of δ, which is equal to:

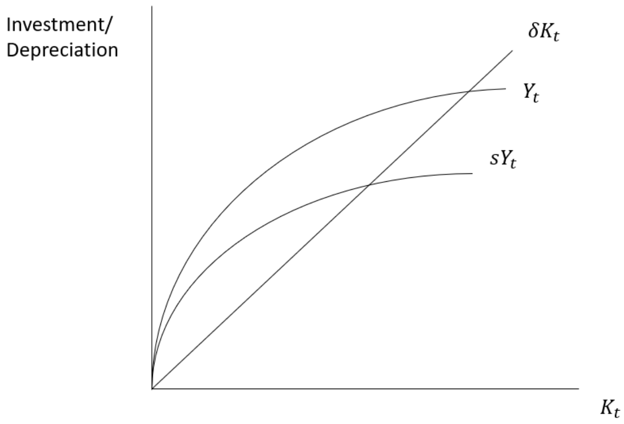
$$K_{t+1} = K_t + I_t - \delta K_t$$

$$y_t = \bar{A}^{1-\alpha} k_t^{\alpha}$$

This implies that output per worker depends on a worker's productivity and the amount of capital that is available to them. For our analysis it is easy to assume there is no natural growth of the labour force or productivity. This version of the production function also exhibits diminishing marginal returns to capital. This is intuitive since one worker can only make use of a limited amount of capital at any point. For example, giving a carpenter two hammers instead of one would not be beneficial.

3.2.2. Steady States

In the long run, the Solow model reaches an equilibrium where output per worker, consumption per worker and capital per worker is constant. Total depreciation increases linearly as the capital stock increases whereas investment increases at a diminishing rate, due to diminishing marginal returns to capital. This means that graphically, the two curves intersect, which is where investment is equal to depreciation, the increase in the capital stock caused by investment is counteracted by the decrease due to depreciation.



This can be mathematically solved:

$$sY = \delta K$$
$$sK^{\alpha}(\bar{A}\bar{L})^{1-\alpha} = \delta K$$
$$s\bar{A}K^{\alpha}\bar{L}^{1-\alpha} = \delta K$$

Therefore, when you solve for:

$$K^* = \left(\frac{\overline{s\bar{A}}}{\bar{\delta}}\right)^{\frac{1}{1-\alpha}} \bar{L}$$

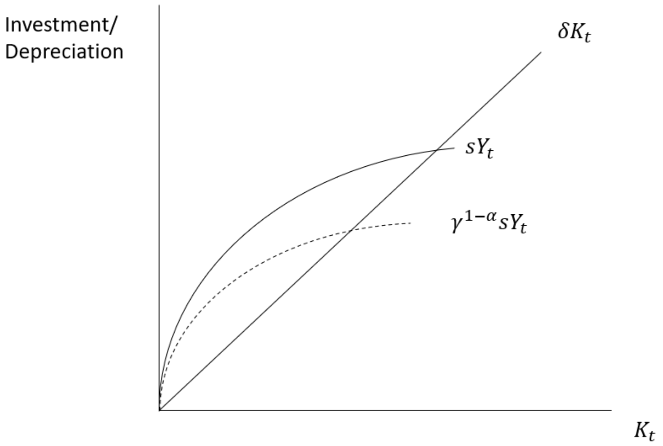
In a steady state the economy is stagnant and no longer growing. Exogenous parameters must change for growth to occur.

Therefore, output at the steady state is equal to:

$$Y^* = \left(\frac{\bar{s}}{\bar{\delta}}\right)^{\frac{\alpha}{1-\alpha}} \bar{A}\bar{L}$$

3.2.3. Pandemic Effects

Assuming economies were at steady state before the pandemic, restrictions act as a negative shock to the labour market, reducing its size. The drop in the labour market effectively reduces output (production function), driving down investment in capital, since investment in capital is a fraction of output. This causes investment in capital to be less than depreciation, so the capital stock falls. Output in this model is reduced if capital reduces, since output is a function of capital (as well as labour). The less capital that is available in the economy, the less productive workers can be, which leads to lower economic output. This cycle continues until investment is equal to depreciation and the economy is at a lower steady state.



