UNIVERSIDADE CATÓLICA PORTUGUESA

The Impacts of the COVID-19 Pandemic on the Portuguese Economy

A Structural Break Analysis

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A Structural Break Analysis

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[1] Saramago (2008)

Abstract

The COVID-19 pandemic could led to one of the worst crises in history (Barro, 2020). It would be the second crisis in the 21st century the Portuguese economy encounters but it is still unknown if its effects would be structural (permanent and related to the supply side) or cyclical (transitory and related to business cycle fluctuations and the demand side).

To test for structural change, a linear regression model is used and the Chow test and Chow test for predictive failure are applied. The model uses quarterly data from various sources, ranging from the first quarter of 1998 to the third quarter of 2020, and is estimated in seasonal differences. It considers as dependent variable the natural logarithm of output per worker and as explanatory variables the natural logarithm of physical capital per worker, a time trend, and other variables on the supply and demand side as controls.

A Chow test was first applied to the 2008 Global Financial Crisis, to rule out any interferences from this period. A structural break was found in the fourth quarter of 2010. Applying a Chow test for predictive failure to a subsample from the first quarter of 2011 to the third quarter of 2020, the null hypothesis of the pandemic not causing a structural break was rejected. T-tests were used to confirm the location of the breaks. The null hypothesis that a break did not occur was rejected for all the coefficients of the regression variables, pointing for the existence of supply side permanent effects.

Keywords: COVID-19; structural break; Portuguese economy.

JEL Codes: C32; E32; E6.

Resumo

A pandemia de COVID-19 poderá causar uma das piores crises de que há memória (Barro et al., 2020). Será a segunda crise que a economia portuguesa enfrenta no século XXI e ainda é incerto se os seus efeitos serão estruturais (permanentes e ligados ao funcionamento do lado da oferta) ou cíclicos (transitórios e ligados a flutuações do ciclo económico e ao lado da procura).

Para testar quebras estruturais, é usada uma regressão linear e aplicados o teste de Chow e o teste de Chow para falha preditiva. O modelo usa dados trimestrais de várias fontes, desde o primeiro trimestre de 1998 ao terceiro trimestre de 2020 e é estimado em diferenças sazonais. Considera como variável dependente o produto por trabalhador efetivo e como variáveis explicativas o stock de capital físico por trabalhador efetivo, uma trend temporal e outras variáveis do lado da procura como controlos.

Foi aplicado um teste de Chow ao período da Crise Financeira Global de 2008 e uma quebra estrutural foi encontrada no quarto trimestre de 2010. Foi, depois, aplicado um teste de Chow para falha preditiva a uma subamostra do primeiro trimestre de 2011 ao terceiro trimestre de 2020 e a hipótese nula de a pandemia não causar quebra estrutural foi rejeitada. Foram ainda usados testes t para confirmar a origem da quebra. A hipótese nula foi rejeitada para todos os coeficientes da regressão, apontando para a existência de efeitos permanentes no lado da oferta.

Palavras-chave: COVID-19; teste de Chow; quebra estrutural; economia portuguesa.

Códigos JEL: C32; E32; E6.

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Chapter 1
Introduction

The main objective of this dissertation is to determine whether the COVID-19 pandemic caused a structural break in the Portuguese economy, by applying a time-series regression using quarterly data, the Chow test, the Chow test for predictive failure and t-tests to confirm the location of the breaks.

In a global context of slowing economic growth, countries were suddenly faced with a trade-off to respond to an unexpected pandemic outbreak, the COVID-19: governments were forced to decide if "the large potential loss in lives and economic activity justify substantial expenditure of resources to attempt to limit the damage" (Barro et al., 2020, p.18).

Most OECD governments opted to impose severe lockdowns that strongly restricted economic activity, as was the case of Portugal, which, until the first quarter of 2020, was on a path of moderate economic growth and recovering from the past 2008 Global Financial Crisis. A decline in economic growth is now expected, although its magnitude and future implications depend on, "amongst other factors, the interaction of the pandemic evolution and the implemented policies" (Banco de Portugal, 2020, p.7), especially because the contention strategy associated with the protection of the national healthcare system is expected to extend the temporal dimension of the outbreak.

Economists have been unanimous: this could be one of the worst crises the country and the world have ever faced, due to the uncertainty associated with the need for restrictive public health protective measures as well as the inherent trade-off between economic activity and infection numbers, the interruption (or complete disruption) on global value chains, the need for public intervention that restricts social interaction and associated activities, (Campos, 2020; Barro et. al.,

2020) and the associated behavioral factors – individuals only consider their own risk of getting infected, not the risk of infecting others (Alvarez et al, 2020). Consumers were forced to reduce their consumption, either by precaution, or by the reduction of in-person interactions; supply chains were disrupted because of the imposed lockdowns and shortages in labor supply caused by fear or by the disease itself; and financial markets reacted to simultaneous demand and supply shocks (Philipp Carlsson-Szlezak et al., 2020).

Costa e Silva (2020) supports that "in short, it is an economic cycle that ends and another that will begin with a systemic change of great amplitude in all activity sectors and in the functioning of the economy as a whole" (Costa e Silva, 2020, p.7). The author argues that the sanitary crisis will have long term consequences for the Portuguese economy. Whether these consequences are cyclical, structural or both, it is still unknown.

While structural changes are linked to a permanent change in potential GDP and its growth rate, cyclical consequences may or may not have permanent effects in an economy's productive potential (Apokin and Ipatova, 2017; Cerra and Saxena, 2017).

A structural change can - and should - impact intertemporal policy options, since not taking it into account can lead to "sizeable upward biases" (Babikir et al, 2017). For that same reason (and to rule out interferences from the 2008 Global Financial Crisis), a Chow test will also be conducted for that crisis period as a control.

This dissertation is organized as follows: after this introduction, Chapter 2 reviews the literature on the economic effects of the pandemic, as well as its transmission channels to the real economy; the Portuguese pre-pandemic macroeconomic context; economic growth models; structural breaks and the Chow test and its variants. Chapter 3 presents the empirical framework, justifying the chosen sample as well as describing and discussing the regression variables, the various regressions and its results and. Chapter 4 concludes with a summary of the main findings, limitations, and future research suggestions.

Chapter 2
Literature Review

2.1. The COVID-19 Pandemic Economic Effects

"Pandemics, like natural disasters, offer a unique opportunity to study how economies work. They are like a randomized control trial, but at a much larger scale." (Jordà et al., 2020, p.5)

At the end of 2019, a new type of coronavirus was reported by China, with an outbreak starting in Hubei, in the province of Wuhan. This was the first epicenter of the disease until the end of January, when the World Health Organization (WHO) declared it as a pandemic, with an enormous outbreak in Italy, the first European country (severely) hit.

The fast spread of the virus was only possible due to the level of integration and globalization the word has nowadays. As Fernandes (2020) states, this level of world integration makes the impacts of the disease go far beyond mortality, having a tremendous potential economic harm. With the lockdown measures adopted by most countries, borders were restricted and the usual flows of goods, capital and individuals were disrupted, working as a force pushing towards "deglobalization" (Barua, 2020).

Countries have to deal with two externalities: the infection externality and the health care congestion externality (Alvarez et al., 2020). First, families and individuals only consider their own risk of getting infected, not the risk of infecting others – hence, the mitigation effects are below the social optimal level. Second, if hospitals get congested with infected individuals, there is an increased risk of death from the disease and from other conditions.

Given the capacity of this virus to rapidly spread from one individual to another, many countries adopted Non-Pharmaceutical Interventions (NPIs), including quarantines and social distancing, to contain the spread of the virus and avoid the collapse of their health systems due to a huge surge of infected individuals.

China was the first country to impose a quarantine, in the Wuhan region, having an advance of 1.5-2.5 months in the tentative control of the crisis and serving as a benchmark. As Banco de Portugal (2020) explains, their quarantine led to a strong and abrupt reduction in economic activity: on one hand, there was the impossibility of keeping workers safe in the factories' environment, reducing (or even stopping) production; on the other hand, there was a decline in demand (especially in situations with social interaction), either for final goods or for intermediary products.

With an interruption in Chinese production associated with the quarantine, "the functioning of global supply chains was disrupted" (Atkeson, 2020, p.2), causing a spillover effect to other distant countries, who, at the time, had not yet imposed lockdown or social distancing measures in their territories. Countries who were strong exporters had no longer a way of trading their production due to the curfew and the interruption of travels and transportation chains; while countries who were strong importers experienced a lack of raw materials (Fernandes, 2020). Companies (of all sizes) across the world started to experience contractions in production even before the country where they were located reported its first cases, given their dependency upon inputs from China, who, at the time, was already quarantined (McKibbin & Fernando, 2020).

While the pause in the Chinese production has had impacts in the world supply chains, having a spillover effect to other distant countries, this was not the only immediate economic effect of the pandemic. The fear factor (also verified in the SARS pandemic, as referred by Atkeson (2020)) induced consumers to reduce their consumption, especially when talking about consumption that requires some form of social interaction. The panic associated with hoard shopping, for example, distorted consumption patterns and created market anomalies (Atkeson, 2020).

The main challenge that a pandemic poses to policy makers has to do with the optimal restraining policy. Targeted public health policies should address the short term effects without creating economic distortions that can outlast the impact of the pandemic itself (Jackson et al., 2020).

Alvarez et al. (2020) analyzed the optimal lockdown policy to control the fatalities while minimizing the costs inherent to a slowdown on economic activity. The authors concluded that the optimal policy would be the imposition of a severe lockdown beginning two weeks after the outbreak, covering 60% of the population and gradually withdrawn after one month, covering only 20% of the population after three months.

Thus, the optimal intensity and duration of the lockdown depend on:

i) The cost of fatalities, measured by the value of a statistical life;

ii) The effectiveness of the lockdown, measured by the decrease in social contacts;

iii) The possibility of testing the immunity the population develops after a while.

For the optimal policy designed by the author, the output cost would be 8% of one year's GDP (equivalent to a 0.4% contraction on output). Here, the key determinant is the elasticity of the fatality rate to the number of infected individuals.

The traditional approach to pandemics is mainly concerned about deaths and illness leading to a loss in future income (Fernandes, 2020). Additionally, social distancing policies and quarantines impose an overwhelming disproportionately high economic and social cost, associated to the slowdown or complete stop in production and consumption for an uncertain period of time (Mera, 2020b).

In an attempt to flatten the epidemiological curve and to gain time, the majority of countries imposed strict shutdowns to avoid hospitals getting overcrowded and trying to gain some time so that the health systems are ready to cope with the pandemic (Mera, 2020a).

This is not the first time that a disease outbreak shakes the economy. In 1918, there was an influenza pandemic (the Spanish Flu) where this type of measures was also applied. Those measures resemble the policies adopted to reduce the spread of COVID-19, including "school, theater and church closures, public gatherings and funeral bans, quarantine of suspected cases, and restricted business hours" (Correia et al., 2020, p.1). More recently, there were the SARS and MERS outbreaks (also coronaviruses), in 2002 and 2012, respectively.

The economic effects of social distancing measures can be quite severe. Indeed, it can be argued that there is a necessary trade-off between NPIs and economic activity during a pandemic. Correia et al. (2020) analyzed the economic effects of the largest influenza pandemic (1918), comparing the effect of early and extensive NPIs with no NPIs at all. The study suggests that this tradeoff is not a necessary condition: while NPIs reduce social interactions, contracting the economic activity that relies on them, with no NPIs economic activity is also diminished as households reduce their consumption and labor supply to lower their chances of getting infected. Data from the Spanish Flu points out that American cities that reacted 10 days earlier to the arrival of the pandemic experienced an increase of manufacturing and employment by around 5% in the post pandemic period, contrasting with cities who did not and were severely hit by influenza, where wages increased in consequence of the labor supply shortage associated with the mortality rates of the pandemic. Barro (2020) concluded that the NPIs used during the 1918 pandemic were not successful in reducing overall deaths, as they were not sustained for a sufficient period of time.

On the contrary, Boone (2020) believes that there is a necessary trade-off between NPIs and economic activity. The author defends that the size of the economic shock will be determined mostly by the measures taken to avoid the spread of the virus.

Having some previous examples of pandemics and their economic impacts, it can be questioned if it would not be easier to assess the COVID-19 economic damage this time and use previous lessons to design public policy with less damage to the economic activity. To Atkeson (2020) it will, providing policymakers have some background experience. To Fernandes (2020), it is impossible – China and the world are completely different in 2020 than they were some years ago and this is a different crisis: the author argues that impacts across sectors will be asymmetric (service oriented are more at risk, because of the lack of confidence of the public regarding activities evolving personal contact) and will affect countries in different ways. Moreover, this is a simultaneous shock in supply and demand.

There were also some comparisons with the recent 2008 Global Financial Crisis, although it can be argued that comparisons should not be made. Jackson et al. (2020) point two main differences between these two crises: the 2008 Global Financial Crisis was rooted in structural weaknesses in the US financial sector and was spread due to the linkage of the world financial markets through credit default swaps, while the current crisis is a supply shock, spread through the disruption of the global value chains caused by the plant closures in China.

Barro et al. (2020) use the Spanish Flu to draw some conclusions regarding the economic effects of COVID-19, although there are some basic differences between the two contexts: while that outbreak had a high mortality rate amongst young adults with no pre-existing medical conditions, the actual pandemic affects, mostly, older individuals with pre-existing conditions. This implies lower economic effects in the labor force.

The authors found a correlation between the cumulative death rate with the log of a country's real GDP per capita in the prior year. If the Spanish Flu death rate (2.1%) was applied to the current population levels, there would be 150 million deaths worldwide – although the probability of the current outbreak reaching these mortality levels is remote, given the different public health scenarios that countries have nowadays. Pushing in another direction there is globalization, a factor that was not at stake for the Spanish Flu and that, as mentioned before, contributed for a world scale outbreak in a short amount of time.

In economic terms, the 2.1% death rate would be associated to a fall of 6% in GDP and of 8% in private consumption. These values are similar to the ones seen in the 2008 Global Financial Crisis.

Barro and Ursúa (2008) ranked macroeconomic disasters since 1870: the great influenza pandemic or Spanish Flu was in the fourth place, preceded by the World War II, the Great Depression and the World War I (in this specific order). If the crisis induced by the COVID-19 pandemic is anything like the one induced by the influenza pandemic, the world could live one of the worst recessions to date.

Following the same reasoning, Jordà et al. (2020) examined the main difference between a pandemic and other economic disasters. The starting point lies on the fact that physical capital is destroyed on wars, but it is not during a pandemic. Defining a pandemic as an event with more than 100 000 deaths, there is a large contraction in the labor force and, thus, inducing relative labor scarcity, and/or a shift to greater precautionary savings.

2.1.1. Transmission Channels

After implementing their own preventive measures, countries experienced disruptions from quarantines. There are three main channels through which these measures spill over (Carlsson-Szlezak et al., 2020b):

i) Demand: through the reduced consumption of goods and services, by consumers staying at home, having less confidence in face-to-face economic activity due to pessimistic expectations;

ii) Supply: through the disruption in supply chains and shortages in labor demand and employment, with the addition of prolonged periods of lay-off;

iii) Financial markets shocks and their effects on the real economy: through the reduction in household wealth, the increase on savings and the further decrease of consumption spending.

Pandemics create a transitory downward shock to the real interest rate: investment demand decreases because of the labor scarcity and the drop in demand in the economy suppressing the need for high investment and, at the same time, savers might react with an increase on savings, either for precaution or to replace lost wealth used in the calamity. These authors defend that pandemics have effects that last for decades: the real interest rate decreases through decades, reaching its minimum about 20 years after the shock and returning to its natural level 40 years later. This can be particularly severe in a pre-existent context of historically low interest rates.

Guerrieri et al. (2020) treat this shock as what they call a "Keynesian supply shock" (a supply shock that triggers changes in aggregate demand larger than the shock itself, under incomplete markets). A negative supply shock induces a demand shortage ("supply creates its own *excess* demand", as a reference to the Say's law), and an overreaction of demand to a supply shock can be seen as and lead to a "demand-deficient recession".

With a shutdown, shocks are concentrated in some economic sectors: some goods are no longer available and it is less attractive to spend overall, increasing the shadow prices of goods in the affected sectors, making total current consumption more expensive and, thus, discouraging it. There can be, though, a shift to spending in other sectors – a substitution channel.

Firms are forced to lay-off large numbers of workers, trying to survive and remain financially feasible during the shock, increasing the unemployment levels (Barua, 2020) – although it may be argued that this does not necessarily happen: it might be a way to control future increases in unemployment, as it can be only a temporary suspension of an employment contract. By making them alter or delay their investment plans, going bankrupt and destroying workers-firms matches, the economic downturn will be a long-lasting supply disruption, having an effect on the future capacity of the economy (Fornaro & Wolf, 2020).

Workers lose their jobs and income and so, consumption contracts. To keep it at the same level as before the shock, workers from unaffected sectors would have to increase their consumption (requiring a degree of substitution across sectors), ignoring the effect of uncertainty on consumption decisions.

Baker et al. (2020) explain how household consumption respond to a pandemic: in a first phase, spending increases sharply due to the stock piling of durable and essential goods (associated with the uncertainty of a pandemic and the duration of the quarantine). In the US, this increase was around 50% between February 26 and March 11 of 2020. After that first phase, a sharp decline on overall spending occurs, being especially harsh in states that issue curfew orders. It should be noted that, by the beginning of march, there were very few cases of COVID-19 in the US – consumers reacted to what they were seeing abroad, expecting similar damages in their own country.

This demand shock induced by the contraction on consumption is different across types of goods – essential goods had an increase in their demand due to consumers hoarding them in the first phase of the pandemic, while luxury goods had a fall on their demand. Nonetheless, in net terms, a fall in aggregated demand should be expected (Barua, 2020).

With reductions in both supply and demand, consequences on the price levels are expected (Barua, 2020): essential goods should suffer a price increase, while luxury goods should suffer the opposite.

What will be the impact of the price change in overall inflation? As Fornaro and Wolf (2020) explain, the overall effect is unknown. The classic notion associated with negative supply shocks is that lower productivity growth pushes inflation up; but lower employment levels push wage inflation down. The relative strength of those effects depends on the slope of the Phillips curve.

2.1.2. Estimated Impacts

There is already some literature trying to forecast and quantify the losses on GDP induced by the COVID-19 pandemic.

The IMF revised its estimates on 2020 growth from 2.9% to 2.4%, while the OECD was more pessimistic, estimating a loss of 2% per month of shutdown (IMF, 2020; OECD, 2020).

Fernandes (2020) estimates the expected GDP growth in three different scenarios: i) the lockdown would last for 1.5 months; ii) it would last for 3 months and iii) it would last for 4.5 months. In this paper, there are estimates for Portugal, varying from -4.8% in the base scenario to -14% in the worst case scenario. By now, it is known that the last Portuguese lockdown lasted for about 1.5 months with an associated contraction of 7.5% (INE, 2021), contrasting with the 5.9% the author predicted.

Atkeson (2020) analyzes seven different scenarios using a hybrid DSGE/CGE equilibrium model. Three degrees of severity (low, medium, and high) and two possibilities for the spread of the disease were considered: either it would be an isolated event in China, or it is spread around the world with different degrees of severity. There is, still, a worst-case scenario: this pandemic (or a pandemic) reoccurring yearly and becoming a permanent shock in the economy, since zoonotic virus will continue to pose a threat to public health. It is already known that this disease was not limited to China - when considering this scenario, the loss estimates for China are less severe than they would be if the outbreak had been confined there: -1.05% in the less severe scenario and -1.4% in the worse one, contrasting with -0.1% and -3.4%, respectively. Regarding the rest of the world, in the low severity scenario the losses will be of 1.29% and in the high severity scenario of 4.16.%. When considering that the pandemic becomes recurring and, thus, the shock becomes permanent, the global losses are estimated in 1.29% and the Chinese one in 1.05%, annually. In either of the scenarios of the disease becoming a global outbreak, Chinese losses are inferior to the world losses.

Maliszweska et al. (2020) simulate the potential impact on GDP and trade using a standard global computable general equilibrium model. Two scenarios were considered: in the case of a global pandemic (other countries only bear half of the chinese shock), the world losses are estimated in about 2.09%; in the case of an amplified pandemic (an uniform shock), the estimated loss is about 3.86%. By now, it is already known that the pandemic can be treated as an amplified pandemic.

A rising question has to do with the aftermath of the recession and the shape of it. As (Carlsson-Szlezak et al., 2020a) explain, there are three possibilities:

i) A "V-shapped" recession, the most optimistic scenario, in which aggreggate output quickly recovers its natural path after a sharp downturn;

ii) A "U-shapped" recession, in which output does not recover its pre-crisis path and a gap between its "old" and "new" path is created; and

iii) A "L-shapped" recession, the most pessimistic scenario, in which output drops and growth rates continuously decline, with a widden gap between pre and post pandemic output paths. This scenario implies significant structural damage.

Previous pandemics led to "V-shapped" recoveries (Carlsson-Szlezak et al., 2020b): Dahl et al. (2020) use the example of the 1918 epidemic in Denmark, that led to a V-shaped recession, with relatively moderate consequences and a full recovery after 2-3 years.

The actual pandemic is not expected to have such a straight forward recovery due to the prolongued NPIs efects on the real economy.

2.2. The Portuguese Macroeconomic Context

"The crisis interacts with pre-existing heterogeneity in asset holdings, income-generation capacity, labor conditions, access to public services, and many other aspects that make some individuals and households particularly vulnerable to an economic freeze of this kind." (Mera, 2020b, p.3).

This section will present a review of the Portuguese macroeconomic context, following the scheme presented by the reports of the UNDP Covid-19 Policy Documents Series.

By 2019, the Portuguese economy was notably consolidating its recovery from the 2008 Global Financial Crisis - "economic conditions in Portugal have improved markedly over the past few years. GDP is now back to its pre-crisis level and the unemployment rate has declined 10 percentage points since 2013 to below 7%, one of the largest reductions in any OECD country over the past decade." (OECD, 2019, p.10). The output gap registered positive values since 2018.

Although expanding, a slowdown was felt, following the global trend associated with the context of uncertainty associated with "comercial tensions between the US and China and the weakening of industrial production, specifically in the automobile sector", besides the normal maturation of the economic cycle (Banco de Portugal, 2020, p.7).

Even with this slowdown, projections for the Portuguese economy were optimistic – GDP was projected increase about 2% anually between 2018 and 2020 and the general macroeconomic context was expected to continue expanding (OECD, 2019).