Suppose the economic shock reduces the labour force by a fraction $(1-\gamma)$, so γ is the fraction of the labour force that remains. the actual size of the labour force is equal to:

$$L_p = \gamma \bar{L}$$

This means the production function is augmented in time period p such that:

$$Y_p = K_p^{\alpha} (\bar{A}\gamma\bar{L})^{1-\alpha}$$

We can find the new steady state level by equating investing to depreciation.

$$s\mathrm{Y_p} = \delta K_p$$

$$sK_p^{\alpha}\left(\gamma\bar{L}\bar{A}\right)^{1-\alpha} = \delta K_p$$

Rearrange for K_p:

$$K_p = \left(\frac{s}{\delta}\right)^{\frac{1}{1-\alpha}} \gamma \bar{A}\bar{L} = \gamma K_P$$

Therefore, output is:

$$Y_p = \gamma \bar{A}\bar{L} \left(\frac{s}{\delta}\right)^{\frac{\alpha}{1-\alpha}}$$

This means the steady state reduction caused by the pandemic is the same percentage of reduction as that of the labour force.

3.2.4. Covid-19 recovery

If furlough schemes are used by a nation, the labour force can immediately bounce back to pre-pandemic levels, since the relationship between employer and employee has been protected. Employees can return to the same employers. This means that the active labour force grows from $\gamma\bar{L}$ to $\bar{L}$.

Therefore, this causes investment to be greater than capital depreciation, causing growth of the capital stock, and therefore growth of output. Capital stock and output grow until the original steady state is reached again. The dynamics are the same as the initial shock, but in reverse.

3.2.5. The Problem of Human Capital

According to Mankiw et al. (Mankiw et al., 1992), empirical data is more supportive of an augmented Solow model which incorporates human capital as part of its production function. The model we use could also address a measure of human capital which can be measured in various ways. According to a paper by Abraham and Mallat (Abraham and Mallat, 2022), there are three approaches to constructing human capital measures.

Firstly, there is a cost approach which values investments in education based on education spending. The downside of this method is that it cannot determine how effectively this money is spent and therefore is inadequate at determining the capital stock. Secondly, there is an income approach, which attempts to measure human capital by looking forward to predicted earnings based on pupil's school enrolments, and then calculating the present value of these earnings. Finally, there is an indicator approach. The indicator approach attempts to capture a country's investments in human capital by using measures such as school enrolment, average years of schooling or adult literacy. This approach has the significant advantage of consistency with national income accounting practices and measures of other types of capital.

However, none of these approaches represent a "human capital stock", as suggested by Mankiw. The whole concept of human capital stock is very difficult to define and even more difficult to analyse empirically. It may be wise to omit this variable from the model. Another problem of human capital is that it is not entirely clear how separate labour productivity and human capital are. Human capital could be said to make workers more productive, which means that human capital has already been incorporated in a sense.

4. Data and Methodology

4.1. OLS Regression

Several data sets used for this analysis. The first is GDP growth from the OECD (OECD, 2022a); the second is the Digital Economy and Society Index (DESI), used by the European Commission (European Commission, 2020). The third is net capital stock, also taken from the OECD (OECD, 2022b). Fourth is productivity, measured as GDP per hour worked (OECD, 2022c). Finally, total labour force measures are taken from the world bank (World Bank, 2019)

The DESI summarises indicators of EU countries digital performance and progress and has been used since 2014. The index is taken annually, and the index represents data collected in the previous year. The year I have chosen to represent the digital performance of each economy is 2020. I believe that this best represents how prepared an economy was for the pandemic because this was the year before restrictions occurred. It is used to identify areas of digital weakness in member states which require priority policy action. The DESI may not perfectly reflect workers' abilities to work from home in each country, but it is a comprehensive measure of the digital advancement in different countries. The index is weighted between human capital, connectivity, integration of digital technology and digital public services. Each dimension is weighted equally. A more detailed structure is included below:

Table 1 DESI structure

Dimension	Sub-dimension	Indicator
1 Human capital	1a Internet user skills	1a1 At least basic digital skills
		1a2 Above basic digital skills
		1a3 At least basic digital content creation skills
	1b Advanced skills and development	1b1 ICT specialists
		1b2 Female ICT specialists
		1b3 Enterprises providing ICT training
		1b4 ICT graduates
2 Connectivity	2a Fixed broadband take-up	2a1 Overall fixed broadband take-up
		2a2 At least 100 Mbps fixed broadband take-up
		2a3 At least 1 Gbps take-up
	2b Fixed broadband coverage	2b1 Fast broadband (NGA) coverage
		2b2 Fixed Very High Capacity Network (VHCN) coverage
	2c Mobile broadband	2c1 5G spectrum
		2c2 5G coverage
		2c3 Mobile broadband take-up
	2d Broadband prices	2d1 Broadband price index
3 Integration of digital technology	3a Digital intensity	3a1 SMEs with at least a basic level of digital intensity
	3b Digital technologies for businesses	3b1 Electronic information sharing
		3b2 Social media
		3b3 Big data
		3b4 Cloud
		3b5 AI
		3b6 ICT for environmental sustainability
		3b7 e-Invoices
	3c e-Commerce	3c1 SMEs selling online
		3c2 e-Commerce turnover
		3c3 Selling online cross-border
4 Digital public services	4a e-Government	4a1 e-Government users
		4a2 Pre-filled forms
		4a3 Digital public services for citizens
		4a4 Digital public services for businesses
		4a5 Open data

The countries included in the analysis and their respective DESI value are included in the table below. Although there is data on the DESI for 27 countries, the data is only complete for 19 countries. Some countries have data missing for other independent variables.

Country	**Digital Economy and Society Index (DESI)**
Austria	54.68
Belgium	50.31
Denmark	69.33
Estonia	56.51
Finland	69.60
France	53.33
Germany	52.88
Greece	38.93
Hungary	43.76
Italy	49.71
Latvia	49.71
Lithuania	52.71
Luxembourg	58.85
Netherlands	67.37
Poland	40.55
Portugal	50.76
Slovenia	53.37
Spain	60.77
Sweden	65.22

All the other variables used in the analysis are either taken from the OECD or the World Bank. These are both reputable sources as the data and information they produce are widely used by governments, policymakers, academics and researchers.

To calculate GDP the expenditure method is used because of its simplicity and the ease with which the GDPs of different nations can be compared. The data for productivity will take the form of GDP per hour worked. Our productivity parameter is a labour productivity parameter, not a general productivity parameter and it takes the form GDP per hour worked.

The econometric model used will take the augmented Cobb-Douglas production function - the one used in our augmented growth model - but our analysis will take logarithms to make our model linear. The model will compare whether the DESI index is a good predictor of output across different European countries. Our other independent variables will be inputs to the production function, hopefully to reduce the chances of omitted variable bias.

$$Y_p = K_p^{\alpha}(\bar{A}\gamma\bar{L})^{1-\alpha}$$

Both sides of the equation can be logged to separate our independent variables:

$$\ln(Y_p) = \alpha \ln(K_p) + (1-\alpha)\ln(\bar{A}) + (1-\alpha)\ln(\gamma) + (1-\alpha)\ln(\bar{L})$$

In theory the level of digitalisation in the economy, measured by the DESI index, is proportional to the flexible workers who are still working during the pandemic. The intuition for this has been provided in the comparative statics section of this paper. Therefore, gamma is a function of digitalisation such that:

$$\gamma \propto D$$
$$\gamma = mD$$

Therefore,

$$\ln(Y_p) = \alpha \ln(K_p) + (1-\alpha)\ln(\bar{A}) + (1-\alpha)\ln(mD) + (1-\alpha)\ln(\bar{L})$$

So:

$$\ln Y_p = \alpha \ln(K_p) + (1-\alpha)\ln(\bar{A}) + (1-\alpha)\ln(m) + (1-\alpha)\ln(\bar{L}) + (1-\alpha)\ln(D)$$

This can be written as an OLS equation. Coefficients are changed to beta values and an error term is added to reflect this. i subscripts are added to show different cross sections, which are in this case, countries. The term $(1-\alpha)\ln(m)$ becomes our constant term.

$$\ln(Y_i) = \beta_0 + B_1 \ln(K_i) + \beta_2 \ln(\bar{L}_i) + \beta_3 \ln(D_i) + \beta_4 \ln(\bar{A}_i) + \varepsilon_i$$

Where Y_i is the dependent variable which represents the GDP for country i. Coefficient β_0 is a constant and ε_i is an error term. D_i is the independent variable that represents the DESI index. The coefficient of interest is β_3, which measures the change in GDP growth for a unit change in the log of the DESI. K_i is the independent variable that represents the capital stock of country i. A_i is the independent variable that represents the productivity of country i. $\bar{L}_i$ is the independent variable that represents the labour force of country i.