The labor market situation is one of the most important aspects to analyze, since emergency measures imposed by the government directly impact it through job losses, lay-offs, wage reductions and even changes in the way of working (remote working) (Mera, 2020b). In 2019, unemployment rate reached 6.5%, its lowest value since 2003. Following 2013, the year when unemployment reached its maximum (16.2%), the number of unemployed individuals decreased 60.3%. An outstanding feature of 2019 was the significant increase on the apparent labor productivity, propelled by the productivity increase in all sectors of activity, although still being inferior to the European average.

Being a small and open economy, the country is more vulnerable to external shocks (Mera, 2020b). The Portuguese openness index was projected to exceed 80% between 2019 and 2021. Exports accounted for 43.51 % of the GDP and imports for 43.28% (World Bank, 2019). High dependence from China in terms of health equipment, machinery and other electronic goods, as well as inputs, posed challenges even before the pandemic hit the country in the first quarter of 2020 due to the disruption in global supply chains (Costa e Silva, 2020).

Before the crisis, tourism represented 13% of GDP and now is one of the most affected sectors (Costa e Silva, 2020). This sector has been the second main contributor for the growth rate of exports (and the first in terms of services). As expected, the pandemic will impose restrictions in tourists flows, having a strong negative impact on tourism and spreading the damage to all activities that are linked to it, as hard impacts on hotels and restauration (Mera, 2020b).

In 2019, emigrant's remittances accounted for 1.5% and kept Portugal as the third country of the European Union with largest emigrant's remittances (PORDATA, 2020). If the variable follows the behavior of the previous crisis, a decline might be expected and, as it helps to mitigate low wage levels and social protection mechanisms with low coverage, households with low levels of income could suffer several risks associated with poverty (Mera, 2020b).

Government expenditure is the only GDP component expected to increase during the health crisis (Campos and Lins, 2020). Portuguese debt and deficit were a relevant topic in the 2008 crisis, but both registered a good recovery path. In 2019, for the first time on the last decade, public administrations reported a positive budget balance (0.2% of the GDP). At the end of 2019, public debt to GDP ratio was 117.7% (minus 4.3 percentage points than in 2018) (Banco de Portugal, 2020).

The answer to the brutal exogenous shock associated with the pandemic was the imposition of the emergency state and an overall lockdown, whose measures represent, by themselves, a simulaneouly shock on supply and demand never seen before, whose complexity is still hard to predict (Costa e Silva, 2020).

2.3. Economic Growth

"In fact, aggregate growth is the single most important factor affecting individual levels of income. Hence, understanding the determinants of aggregate economic growth is the key to understanding how to increase the standards of living of individuals in the world and, thereby, to lessen poverty." (Barro & Sala-i-Marin, 2004, p.6)

The determinants of economic growth have always been an issue to economists. The basis for modern growth theories goes way back to mercantilists, that viewed the accumulation of wealth as the main source of economic growth (Sharipov, 2015).

According to Barro and Sala-i-Marin (2004), the main assumptions on which growth theory still lays today were constructed by classical economists such as Adam Smith and David Ricardo: competitive behavior, equilibrium dynamics, the role of diminishing returns and its relation to capital accumulation, the interplay between per capita income and the population growth, the effects of technological progress on specialization (similar to Ricardo's theory) and the discovery of new goods and forms of production and the role of monopoly power on technological progress.

The Solow-Swan model implemented the basis where the neoclassic theory of growth still lays (Aguiar et al., 2016). Solow and Swan treat technological progress as a given and investigate the effects of the division of output between consumption and investment on capital accumulation and growth (Romer, 2011). This neoclassical model relies on constant returns to scale, diminishing returns to each input and some positive and smooth elasticity of substitution between them (Barro and Sala-i-Marin, 2004).

The model also assumes conditional convergence, implying that, the further away a country is from its steady state position, the faster its growth rate is –

deriving from the assumption of diminishing returns to capital and explaining the growth rate differences between developed and developing countries. The conditional part derives from the fact that the steady state levels of capital per worker and output per worker depend on the savings rate, population growth rate and the position of the country's production function – characteristics that might vary across countries (Barro and Sala-i-Marin, 2004).

Relying on the work left by Solow, many authors contributed to the literature about what determines economic growth. Barro and Lee (1994) argue that the basic empirical framework relates real per capita growth rate to two kinds of state variables: the stock of physical and human capital (very much like in Swan and Solow (1956) and in Mankiw et al. (1992)) and control or environmental variables such as terms of trade, institutions and tariff rates.

Kahwaja et al. (2018) extend the Solow growth model by incorporating fiscal policy and institutions using Total Factor Productivity (TFP). The authors support that fiscal policy does, indeed, lead to growth but only in developed economies that have a solid set of institutions.

Chungtai et al. (2015), on the opposite paradigm, argue that countries do not grow because of high inflation, rising foreign debt, exchange rate volatility, trade imbalances, budget deficits, energy and water shortages and political instability. To continuously increase the rate of economic growth, a country must assure a low inflation rate as one of the main objectives for policy makers.

Although the Solow model was a success by providing organized information on the sources of economic growth, much was left to explain (Renelt, 1997): paradoxically, the main limitation of the model is the fact of "explaining everything but long run growth" (Barro & Sala-i-Martin, 2004, p.18), as it depends on exogenous factors (rate of technological progress and population growth rate) whose explanation is outside the model.

Mankiw et al. (1992) augmented the Solow model to include the accumulation of human capital, improving the predictions of the basic model. Estimating a cross sectional regression model, using countries' average data for the period 1960-1985 on real income, government and private consumption, investment and population growth, the authors proved that, let alone, the Solow model was already able to predict long run growth. The coefficients of savings and population growth had the signs predicted by Solow, although the estimated impacts of savings and labor force growth were much larger than the model predicted. Introducing human capital reduces the magnitude of the coefficient on physical capital investment and improves the fit of the regression (Mankiw, Romer, and Weil, 1992).

In these models, per capita growth ceases when there is no technological progress, coming from the assumption of diminishing returns to capital. However, this was proven as a non-realistic assumption and, empirically, it is observed that per capita growth rates can remain positive for more than a century without a clear tendency to decline (Barro & Sala-i-Martin, 2004). Yeager (1998) argues that rich countries can have higher R&D expenditure and, therefore, enjoy positive returns and spillover effects from that investment in technology.

In the 1990s, R&D theories were incorporated into growth models with imperfect competition through the work of Romer (1987, 1990), Aghion and Howit (1992), and Grossman and Helpman (1991). Technological progress is brought by technological activity and, as long as the economy does not run out of new ideas, the growth rate would be perpetual positive (Barro & Sala-i-Martin, 2004). In these analyses, the long run growth rate is determined within the model – endogenous growth models surged. To Romer (1986), Lucas (1988) and Rebelo (1991), growth can just keep on going since "returns to investment in a broad class of capital goods do not dimmish as economies develop" (Barro & Sala-i-Martin, 2004).

To understand what affects growth, it would be important to understand the determinants of savings, population growth, and worldwide technological change (treated as exogenous in the Solow model) and, for that, the appropriate model would treat those variables as endogenous, even though this would imply an increase in its complexity. Nevertheless, it should be noted that "the Solow model gives the right answers to the questions it is designed to address" (Mankiw et al., 1992, p.409).

Ramsey's model has an advantage towards the Solow-Swan model and its limitations when it comes to exogeneity. By having and endogenous savings rate that results from consumer optimization, the analysis allows the discussion of economic incentives and, in particular, the effects of changes in interest rates, tax rates or any other variables (Barro & Sala-i-Martin, 2004).

Cass (1965) and Koopmans (1963) brought back Ramsey's model, providing for a decentralized environment where households supply labor, hold capital and consume optimally, given prices and wages, while firms rent capital, hire labor to maximize profits, given prices and wages; and markets clear. Their extension to the Ramsey's model allowed for richer transitional dynamics.

It should be noted, however, that endogeneity of the savings rate does not solve the problem associated with the exogeneity of technological progress (Barro & Sala-i-Martin, 2004). The issue associated with incorporating technological change in this kind of models is mainly related to the economical classification of ideas (treated as non-rival goods and similar to public ones). This would lead the competitive assumptions to fall.

Romer (1986) argued that the competitive framework could be maintained to determine an equilibrium rate of technological progress but the resulting output growth rate would not be Pareto optimal.

After Cass (1965) and Koopmans (1963), the field of growth economics became more technical and focused on short term fluctuations, with development economics and growth economics drifting apart as study fields (Barro & Sala-i-Martin, 2004). A new boom emerged in the 1980s with the work of Romer (1986) and Lucas (1988), with the remembrance that the determinants of long run economic growth are crucial issues.

The last developments on growth models try to endogenize population growth, by incorporating fertility choices into the neoclassical models and also by endogenizing labor supply through migration and the integration of the choice labor vs leisure (Romer, 2011).

The main conclusion to keep in mind regarding economic growth is that "there does not seem to be a single receipt with one variable that is able to explain economic growth (…) moreover, a consistent part of economic growth comes from a residual which is not explained by traditional variables such as capital and labor" (Tridico, 2008, p.7).

2.4. Structural Breaks

"Structural change is pervasive in economic time series relationships, and it can be quite perilous to ignore. Inferences about economic relationships can go astray, forecasts can be inaccurate, and policy recommendations can be misleading or worse." (Hansen, 2001, p.127)

Until recently, business cycles were commonly thought of as departures from the trend. Therefore, when collecting time series macroeconomic data, variables were "usually decomposed into a trend component and a cyclical component. The trend was believed to be deterministic, often linear, while departures were assumed to be stationary, therefore transitory." (Banerjee and Urga, 2005, p.3).

Nelson and Plosser (1982) used US historical time series data to analyze whether these series are, indeed, stationary processes with a tendency to return to their trend line or not. Typically – and following the Real Business Cycles

Theory - it was broadly accepted that macroeconomic cyclical fluctuations tended to dissipate over time, being the permanent effects attributed to the secular component of the cycle. The authors rejected this theory, finding that economic time series do not contain deterministic time trends, but stochastic ones. One of the main implications of this conclusion has to do with models that focus on monetary disturbances as a source of temporary disturbances, which will fail when attempting to explain a large fraction of output variation. Moreover, the stochastic variation caused by real factors should be treated as an essential element of any model with the purpose of explaining macroeconomic fluctuations.

Raport and Reichlin (1989) and Perron (1989) argued that the majority of the shocks on key economic variables would be transitory and only very few events would be capable of causing permanent effects on the economic structure. The latter would, therefore, cause a break in the underlying deterministic trend. These authors were criticized by Zivot and Andrews (1992), who argued that the specification and choice of the specific breaking point that Perron (1989) chose was influenced by a prior examination of the data and, therefore, biased.

By specifying a regression model, it is assumed that its assumptions apply to all observations in the sample (Greene, 2003). If, at a given moment in time, something causes a change in the data, there will be different regression coefficients in different subsets of the data.

Time series data can often contain a structural break due to changes in policy or an exogenous economic shock (Yi & Li, 2012). With the dynamics associated to the real world, a previously estimated model is disrupted by the emergence of new data (Chu et al., 1996). A question appears – is the old model still able to explain the established relationship?

Tests for structural breaks can be divided into three categories (Eksi, 2009):

i) Whether the series has a break in a specific tested breakpoint;

ii) To look for the presence of a break;

iii) To estimate the unknown date of break and then, test it.

To test if the series has a break in a specific *a priori* determined breakpoint, the most used method is the Chow test, that will be described in the next subsection.