Realistically, the data we will analyse is short run data. The peak of the Covid-19 pandemic only lasted for a duration of 2 years.

4.2. Results

The results are as follows:

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                  log_Y   R-squared:                       0.100
Model:                            OLS   Adj. R-squared:                 -0.157
Method:                 Least Squares   F-statistic:                    0.3891
Date:                Mon, 10 Apr 2023   Prob (F-statistic):              0.813
Time:                        15:31:33   Log-Likelihood:                -4.1822
No. Observations:                  19   AIC:                             18.36
Df Residuals:                      14   BIC:                             23.09
Df Model:                           4
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          3.9275      7.053      0.557      0.586     -11.200      19.055
log_desi      -0.1491      0.687     -0.217      0.831      -1.624       1.325
log_K          1.3851      1.285      1.078      0.299      -1.370       4.141
log_A          0.1159      0.368      0.315      0.758      -0.674       0.906
log_L          0.0312      0.063      0.495      0.629      -0.104       0.167
==============================================================================
Omnibus:                        3.557   Durbin-Watson:                   1.623
Prob(Omnibus):                  0.169   Jarque-Bera (JB):                1.602
Skew:                           0.573   Prob(JB):                        0.449
Kurtosis:                       3.844   Cond. No.                     1.52e+03
==============================================================================
```

After conducting t-tests, none of the independent variables were statistically significant, even at the 10% level. We must accept the null hypotheses that the beta coefficients for all the independent variables are equal to zero.

4.3. Robustness

Our model fails to analyse the dynamic effect of COVID-19 on GDP. Hence our model does not show that there has been a shock and whether the size of the shock reflects levels of digitalisation.

There are many limitations to the data collected, which explains the lack of significant results. For example, our measurement for the DESI probably doesn't properly reflect a workforce's ability to adapt to lockdown restrictions,
as it is unlikely to capture all the relevant factors. It is also worth noting that the DESI is weighted between connectivity, human capital, use of internet services, integration of digital technology and digital public services. There is no reason to think that how the DESI is weighted reflects which were the most important factors in allowing a workforce to adapt to the pandemic and its restrictions. It is also worth noting that it does not measure how well a workforce adapted to the pandemic, since it is a static annual measure. Different policies would have been taken by different nations to adapt to economic challenges.

Another problem is that there are only 19 observations in my sample. Small samples limit the statistical power of an analysis because it is more difficult to detect statistically significant relationships. This increases the likelihood of Type 1 and Type 2 errors, which means a null hypothesis is more likely to be falsely rejected or accepted. The DESI is also limited in this sense because it only covers EU member countries. The number used in the regression above is even less than the number of EU member countries because data on all the other independent variables is required for each country, there were several countries which had data missing. Also, since all the data collected is from EU members, it is likely that there is a large degree of homogeneity between observations. This is because the European Union has established common policies that must be followed by all EU members. Having observations from countries from other continents would make the sample more globally representative.

There is a low degree of heteroscedasticity in the model. From conducting the Breusch-Pagan test, the p-value is greater than 0.05, therefore we can accept the null hypothesis that the model is homoscedastic. There is not enough evidence to suggest that heteroscedasticity is present in the model. Homoskedasticity is important because a changing variance can lead to standard errors and coefficients not being estimated correctly, biasing the results and the precision of the model.

However, it is highly likely that there is omitted variable bias in the model. The response to Covid-19 varied wildly from country to country and there is also a large degree of heterogeneity between different countries. For example, the severity of Covid-19 restrictions (s) would have most likely had an impact on the GDP contraction of different countries. Suppose the true relationship is given by:

$$y_i = \beta_0 + \beta_1 d_i + \beta_2 s_i + u_i$$

Two conditions must be met for omitted variable bias to exist: the omitted variable must be a determinant of the dependent variable and the omitted variable must be correlated with an independent variable. Let the model take a vector form where:

$$D = \begin{bmatrix} d_1 \\ \vdots \\ d_n \end{bmatrix} \in \mathrm{R}^{n \times p}$$