There can also be more than one break in the data. Therefore, estimators to look for the presence of breaks can be subdivided into two groups:

i) Single break estimators, where consistency is satisfied even if there are multiple breaks (Bai & Perron, 1998), by finding one breakdate and then splitting again the data to search for more;

ii) Multiple break estimators, which present more precise estimates, with smaller confidence intervals around the breaks and, therefore, more efficient.

2.4.1. The Chow Test

The Chow test was created to "statistically determine if two sets of observations can be regarded as belonging to the same regression model" (Lee, 2008, p.47), being a single break estimator.

By using a linear regression to represent an economic relationship, there are two questions that can be asked (Chow, 1960):

i) Is the relationship stable for two different periods of time?

ii) Does the relationship hold for two different groups of economic individuals?

It can be more reasonable to suppose that "only parts of the relationship are equal for two different periods of time or groups" (Chow, 1960, p.591). A F test can help decide what is more efficient (and whether there was, indeed, a structural break or not) – either a single regression that applies to all observations, and uses dummies to separate the two subperiods, or two separate regressions, splitting the data into two subsamples.

The following steps are necessary to run a Chow test (Hansen, 2001):

i) The sample should be split into two subperiods, being the break date the division marker;

ii) Estimate the parameters for each period;

iii) Test the equality of the two subtests using a Chow F-statistic.

Most of the times, the breakdate is based on exogenous occurrences – crisis, recessions, events that are expected to shake the world's economy (Muthuramu & Uma Maheswari, 2019). This is, however, a limitation of the Chow test: the break date must be known *a priori* (Hansen, 2001).

There are two ways for picking an alternative break date, assuming it is unknown:

i) Pick an arbitrary candidate, in which case the test may be uninformative and the real break date can be dismissed;

ii) Pick a break date based on some known feature of the data, in which case the test may be misleading, as the candidate break date is endogenous and, therefore, correlated with the data, causing the test to inform a break where there is not one.

Hansen (2001) uses the US labor productivity in the manufacturing/durables sector to illustrate this issue. Two different (but close – 1973 and 1975) years are tested under a chi-square distribution. Only 1975 is accepted as structural break, but given the similarity of the two dates, the author questions "how can we be confident?" using it.

Quandt (1960) suggests one solution to this problem – to treat the breakdate as unknown and take the largest Chow statistic over all possible breakdates, plotting the sequence of Chow statistics as a function of candidate breakdates.

Another issue concerning structural breaks relates to the possibility of having more than one breakdate. Bai and Perron (1998) designed tests to allow for multiple structural breaks, using a sequential method to test each subsample to find evidence of a break.

Chow (1960) also suggests a way (Chow's Predictive Failure Test) to test when one of the samples does not have enough observations to perform this correspondent regression model. As Gujarati and Porter (2009) explain, this modified version of the Chow test is performed comparing the Residual Sum of Squares (RSS) of the regression with all the observations and the RSS of the regression with the subset of observations. Essentially, estimation errors are tested in order to understand if, on average, they are null – their significance is tested (Valle & Rebelo, 2002).

There is some literature using the Chow test and its variants to study structural changes in the economy. Greene (2003) uses the oil shock of 1973 to illustrate the usage of this kind of test. If before the shock the market was predictable and functioned in a "unremarkable fashion", after that there were shortages, an increase on prices and turmoil, changing the relationship observed before.

Hansen (2001) used data on US labor productivity from February 1947 to April 2001, employing a simple first-order autoregressive dynamic model. The author focuses on three main aspects of the Chow test: firstly, on the unknown timing of the structural break. Secondly, an estimation of the timing of structural breaks; and finally, the distinction between random walk and broken time trend. Substantial evidence of structural break between 1992 and 1996 and weaker evidence of the structural break in the 1960s and early 1980s was found.

Yi and Li (2012) apply the test to housing prices in New Zealand, concluding that there was, indeed, a breaking point in the first quarter of 2008. Before that date, GDP, unemployment rate and exchange rate are positively related to Housing Price Index, while the supply of housing has a negative impact; after the breaking date the relationship is inverted.

In an attempt to understand the farmer participation in markets in Kenya, Otieno and Omiti (2009) divided the farmers into two groups – rural and peri-urban farmers. The main advantage of the Chow test, as the authors suggest, is "that it has enabled the disaggregated analysis to capture the effects of three important factors (non-farm income, household size and education) which would otherwise been ignored if only a pooled sample model were used." (Otieno & Omiti, 2009, p.12).

Singh and Singh (2017) studied the impact of the 2008 Global Financial Crisis on the volatility of the Chinese crude spot market, collecting data from 2005 to 2014. Their main conclusion was the inexistence of effects of the referred crisis on that specific market.

Babikir et al. (2012) empirically observed the relevance of structural breaks in forecasting stock return volatility. Consistent with the literature, the authors verified that structural breaks are, indeed, a relevant factor for stock return volatility and that should be included in those forecasts for greater accuracy.

As pointed out by Ruslan (2020), details on economic growth are constantly changing and it is not empirically possible to explore all its variations. The author conducts an empirical study with Malaysian data from 2010 to 2020 to find structural breaks in consumer prices from 2004 to 2014, when the country experienced several incidents and policy shifts. The structural breaks found occurred, mainly, in 2008, as a result of the increase in oil prices from the financial crisis, which indirectly increased food and other commodities prices.

Although widely accepted as one of the main contributors for structural break testing, the Chow test has the (main) disadvantage of not allowing to identify in which regression variable the break occurred. Gujarati (2016) suggests a dummy variable procedure to deal with that limitation and to simplify the Chow test: a dummy variable that takes the value 1 if the observation is post break date and 0 otherwise is created and enters the regression in additive and multiplicative form. The additive form controls for breaks in the regression intercept while the multiplicative from controls for breaks in slope. If one of them (or both) is statistically significant, there is a break. This method also allows to quantify the changes between observation groups: the additive dummy – differential intercept – and the multiplicative dummy – differential slope coefficient (Gujarati & Porter, 2009).

The dummy variable method has its advantages relative to the traditional Chow test (Gujarati, 2016):

i) If the linear regressions are, in fact, different, the dummy method points right away where the difference is;

ii) This method can be used as an alternative to variance and covariance analysis (Chow test is basically an analysis of covariance, the author argues);

iii) It simplifies the procedure, by having just one regression that shows both if there was a break and where the break occurred, instead of being a "multistage procedure".

Finally, the dummy variable approach is problematic when one of the subsamples has very few observations (Gujarati & Porter, 2009). In this case, the Chow test for predictive failure complemented with t-student tests for the differences between coefficients is a better approach.

Chapter 3
Empirical Model

This chapter describes the econometric model used to investigate whether the COVID-19 pandemic caused a structural break in the Portuguese economy and the data sample used as well as the choice of the subsamples.

To test for structural breaks, a Chow test for predictive failure will be used (see Chow, 1960; Gujarati and Porter, 2009). The test will be complemented with t-student tests, which help to locate the structural breaks in terms of regression coefficients.[2]

3.1. Econometric Specification

A production function is "often used to measure a country's productive potential", as it takes into account "different sources of an economy's productive capacity, namely the contributions of labor, capital and total factor productivity, the later containing information about technological and allocative efficiency" (Hájková and Hurník, 2007, p.495). By using a production function, changes in the functioning of the supply can be addressed. Therefore, a Cobb-Douglas production function will be used to test for structural breaks in the Portuguese economy.

Chow and Li (2002) present the following Cobb-Douglas production function:

[2] Although the methodology proposed by Bai and Perron (1998) allows the examination of multiple structural breaks, that would not be the better fit for the aim of this work: more than knowing if there was a break induced by the pandemic, it is also interesting to know where (in terms of regression coefficients) the break occurred. This later test would not be possible with the multiple break methodology, since it does not allow to isolate the effects of the three quarters of 2020 from the ones coming from the 2008 Global Financial Crisis.

$$\frac{Y}{L} = A\left(\frac{K}{L}\right)^{\alpha_3} \quad (1)$$

Where $\frac{Y}{L}$ denotes output per worker, 'A' denotes the rate of technological progress and $\frac{K}{L}$ the stock of physical capital per worker.

For regression purposes, the production function in (1) can be linearized trough a logarithm transformation:

$$\ln\left(\frac{Y}{L}\right)_t = lnA_t + \alpha_3 \ln\left(\frac{K}{L}\right)_t \quad (2)$$

Any production function contains information about technology and efficiency (Hájková & Hurník, 2007). This is the case of the production function considered in (1) and (2). It is related to the supply side of the economy. However, with quarterly data, the short run is clearly present, and its effects should be considered, namely by controlling variables from the demand side of the economy. Henceforth, the control variables are "a few of the most closely followed macroeconomic variables" (Knoop, 2015, p.26) and were inserted to accommodate those demand side fluctuations.

Human Capital is also introduced as a control variable and not as a variable entering the production function. The latter was proposed by Mankiw et al. (1992) but the attempt to estimate that long run relationship, with this specific time series quarterly data, did not report the results predicted by the authors in terms of coefficient magnitudes and signs.

Finally, a quadratic time trend was considered to accommodate the possibility of technological change and also to work as a control.

The estimated regression is as follows:

$$\ln\left(\frac{Y}{L}\right)_t = \alpha_0 + \alpha_1 t + \alpha_2 t^2 + \alpha_3 \ln\left(\frac{K}{L}\right)_t + \alpha_4 s_{H_t} +$$
$$+\alpha_5 C_t + \alpha_6 G_t + \alpha_7 I_t + \alpha_8 NX_t + \alpha_9 U_t + \alpha_{10} LR_t + \alpha_{11} SR_t + \alpha_{12} Inf_t + \varepsilon_t \quad (3)$$

Where, for each quarter t, variables are defined as follows in Table 1:

Table 1 - Variable Definition

Variable	Definition
Y/L	Output per worker
K/L	Physical capital per worker
s_H	Human capital
C	Private Consumption
G	Government Expenditure
I	Investment
NX	Net exports
U	Unemployment Rate
Inf	Inflation rate
SR	Short term interest rate
LR	Long term interest rate

Being output per worker the explained variable and the physical stock of capital per worker the explanatory variables. All other independent variables, including the time trend, are control variables. ε_t is the regression error term

For estimation purposes, the regression equation in (3) is transformed in seasonal differences as follows:

$$\Delta \ln \frac{Y}{L} = (4\alpha_1 + 16\alpha_2) + (8\alpha_2)t + \alpha_3 \Delta \ln \left(\frac{K}{L}\right) + \alpha_4 \Delta s_H + \alpha_5 \Delta C + \alpha_6 \Delta G + \alpha_7 \Delta I + \alpha_8 \Delta NX + $$
$$+ \alpha_9 \Delta U + \alpha_{10} \Delta LR + \alpha_{11} \Delta SR + \alpha_{12} \Delta Inf \; + \; u_t \qquad (4)$$

Where, for instance, $\Delta \ln \left(\frac{Y}{L}\right)$ denotes $y_t - y_{t-4}$, referring to the variable variation in relation to the homologous quarter.

Regression (4) gives rise to more realistic coefficients when t is included. A linear time trend in (4) corresponds to a quadratic time trend in (3).

Seasonal differences are used for two reasons. First, time series macroeconomic data usually has a unit root, and differencing it is a way to remove any linear time trend and, therefore, to stationarize the series, guarantying that the statistical properties are constant over time and the estimates are efficient (Wooldridge, 2016). Second, with quarterly data, the effects of seasonality are captured in between quarters and "the proper interpretation of a seasonal unit root in a macroeconomic time series is then, that the seasonal pattern is changing rather than constant. Consequently, a satisfactory econometric model must be able to account for this variation in order for the model to be congruent with the available information" (Hylleberg et al., 1993, p.323). Quarterly macroeconomic variables for the Portuguese economy are, also, often presented as seasonally adjusted to take this into account (see Banco de Portugal, 2020).