and

$$Y = \begin{bmatrix} y_1 \\ \vdots \\ y_n \end{bmatrix}, \qquad S = \begin{bmatrix} s_1 \\ \vdots \\ s_n \end{bmatrix}, \qquad U = \begin{bmatrix} u_1 \\ \vdots \\ u_n \end{bmatrix} \in \mathrm{R}^{n \times 1}$$

Suppose that S is omitted and Y is regressed on D.

$$Y = \beta_0 + \beta_1 X + \mathrm{E}$$

The estimated value of $\beta_1{}^*$ is:

$$\widehat{\beta_1}^* = \frac{cov(D, Y)}{V(D)} = \frac{cov(D,\ \beta_0 + \beta_1 \mathrm{D} + \beta_2 \mathrm{S} + \mathrm{U})}{V(D)}$$

$$= \frac{cov(D,\ \beta_0) + cov(D,\ \beta_1 \mathrm{D}) + cov(D, \beta_2 \mathrm{S}) + cov(D, \mathrm{U})}{V(D)}$$

$$= \beta_1 \frac{V(D)}{V(D)} + \frac{\beta_2 cov(D,S)}{V(D)} + \frac{cov(D,U)}{V(D)}$$

$$= \beta_1 + \frac{\beta_2 cov(D,S)}{V(D)} + \frac{cov(D,U)}{V(D)}$$

Therefore, the estimate of β_1, is likely biased because $cov(D,S)$ is likely non-zero. If a country has a large DESI, it may have been less reluctant to impose severe restrictions on its citizens, as their ability to adapt is high compared to citizens of a country with a low DESI. Countries had to conduct policy to balance both economic and health risks of the COVID-19 pandemic. In addition, the result of the Breusch-Pagan test suggests that $cov(D,U)$ is also non-zero, since there is evidence that our model exhibits heteroscedasticity. Both these factors mean that the that the error term is correlated with regressors, which violates one of the Gauss-Markov assumptions. Therefore, our model does not provide the most efficient, linear and unbiased estimators.

Although literature has been used to narrow down significant explanatory variables, a modern economy is extremely complex. There are certain qualitative factors that are sometimes hard to measure which could have large impacts on inflation and output. For example, this could be which countries a country chooses to trade with.

Another weakness of this model is that it says nothing about the recovery from the shock caused by the pandemic. As the capital stock recovers back to a steady state the economy should reach a constant growth rate. The model does not analyse whether this is the case. Unfortunately, there was not enough data for me to analyse the pandemic recovery to the original steady state.

5. Topics for Future Research

Firstly, the analysis in this paper could be reworked with methodological improvements by using an index that is a better proxy for how well a workforce can adapt to Covid-19. In addition, this index would ideally be more globally representative, and include a larger sample size, as well as being updated more consistently so that Covid policy could be better interpreted. This would allow cross-cultural perspectives of remote work on the economy.

Future research could also focus on how remote work affected different sectors. For example, the technology sector experienced a huge surge in demand during the pandemic, due to the increased reliance on digital tools, platforms and services. Remote work also accelerated the adoption of certain technologies, such as artificial intelligence, automation and augmented reality. Conversely, the hospitality and tourism sector has experienced severely reduced demand, by travel restrictions, lockdowns, and social distancing measures affecting many businesses in these sectors. This led to substantial job and economic losses. Other sectors experienced more ambiguous disruptions.

The post- pandemic global economy has been chaotic and complicated. From supply chain issues to war in Europe, there have been subsequent shocks that make it very difficult to analyse how economies recovered from Covid-19. This project has not analysed the effects of monetary policy or inflation on Covid recovery. Furlough schemes and other types of stimuli were radical economic policies that cost government played a major role in the events of the pandemic and should be incorporated into a similar model.

6. Conclusion

The regression results in this paper show that the level of digitalisation in an economy is not a good predictor of its GDP during the Covid-19 pandemic. However, this is likely due to limitations of data. 19 observations are a very small amount that could introduce type 1 and type 2 errors. In addition, using the DESI as a proxy for the workforce's ability to adapt, while convenient, is unlikely to accurately represent this.

The conceptual framework laid out suggests that the more "digitalised" an economy is, the higher the proportion of workers will be able to work throughout the pandemic. Workers that cannot adapt cause output to reduce, since production requires labour as one of its inputs. This in turn reduces the level of investment in the next period, causing capital stock to fall. Hence output is reduced further because of a reduction in capital, as well as a reduction in labour.

Our literature review suggests that furlough schemes and short-term work schemes are good tools for policy makers to mitigate the employee shortages that firms and economies experience. However, it is also the case that the disruption caused by Covid may have led to increased worker wellbeing, through more unionisation and allowing workers to prioritise their own health and well-being.

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