For matters of stationarity, Augmented-Dickey Fuller tests were performed to the seasonal differences series with 2-time lags. The null hypothesis (the series having a unit root) was rejected at 5% significance level.

The selected breakpoint to test for structural break due to COVID 19 is the first quarter of 2020. Lockdown in Portugal was imposed on the third week of March 2020, although individuals were already voluntarily confining and avoiding social contact and related activities since, at least, one week before. Global value chains were also disrupted previously (on the beginning of the year) (Campos and Lins, 2020).

3.2. Sample

3.2.1. Sample Description

The sample contains time series quarterly data for the Portuguese economy between 1998 and the third quarter of 2020. This time period was considered, most of all, for a matter of data availability, but also to avoid interferences from the 20th century IMF interventions in Portugal (1977 and 1983), the effects of the country joining the European Union (1986), and the effects of the convergency criteria implemented before the country adopted the Euro in 1999. Even though the IMF was, again, present in Portugal in 2011, through the Troika, excluding observations of the period 1998-2014 could pose a problem. No evidence of structural break tests related to the 2008 Global Financial Crisis were found in the literature. Nonetheless, to avoid interferences in the 2020 structural break test, the 2008 Global Financial Crisis will also be tested for structural breaks.

Raw data sources and units are reported in Table 2:

Table 2 - Data Sources and Units

	Source	Units
Gross Domestic Product at constant prices (basis 2016)	INE	Millions of euros
Labor Force	Eurostat	Individuals
Gross Fixed Capital Formation	FRED St. Louis Fed	Millions of Euros
Capital Stock at constant prices (basis 2016)	FRED St. Louis Fed	Euros
Resident population enrolled in secondary schooling	PORDATA	Percentage

Government Expenditure	FRED St. Louis Fed	Millions of euros
Private Consumption	FRED St. Louis Fed	Millions of euros
Inflation Rate	OECD Stat	Percentage
Imports	PORDATA	Euros
Exports	PORDATA	Euros
Long term interest rate	OECD Stat	Percentage
Short term interest rate	ECB	Percentage
Unemployment Rate	OECD Stat	Percentage

Table 3 describes how raw data was used to create the variables included in the regression:

Table 3 - Variable Description

Variable	Definition	Computed as:
Y/L	Output per worker	The ratio between GDP and labor force for each quarter
K/L	Physical capital per worker	The ratio between physical capital and labor force. Physical capital is the sum of the net fixed capital formation to the capital stock, for each quarter, since capital stock was an annual series, available only until 2017 (see Chow and Li, 2002)

s_H	Human capital	The product between the percentage of resident population enrolled in secondary schooling by the resident population and then dividing it by the active population, therefore obtaining the share of active population enrolled in secondary schooling. "Percentage of active population enrolled in secondary schooling", also available, was not used because of a break in the series. This methodology and proxy for human capital accumulation follows the suggested by Mankiw et al. (1992).
C	Private consumption	Not Applicable
G	Government expenditure	Not Applicable
I	Investment	Gross fixed capital formation
NX	Net exports	The difference between Exports and Imports
U	Unemployment rate	Not Applicable
Inf	Inflation rate	Not Applicable
SR	Short term interest rate	Not Applicable
LR	Long term interest rate	Not Applicable

Table 4 provides total sample (1998-2020) summary statistics for the regression variables:

Table 4 - Total Sample Summary Statistics for the Regression Variables

	Observations	Mean	St.Dev.	Min	Max
Y/L	91	8629.351	375.724	7855.967	9638.934
K/L	91	93164.770	32651.860	34216.000	146418.400
s_H	91	32.505	6.247	3.189	40.541
C	91	2.690	449.000	1700.000	34500.000
G	91	7900.000	1200.000	4800.000	9630.000
I	91	8530.000	1150.000	6150.000	10400.000
NX	91	-2030.000	2320.000	-16.800	8.600
U	91	9.040	3.742	3.953	17.801
LR	91	4.489	2.398	0.270	13.223
SR	91	1.773	1.787	-0.470	5.020
Inf	91	1.870	1.455	-1.513	4.793

Between 1998 and the third quarter of 2020, for the average quarter, output per worker was of 8629.351 million euros for the Portuguese economy. Physical capital per worker was 93164.770 million euros, human capital was predicted in about 33 individuals per thousand of individuals belonging to the labor force, private consumption 2.690 million euros, government expenditure 7900 million euros, Investment 8530 million euros, net exports presented a deficit of 2030 million euros, unemployment was at about 9%, the Long-term Interest Rate at 4.489%, the Short-term one at 1.773% and the Inflation rate was 1.870%.

3.1.2. Considered Subsample

Quarterly data for the Portuguese economy and the considered variables were available for the period 1998-2020. However, to test for a structural break in the beginning of 2020, it should first be verified if there were no other structural breaks in this time period that might bias the results (Greene, 2003).

The 2008 Global Financial Crisis was an obvious candidate. It is consensual that Portugal went through a severe crisis, the biggest since its adherence to the EU, and that there was no particular solidarity from the "richer" EU countries with the situations of the "GIPSI" (Andrade & Duarte, 2011). The recovery package designed was agreed upon in May 2011 and included a total bailout out of 78 billion euro for the Portuguese economy.

Caldas (2013) divides the impact felt in European countries in three different phases with different problems:

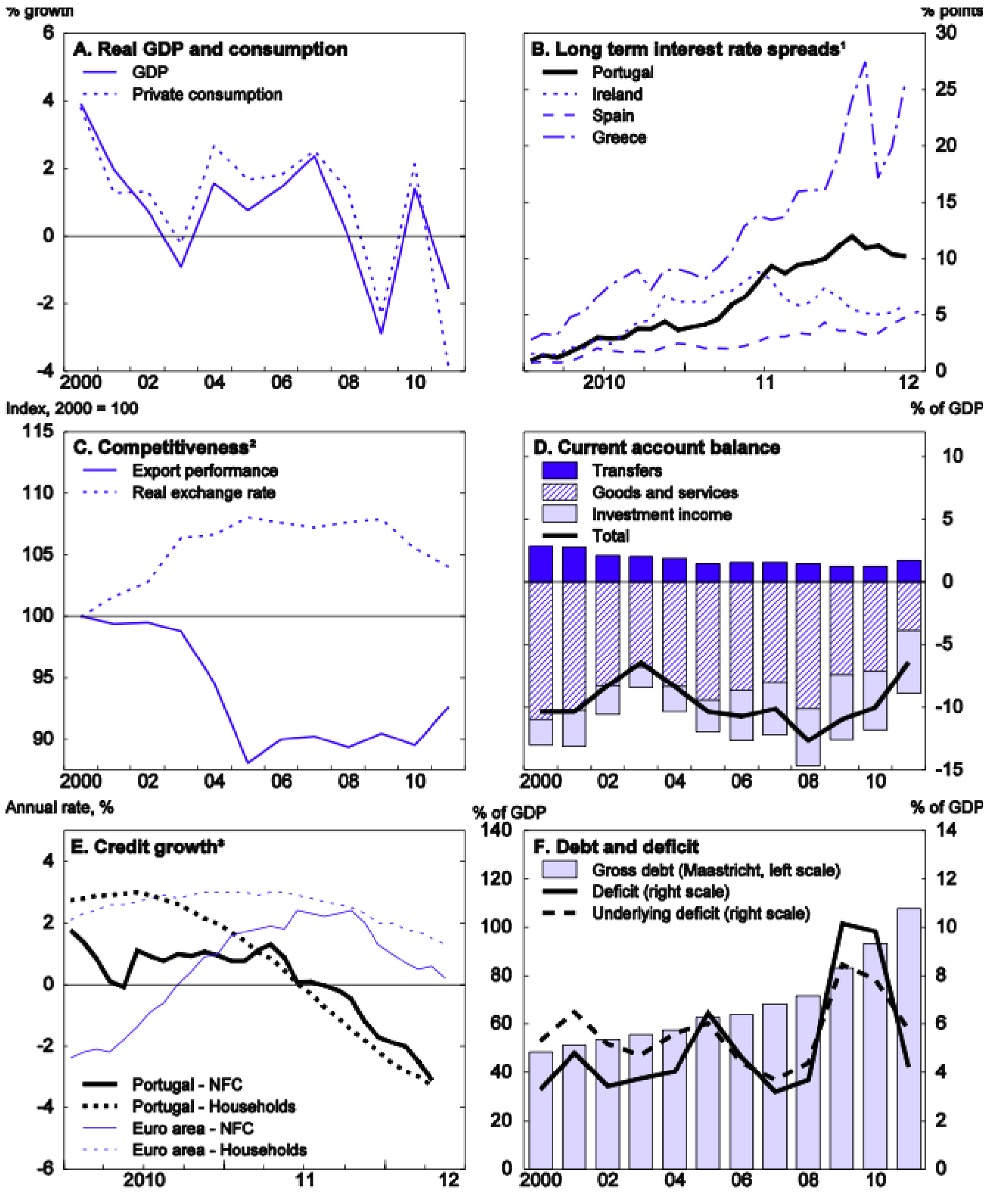
i. Financial phase, right after the collapse of the American banking system in 2008, when the main objective was to stabilize the financial system;

ii. Economic phase, from the end of 2008 to mid 2010, when there was already the perception of a future recession and the main goal was to minimize the economic impacts through expansionist policies;

iii. Budgetary phase, after 2010 to "the present" (2013), where the focus shifted completely from expansionism to austerity, with a specific target on budgetary consolidation across the union.

There are some factors contributing for a suspicion of a structural break occurring in the Portuguese economy in the aftermath of the Global Financial Crisis, supported by changes in some key indicators presented in Figure 1.

Figure 1 - Key Economic Variables



1. Ten-year government bond spreads relative to the German rate.
2. Export performance is the ratio between export volumes and export markets for total goods and services. The real exchange rate is a harmonised competitiveness indicator based on unit labour cost indices for the total economy.
3. Loans adjusted for sales and securitisation. NFC: non-financial corporations. Households includes non-profit institutions serving households.

Source: OECD 2014 Economic Survey for Portugal

Real GDP and private consumption growth followed the same pattern, falling sharply in 2008 and 2010. Real GDP growth went from 2% in 2007 to less than -3% in 2009 and private consumption growth deteriorated even more in 2010, to less than -4%. Long term interest rate spreads of the "GIPSI" were a recurrent topic. The Portuguese spread was about 12% in the last quarter of 2011, the second highest within the EU behind Greece, at the time. The competitiveness of Portuguese exports was a fact during the crisis, with a growth tendency, although with the presence of a trade imbalance. Current account balance deteriorated between 2008 and 2010, with a slow recovery after.

Credit growth followed the reduction tendency felt in the Euro Area, although more pronounced: Portuguese households credit growth was negative from 2011 onwards, reaching approximately -12% in the fourth quarter of 2011.

Public debt followed the recessive path, reaching the barrier of 100% of the GDP in 2010. In the opposite direction, current account deficit felt in 2010 to -6.4% of the GDP "due to weak domestic demand and strong export performance" (OECD, 2012, p.8).

Even though the scenario was pessimistic, all indicators pointed to a slow recovery from 2012 onwards, which might indicate a structural break. Therefore, to rule out interferences from this recessive period, structural break tests were performed for all the quarters of 2009, the three last quarters of 2011 and the two first quarters of 2012. The null hypothesis is that no structural break occurred and, therefore, the pooled regression is correct and there is no relevant fit improvement by dividing the sample.

The results suggested a structural break occurred in the third quarter of 2012. To rule out any biases induced by that break, only observations after the third quarter of 2012 until the third quarter of 2020 will be considered in the next sections. The location of the Portuguese economy 2008 Global Financial Crisis break goes beyond the scope of this research.

With a smaller sample (38 observations instead of 91), the descriptive statistics are as follows (Table 5):

Table 5 - Summary Statistics for the Considered Subsample for the Regression Variables

	Observations	Mean	St.Dev.	Min	Max
Y/L	38	8838.286	454.627	8019.856	9638.934
K/L	38	125511.000	10766.080	106693.000	146418.400
s_H	38	31.779	8.631	3.189	37.592
C	38	30400.000	2210.000	27400.000	34500.000
G	38	83800.00	515.000	7690.000	9630.000
I	38	7760.000	1250.000	6150.000	9830.000
NX	38	-405.000	2820.000	-16.800	8.610
U	38	11.670	3.799	6.002	17.807
LR	38	4.278	3.611	0.270	13.223
SR	38	0.056	0.542	-0.470	1.560
Inf	38	0.976	1.190	-0.536	3.914

Between 2011 and the third quarter of 2020, for the average quarter, output per worker was of 8838.286 million euros for the Portuguese economy. Physical capital per worker was 125511 million euros, human capital was predicted in about 32 individuals per thousand individuals belonging to the labor force, private consumption 30.4million euros, government expenditure 83800 million euros, Investment 7760 million euros, net exports presented a deficit of 405 million euros, unemployment was at about 11%, the Long-term Interest Rate at 4.278%, the Short-term one at 0.056% and the Inflation rate was 0.976%.

3.3. Results and Discussion

OLS estimators were used in (4). For the period between the fourth quarter of 2012 and the fourth quarter of 2019 the regression estimates are as follows (Table 6):

Table 6 - Regression Results, Q1 2011 - Q4 2019

	Coefficient	St. Deviation
ln(K/L)	0.561086***	0.144662
s_H	0.003022 **	0.001108
C	1.23×10^{-11}***	2.93×10^{-12}
G	6.74×10^{-12}*	3.49×10^{-12}
I	9.66×10^{-12}*	2.68×10^{-12}
NX	5.69×10^{-12}***	1.57×10^{-12}
U	-0.002712*	0.001384
LR	0.000706**	0.000342
SR	-0.000362	0.003656
Inf	-0.001090	0.000615
Constant	0.014623*	0.012064
t	-0.000440***	0.000118
RSS	0.00012659	
Adjusted R^2	0.9878000	

This regression is based on 35 observations. *** denote p-values<0.01, ** denote p-values <0.05 and * denote p-values<0.1.

The coefficient for the logarithm of the physical stock of capital per worker (from now on referred to as alpha, following the term used by Solow and Swan (1956)) for the sample period is, approximately, 56%. Ergo, on the considered period, the share of income dedicated to physical capital is 56%. This value is acceptable for the Portuguese economy and follows the findings of Easterly and Levine (2001) for the OECD countries.

When including the three quarters of 2020, the results change drastically, as follows (Table 7):

Table 7 - Regression Results, Q1 2011 - Q3 2020

	Coefficient	St. Deviation
ln(K/L)	0.035685	0.281609
s_H	0.007846	0.000894
C	$3.01x10^{-11}$***	$2.47x10^{-8}$
G	$-1.85x10^{-13}$	$1.96x10^{-12}$
I	$1.10x10^{-11}$	$4.80x10^{-12}$
NX	$-1.30x10^{-13}$	$5.26x10^{-12}$
U	0.003364*	$5.18x10^{-13}$
LR	0.000953	0.000759
SR	0.005327	0.004697
Inf	-0.003406**	0.001627
Constant	0.060009**	0.020586
T	-0.000897***	0.000220
RSS	0.001150	
Adjusted R^2	0.969700	

This regression is based on 38 observations. *** denote p-values<0.01, ** denote p-values <0.05 and * denote p-values<0.1.

Performing a preliminary comparison between both sets of results, it seems that the addition of the three 2020 observations did, indeed, cause a structural shift, meaning there was a structural break. The coefficient for alfa changed drastically (for a value that is not coherent nor supported by the literature), varying 0.5254010 percentage points and losing its statistical significance.

Affecting this coefficient, the productive potential of the economy, it is reasonable to infer that the economy did, indeed, suffer a structural break. Moreover, to support this statement and to control for plausible and natural variations in alfa due to the addition of observations, the regression was ran from the first quarter of 2011 to the last quarter of 2018 and the results did not differ much from those found when including 2019 (see Appendix I).

Most of the variables present a change in their coefficients and/or a loss of statistical significance: the H coefficient becomes larger and loses its significance, although its variation (presented below in table 7) is not relevant; C does not suffer any relevant change, although it might be suspicious, from an economic point of view, since the lockdown affects directly private consumption, as supported by the literature presented in Chapter 2; G becomes negative and loses significance; I becomes larger and the change in its significance is not relevant; NX becomes negative and loses its significance; U has a marginal change (that might be ambiguous) and loses significance; LR and SR do not present significant changes and neither does Inf. The time trend t coefficient remains statistically significant and does not present relevant changes, and finally the regression intercept gains significance. Table 8 presents the variations between regression coefficients, calculated by the simple difference between sets of coefficients, i.e., the coefficient variations caused by the break:

Table 8 - Coefficient Variation

	Variation
ln(K/L)	0.5254010
s_H	-0.0048233
C	-1.78×10^{-11}
G	8.59×10^{-12}
I	-1.34×10^{-12}
NX	5.82×10^{-12}
U	-0.0061715
LR	-0.0002079
SR	-0.0057032
Inf	0.0022722
Constant	-0.0462110
t	0.0004566

Besides the alfa variation referred above, all other coefficients had small variations (C, G, I and NX variations are practically 0).

Formally, the break would be tested through a procedure like the one suggested by Chow (1960). However, with only three additional observations for 2020, the regressions corresponding to the subsample after the break date cannot be ran. The alternative is the Chow test for predictive failure (Chow, 1960), which tests the equality between two sets of coefficients: i) coefficients from the regression until the last quarter of 2019 (see Table 5); and ii) coefficients from the regression that includes the three quarters of 2020 (see Table 6) (Gujarati and Porter, 2009).

To test which specific regression coefficients suffered the break, the dummy variable procedure suggested in the literature to locate where the break occurred (Valle & Rebelo, 2002; Gujarati & Porter, 2009; Gujarati, 2016) might not be the best option, since the post break dummy would only have 3 observations, leading to a loss of efficiency on the estimator. The alternative is to run t-tests on coefficient equality between the two regressions (Appendix II). The null hypothesis of equality between the corresponding coefficients of the two regressions is rejected for all the coefficients, implying that, only by adding the 3 observations from 2020 the means between regression coefficients become statistically different, suggesting a structural break in all coefficients. It is also interesting to highlight that most control variables were from the demand side, implying that it is, indeed, a simultaneous demand and supply shock.

The difference between a statistical structural break and an economic structural break should be noted. In statistic terms, the break implies that the computed F statistic exceeds the F critical value, therefore, that the linear regression suffered a sudden change over time in its coefficients – one gets a better fit if performing two separate regressions: before and after the break date. The consequence from this is that, if the break is not considered and the sample is not split, the estimates might be wrong. The statistical relationship (or only parts of it) are not equal for two periods or groups (Chow, 1960). The t-student tests conducted show this statistical structural break in all coefficients.

In economic terms, the implications are more serious. The long-term structure of the economy changes when a structural break happens, and while the "majority of the shocks to key economic variables of any economy would be transitory" (Raport and Reichlin, 1989, p.169), a structural break is one of the few events that would have permanent effects on supply.

The changes in the coefficients of the production function have serious implications in the way the supply side works, with permanent effects on the long-term potential output level and, thus, the potential growth and improvement in Portuguese living standards. Ceteris paribus, there will be a dramatic shift in the way the country economy operates, with a loss in the productive potential. The "new" structure would not fit in any historical structure known to the Portuguese economy. These results support the existence of negative permanent effects due to the COVID-19 pandemic and/or a loss of potential output.

Right after the lockdown, the Portuguese government designed a package of stimulus to compensate families and business for eventual unemployment situations and business closures. The effect of those measures is still being felt and the economy is still being supported in what might be considered an artificial way. This dramatic increase in public spending already projected public debt for its highest value ever – 130.9% of the GDP (Banco de Portugal, 2021) – and it is still unknown if this topic will be a resurging issue amongst the European Union, as it was in 2011.

There were (and will be) changes in macroeconomic variables, its trends and in the long run dynamics. In theoretical terms, all forecasting models should be adjusted to account for such changes in order to provide more accurate estimates (Agostino et al., 2010).

However, this is not only a pessimistic scenario: "crisis mask weaknesses in existing policies that were hidden by cyclical buoyancy" (OECD, 2009, p.19) and this crisis is an opportunity to initiate a structural reform in the Portuguese economy. Costa e Silva (2020) already proposed a plan focused on structural reforms for the upcoming times, while the economy is still readjusting to its post-lockdown paradigm (although a new lockdown was imposed in January 2021).

After the crisis, it is important to conduct a reform that increases the ability of the policy institutions and of the political framework to cushion the initial impact of economic shocks and to diminish the persistence of the ensuing negative output gap, strengthening the Portuguese economy and giving it tools to avoid structural breaks that imply permanent losses.

Chapter 4
Conclusion

The main objective of this dissertation was to determine whether the COVID-19 pandemic caused a structural break on the Portuguese economy.

To do so, a Cobb-Douglas production function was used to represent the productive structure of the economy. A time-series regression using quarterly data was ran, and the structural break test was formalized with the Chow test for predictive failure and a coefficient t-test to locate in which variables the break did occur. Besides physical capital, control variables related to the supply side (namely Human capital), the demand side and a time trend were used as controls. Demand side variables were used to capture the short run business cycle effects associated to the quarterly data.

On a first phase, the Chow test for predictive failure was applied to two OLS regressions: one containing observations from the first quarter of 2011 (after the break occurring due to the 2008 Global Financial Crisis) to the third quarter of 2020 and other containing only observations until the fourth quarter of 2019. The null hypothesis of no structural break occurring was rejected, therefore, it is possible to conclude that the COVID-19 pandemic caused a change in the structure of the Portuguese economy, with a break date in the first trimester of 2020.

Then, to locate in which variables the break occurred, a t-test was applied to each variable. The null hypothesis of equality between the coefficients of both regressions was rejected for all the coefficients. The structure of the economy changed (for instance, there was a structural break in alfa) and the demand side control variables also suffered a break.

Besides the statistical implications of a change in the dependent-independent variable relationship, the economic implications are more serious: the structural break implies a permanent loss of productive capacity and a decrease in the output gap.

With more data, the original Chow test could be ran with three regressions: i) the full sample; ii) with observations from the first quarter of 2011 to the last quarter of 2019; iii) with observations from the first quarter of 2020 to the last available data. Besides that, it would be possible to simplify the procedure, by applying a dummy variable procedure to test and locate for structural breaks simultaneous (as proposed by Gujarati (2016) and explained in Chapter 2) without losing estimation efficiency. The fact of only 3 observations from 2020 were available for all variables was the main limitation faced during the elaboration of this work. Other limitations were related to the choice of the model: the Solow model with human capital long run relationship, as proposed by Mankiw et al. (1992), did not behaved as predicted by the authors with the obtained data sample).

Given that, in October 2020 and January 2021 new lockdowns were imposed (a partial lockdown in the fall and a complete one in the first days of 2021, respectively), it might be interesting to study the impacts of these new disruptions in the Portuguese economy, as well as the capability of the public policies to cushion the economic impacts.

It could also be interesting to determine where did the break associated with the 2008 Global Financial Crisis happened, now that it is known that the prior crisis led to a structural break in the Portuguese economy. One could also compare the losses of both 2010 and 2020 breaks and study the loss in the productive potential of each one, as well as to investigate the total loss in potential output and whether the reform policies undertaken were able to restore some of the economy's potential.

Bibliography

Agostino, A. D., Gambetti, L., & Giannone, D. (2010). *Macroeconomic Forecasting and Structural Change* (Issue 1167).

Alvarez, F., Argente, D., & Lippi, F. (2020). A Simple Planning Problem for COVID-19 Lockdown. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3569911

Andrade, J. S., & Duarte, A. (2011). The fundamentals of the Portuguese crisis. *Panoeconomicus*, *58*(2), 195–218. https://doi.org/10.2298/PAN1102195A

Apokin, A. Y., & Ipatova, I. (2017). Structural Breaks in Potential GDP of Three Major Economies: Just Impaired Credit or the "New Normal"? *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2803163

Atkeson, A. (2020). What Will Be the Economic Impact of COVID-19 in the US? Rough Estimates of Disease Scenarios. In *NBER Working Paper Series* (Issue 595, p. 25). NATIONAL BUREAU OF ECONOMIC RESEARCH. https://doi.org/10.3386/w26867

Babikir, A., Gupta, R., Mwabutwa, C., & Owusu-Sekyere, E. (2012). Structural breaks and GARCH models of stock return volatility: The case of South Africa. *Economic Modelling*, *29*(6), 2435–2443. https://doi.org/10.1016/j.econmod.2012.06.038

Bai, J., & Perron, P. (1998). Estimating and Testing Linear Models with Multiple Structural Changes. In *Econometrica* (Vol. 66, Issue 1, p. 47). https://doi.org/10.2307/2998540

Baker, S. R., Farrokhnia, R. A., Meyer, S., Pagel, M., & Yannelis, C. (2020). How Does Household Spending Respond to an Epidemic? Consumption During the 2020 COVID-19 Pandemic. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3565521

Banco de Portugal. (2020). A Economia Portuguesa em 2019. In *Boletim Económico*.

Banerjee, A., & Urga, G. (2005). Modelling structural breaks, long memory and stock market volatility: An overview. *Journal of Econometrics*, *129*(1–2), 1–34. https://doi.org/10.1016/j.jeconom.2004.09.001

Barro, R. J., & Sala-i-Marin, X. (2004). Economic Growth. In *MIT Press* (2nd ed.). https://doi.org/10.1057/9781137022974_1

Barro, R. J., Weng, J., & José, U. F. (2020). The Coronavirus and the Great Influenza Pandemic: Lessons from the "Spanish Flu" for the Coronavirus's Potential Effects on Mortality and Economic Activity. *CESifo Working Paper Series*, *No. 8166*(March), 25. http://www.nber.org/papers/w26866

Barua, S. (2020). Understanding Coronanomics: The Economic Implications of the Coronavirus (COVID-19) Pandemic. *SSRN Electronic Journal*, *April*. https://doi.org/10.2139/ssrn.3566477

Caldas, J. C. (2013). O impacto das medidas 'anti-crise' e a situação social e de emprego - Portugal. *Comité Económico e Social Europeu*, 1–12. https://www.eesc.europa.eu/sites/default/files/resources/docs/qe-31-12-351-pt-c.pdf

Campos, L. P., & Lins, T. (2020). Pandemia à Portuguesa: um relato sobre o Covid-19 em PortugalPandémie à portugaise: témoignage sur le Covid-19Pandemia à portuguesa: un informe sobre Covid-19 en PortugalPortuguese Pandemic: an account of Covid-19 in Portugal. *Espaço e Economia*, *17*. https://doi.org/10.4000/espacoeconomia.10369

Carlsson-Szlezak, Philip, Reeves, M., & Swartz, P. (2020). *Understanding the Economic Shock of Coronavirus*.

Carlsson-Szlezak, Philipp, Reeves, M., & Paul Wartz. (2020). *What Coronavirus Could Mean for the Global Economy*. https://hbr.org/2020/03/what-coronavirus-could-mean-for-the-global-economy

Cass, D. (1965). Optimum growth in an aggregative model of capital accumulation. *Review of Economic Studies*, *32*(3), 233–240. https://doi.org/10.2307/2295827

Chow, G. C. (1960). Tests of Equality Between Sets of Coefficients in Two Linear Regressions Author(s): Gregory C. Chow Source: *Econometrica*, *28*(3), 591–605.

Chow, G. C., & Li, K.-W. (2002). China ' s Economic Growth. *Economic Development and Cultural Change*, *51*(1), 247–256.

Chu, C.-S. J., Stinchcombe, M., & White, H. (1996). Monitoring Structural Change. *Econometrica*, *64*(5), 1045. https://doi.org/10.2307/2171955

Dahl, C. M., Hansen, C. W., & Jensen, P. S. (2020). The 1918 epidemic and a V-shaped recession: Evidence from municipal income data. In *Covid Economics: Vetted and Real-Time Papers* (Vol. 6).

David Jakinda Otieno, John Omiti, T. N. and E. M. (2009). Application of Chow test to improve analysis of farmer participation in markets in Kenya. In *27th Conference of the International Association of Agricultural Economists (IAAE)* (Issue August, pp. 16–22).

Easterly, W., & Levine, R. (2001). It's not factor accumulation: Stylized facts and growth models. *World Bank Economic Review*, *15*(2), 177–219. https://doi.org/10.2139/ssrn.269108

Eksi, O. (2009). *Structural Break Estimation : A Survey*. *October*, 1–9.

Fernandes, N. (2020). Economic Effects of Coronavirus Outbreak (COVID-19) on the World Economy. *SSRN Electronic Journal*, 0–29. https://doi.org/10.2139/ssrn.3557504

Fornaro, L., & Wolf, M. (2020). Covid-19 Coronavirus and Macroeconomic Policy. *CEPR Discussion Papers*.

Greene, W. H. (2003). *ECONOMETRIC ANALYSIS Senior Media Project Manager : Victoria Anderson Production Editor : Michael Reynolds*.

Guerrieri, V., Lorenzoni, G., Straub, L., & Werning, I. (2020). Macroeconomic

Implications of COVID-19: Can Negative Supply Shocks Cause Demand Shortages? *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3570096

Gujarati, D. (2016). *Use of Dummy Variables in Testing for Equality between Sets of Coefficients in Two Linear Regressions : A Note Author (s): Damodar Gujarati Source : The American Statistician , Vol . 24 , No . 1 (Feb ., 1970), pp . 50-52 Published by : Taylor & Franci*. *24*(1), 50–52.

Gujarati, D. N., & Porter, D. C. (2009). *Basic Econometrics, 5th Edition*.

Hájková, D., & Hurník, J. (2007). Cobb-Douglas production function: The case of a converging economy. *Finance a Uver - Czech Journal of Economics and Finance*, *57*(9–10), 465–476.

Hansen, B. (2001). *The New Econometrics of Structural Change: Dating Breaks in U.S. Labor Productivity*.

Hylleberg, S., Jørgensen, C., & Sørensen, N. K. (1993). Seasonality in macroeconomic time series. *Empirical Economics*, *18*(2), 321–335. https://doi.org/10.1007/BF01205406

IMF. (2020). WORLD ECONOMIC OUTLOOK INTERNATIONAL MONETARY FUND The Great Lockdown. In *World Economic Outlook* (Issue May). https://www.imf.org/en/Publications/WEO/Issues/2020/04/14/weo-april-2020

INE. (2021). *SÍNTESE INE @ COVID-19*.

Jackson, J., Weiss, M., Schwarzenberg, A., & Nelson, R. (2020). Global Economic Effects of COVID-19. *Congressional Research Service*, *20*, 78. https://crsreports.congress.gov

Jordà, Ò., Singh, S. R., & Taylor, A. M. (2020). Longer-Run Economic Consequences of Pandemics. *Federal Reserve Bank of San Francisco, Working Paper Series*, 01–16. https://doi.org/10.24148/wp2020-09

Knoop, T. A. (2015). *Business Cycle Economics: Understanding Recessions and Depressions From Boom to bust*. https://doi.org/10.1088/1751-8113/44/8/085201

Koopmans, T. C. (1963). On the concept of optimal economic growth. The econometric approach to development planning. In *Cowles Foundation Discussion Paper* (Vol. 163).

Lee, H. H. (2008). Using the Chow Test to Analyze Regression Discontinuities. *Tutorials in Quantitative Methods for Psychology*, *4*(2), 46–50. https://doi.org/10.20982/tqmp.04.2.p046

Maliszewska, M., Mattoo, A., & Mensbrgghe, D. (2020). The Potential Impact of COVID-19 on GDP and Trade A Preliminary Assessment. *Policy Research Working Paper*, *9211*(April), 1–24.

Mankiw Gregory, N., Romer, D., & Weil, D. N. (1992). A contribution to the empirics of economic growth. *Quarterly Journal of Economics*, *107*(2), 407–437. https://doi.org/10.2307/2118477

McKibbin, W., & Fernando, R. (2020). The Global Macroeconomic Impacts of COVID-19: Seven Scenarios. *Asian Economic Papers*, 1–55. https://doi.org/10.1162/asep_a_00796

Mera, M. (2020a). Social and economic impact of the COVID-19 and policy options in Argentina. *Undp Lac*, *4*, 1–27.

Mera, M. (2020b). Social and economic impact of the COVID-19 and policy options in Honduras. *Undp Lac*, *4*, 1–27.

Muthuramu, P., & Uma Maheswari, T. (2019). Tests for Structural Breaks in Time Series Analysis: A Review of Recent Development. *Shanlax International Journal of Economics*, *7*(4), 66–79. https://doi.org/10.34293/economics.v7i4.628

Nelson, C. R., & Plosser, C. R. (1982). Trends and random walks in macroeconmic time series. Some evidence and implications. *Journal of Monetary Economics*, *10*(2), 139–162. https://doi.org/10.1016/0304-3932(82)90012-5

OECD. (2009). Structural Reform at a Time. *Economic Policy Reforms*, 17–25.

OECD. (2012). OECD Economic Surveys Portugal. *Ocde*, *July*.

OECD. (2019). *OECD Economic Surveys - Portugal* (Issue February).

OECD. (2020). *OECD Economic Outlook, Interim Report March 2020*. OECD. https://doi.org/10.1787/7969896b-en

Perron, P. (1989). The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis. *Econometrica*, *57*(6), 1361. https://doi.org/10.2307/1913712

Quandt, R. E. (1960). Tests of the Hypothesis That a Linear Regression System Obeys Two Separate Regimes. *Journal of the American Statistical Association*, *55*(290), 324–330. https://doi.org/10.1080/01621459.1960.10482067

Raport, P., & Reichlin, L. (1989). Segmented Trends and Non-Stationary Time Series. *The Economic Journal*, *99*(395), 168–177.

Renelt, D. (1997). Economic Growth - A review of the theoretical and empirical literature. In *Country Economic Department*. https://doi.org/10.4324/9781315678535-ch3

Robert J. Barro José F. Ursúa. (2008). *Macroeconomic Crises Since 1870* (No. 13940). https://doi.org/10.1017/CBO9781107415324.004

Romer, D. (2011). *Advanced Macroeconomics*.

Sharipov, I. (2015). Contemporary economic growth models and theories: A literature review. *Ces*, *VII*(3), 759–773.

Singh, A., & Singh, N. P. (2017). *Crude oil market and global financial crisis - Structural break and market volatility analysis*. *13*(2), 203–216. https://doi.org/10.1504/IJEBR.2017.082274

Swan, T. W., & Solow, R. (1956). ECONOMIC GROWTH AND CAPITAL ACCUMULATION. *Economic Record*, *33*(64), 103–108. https://doi.org/10.1111/j.1475-4932.1957.tb01279.x

Valle, P. O. do, & Rebelo, E. (2002). Testes à estabilidade dos parâmetros de um modelo de regressão: uma aplicação especial dos regressores dummy. *Revista de Estatística*, *3*, 41–70.

Wooldridge, J. M. (2016). *Wooldridge J.M - Introductory econometrics. A modern approach*.

Yi, R., & Li, M. A. N. (2012). *Chow Test Analysis on Structural Change in New Zealand Housing Price During Global Subprime Financial Crisis*. 15–18.

Zivot, E., & Andrews, D. W. K. (1992). Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis. *Journal of Business and Economic Statistics*, *10*(3), 251–270. https://doi.org/10.1080/07350015.1992.10509904

Appendices

Appendix I – Q1 2011- Q4 2018Regression Results

Source	SS	df	MS
Model	.014154778	11	.001286798
Residual	.000114846	19	6.0445e-06
Total	.014269624	30	.000475654

Number of obs	=	31
F(11, 19)	=	212.89
Prob > F	=	0.0000
R-squared	=	0.9920
Adj R-squared	=	0.9873
Root MSE	=	.00246

lnYL_s4	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnKL_s4	.6038768	.1792523	3.37	0.003	.2286974	.9790562
t	-.0004454	.0001396	-3.19	0.005	-.0007375	-.0001533
HumanCapital_s4	2.18e-07	1.40e-07	1.56	0.135	-7.42e-08	5.11e-07
C_s4	1.12e-11	3.61e-12	3.11	0.006	3.67e-12	1.88e-11
G_s4	9.02e-12	4.55e-12	1.98	0.062	-5.03e-13	1.85e-11
I_s4	1.14e-11	3.31e-12	3.43	0.003	4.44e-12	1.83e-11
NX_s4	7.15e-12	2.15e-12	3.33	0.004	2.65e-12	1.16e-11
LInterestrate_s4	.0007596	.0003996	1.90	0.073	-.0000769	.001596
SInterestRate_s4	-.0029377	.005164	-0.57	0.576	-.0137461	.0078707
Unemployment_s4	-.0037511	.0019503	-1.92	0.070	-.0078332	.000331
Inflation_s4	-.0008045	.0007792	-1.03	0.315	-.0024355	.0008265
_cons	.01149	.0138575	0.83	0.417	-.017514	.0404941

Appendix II – Coefficient T-Tests

```
ttest lnKL_s4_1 == lnKL_s4, unpaired unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
lnKL_s~1 |      36    .0338603    .0014224    .0085344    .0309727     .036748
 lnKL_s4 |      39    .0344383    .0013906    .0086845    .0316231    .0372534
---------+--------------------------------------------------------------------
combined |      75    .0341609    .0009884    .0085594    .0321915    .0361302
---------+--------------------------------------------------------------------
    diff |           -.0005779    .0019892               -.0045427    .0033869
------------------------------------------------------------------------------
    diff = mean(lnKL_s4_1) - mean(lnKL_s4)                        t =  -0.2905
Ho: diff = 0                     Satterthwaite's degrees of freedom =  72.7046

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.3861         Pr(|T| > |t|) = 0.7722          Pr(T > t) = 0.6139

. ttest HK_1 == HumanCapital_s4, unpaired unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
    HK_1 |      36   -.2893013    .3418429    2.051058   -.9832794    .4046768
HumanC~4 |      39   -.4271945    .3426943    2.140125   -1.120943    .2665539
---------+--------------------------------------------------------------------
combined |      75   -.3610058    .2407348    2.084824   -.8406803    .1186688
---------+--------------------------------------------------------------------
    diff |            .1378932    .4840413                -.826824     1.10261
------------------------------------------------------------------------------
    diff = mean(HK_1) - mean(HumanCapital_s4)                     t =   0.2849
Ho: diff = 0                     Satterthwaite's degrees of freedom =  72.8912

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.6117         Pr(|T| > |t|) = 0.7765          Pr(T > t) = 0.3883

. ttest C_s4_1 == C_s4, unpaired unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  C_s4_1 |      36    4.96e+08    1.46e+08    8.76e+08    2.00e+08    7.93e+08
    C_s4 |      39    3.11e+08    1.91e+08    1.20e+09   -7.68e+07    6.98e+08
---------+--------------------------------------------------------------------
combined |      75    4.00e+08    1.21e+08    1.05e+09    1.58e+08    6.42e+08
---------+--------------------------------------------------------------------
    diff |            1.86e+08    2.41e+08               -2.94e+08    6.66e+08
------------------------------------------------------------------------------
    diff = mean(C_s4_1) - mean(C_s4)                              t =   0.7721
Ho: diff = 0                     Satterthwaite's degrees of freedom =  69.5417

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.7787         Pr(|T| > |t|) = 0.4427          Pr(T > t) = 0.2213
```

```
. ttest G_s4_1 == G_s4, unpaired unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  G_s4_1 |      36   -2.72e+07    7.57e+07    4.54e+08   -1.81e+08    1.26e+08
    G_s4 |      39    1.55e+07    7.38e+07    4.61e+08   -1.34e+08    1.65e+08
---------+--------------------------------------------------------------------
combined |      75    -4998867    5.26e+07    4.55e+08   -1.10e+08    9.97e+07
---------+--------------------------------------------------------------------
    diff |           -4.27e+07    1.06e+08               -2.53e+08    1.68e+08
------------------------------------------------------------------------------
    diff = mean(G_s4_1) - mean(G_s4)                              t =  -0.4041
Ho: diff = 0                     Satterthwaite's degrees of freedom =  72.6853

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.3436         Pr(|T| > |t|) = 0.6873          Pr(T > t) = 0.6564

. ttest I_s4_1 == I_s4, unpaired unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  I_s4_1 |      36    5.24e+07    1.45e+08    8.68e+08   -2.41e+08    3.46e+08
    I_s4 |      39    3.68e+07    1.35e+08    8.43e+08   -2.36e+08    3.10e+08
---------+--------------------------------------------------------------------
combined |      75    4.43e+07    9.81e+07    8.49e+08   -1.51e+08    2.40e+08
---------+--------------------------------------------------------------------
    diff |            1.56e+07    1.98e+08               -3.79e+08    4.10e+08
------------------------------------------------------------------------------
    diff = mean(I_s4_1) - mean(I_s4)                              t =   0.0789
Ho: diff = 0                     Satterthwaite's degrees of freedom =  72.1114

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.5313         Pr(|T| > |t|) = 0.9373          Pr(T > t) = 0.4687

. ttest NX_s4_1 == NX_s4, unpaired unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
 NX_s4_1 |      36    3.95e+08    1.44e+08    8.66e+08    1.02e+08    6.88e+08
   NX_s4 |      39   -1.22e+08    4.62e+08    2.89e+09   -1.06e+09    8.14e+08
---------+--------------------------------------------------------------------
combined |      75    1.26e+08    2.50e+08    2.17e+09   -3.73e+08    6.25e+08
---------+--------------------------------------------------------------------
    diff |            5.17e+08    4.84e+08               -4.58e+08    1.49e+09
------------------------------------------------------------------------------
    diff = mean(NX_s4_1) - mean(NX_s4)                            t =   1.0674
Ho: diff = 0                     Satterthwaite's degrees of freedom =  45.3002

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.8543         Pr(|T| > |t|) = 0.2914          Pr(T > t) = 0.1457
```

```
. ttest Unemployment_s4_1 == Unemployment_s4, unpaired unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
Unempl~1 |      36   -.5232884    .3317182    1.990309   -1.196712    .1501353
Unempl~4 |      39   -.4590734    .3116787    1.946433   -1.090034    .1718872
---------+--------------------------------------------------------------------
combined |      75   -.4898966    .2256884    1.954519   -.9395906   -.0402027
---------+--------------------------------------------------------------------
    diff |            -.064215    .4551709               -.9715328    .8431029
------------------------------------------------------------------------------
    diff = mean(Unemployment_s~1) - mean(Unemployment_s4)         t =  -0.1411
Ho: diff = 0                     Satterthwaite's degrees of freedom =  72.2275

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.4441         Pr(|T| > |t|) = 0.8882          Pr(T > t) = 0.5559

. ttest Inflation_s4_1 == Inflation_s4, unpaired unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
Inflat~1 |      36   -.1180995    .2285833      1.3715   -.5821483    .3459493
Inflat~4 |      39   -.1391366    .2115772    1.321299   -.5674523    .2891791
---------+--------------------------------------------------------------------
combined |      75   -.1290388    .1543281    1.336521   -.4365443    .1784667
---------+--------------------------------------------------------------------
    diff |            .0210371    .3114727               -.5998737    .6419478
------------------------------------------------------------------------------
    diff = mean(Inflation_s4_1) - mean(Inflation_s4)              t =   0.0675
Ho: diff = 0                     Satterthwaite's degrees of freedom =  71.9916

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.5268         Pr(|T| > |t|) = 0.9463          Pr(T > t) = 0.4732

. ttest LInterestrate_s4_1 == LInterestrate_s4_1 , unpaired unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
LInter~1 |      36   -.5154343    .4833827    2.900296   -1.496753    .4658847
LInter~1 |      36   -.5154343    .4833827    2.900296   -1.496753    .4658847
---------+--------------------------------------------------------------------
combined |      72   -.5154343    .3393876    2.879799   -1.192154    .1612853
---------+--------------------------------------------------------------------
    diff |                   0    .6836064                -1.36341     1.36341
------------------------------------------------------------------------------
    diff = mean(LInterestrate_~1) - mean(LInterestrate_~1)        t =   0.0000
Ho: diff = 0                     Satterthwaite's degrees of freedom =       70

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.5000         Pr(|T| > |t|) = 1.0000          Pr(T > t) = 0.5000
```

```
. ttest SInterestRate_s4_1 == SInterestRate_s4_1 , unpaired unequal

Two-sample t test with unequal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
SInter~1 |      36   -.1297222    .0686635    .4119812   -.2691166    .0096722
SInter~1 |      36   -.1297222    .0686635    .4119812   -.2691166    .0096722
---------+--------------------------------------------------------------------
combined |      72   -.1297222    .0482093    .4090696   -.2258489   -.0335956
---------+--------------------------------------------------------------------
    diff |                   0    .0971049               -.1936696    .1936696
------------------------------------------------------------------------------
    diff = mean(SInterestRate_~1) - mean(SInterestRate_~1)        t =   0.0000
Ho: diff = 0                     Satterthwaite's degrees of freedom =       70

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.5000         Pr(|T| > |t|) = 1.0000          Pr(T > t) = 0.5000
```