The state of Baumol's disease for the OECD countries

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Executive Summary

Industries such as health care and education have seen significant price growth for decades, despite economy-wide productivity growth. The service industry has grown substantially and income inequality in developed countries has been rising since the 1970s. Many suggestions have been offered to rationalise these price increases, mostly focusing on a single one of the aforementioned trends. One theory in particular provides an explanation for the whole set.

The Baumol effect was first introduced in 1965, when Baumol and Bowen (1965) published about their theory of unbalanced growth. This theory was based on the notion that industries can be divided into two sectors. One sector has consistently low productivity growth, the stagnant sector. The other sector has consistently high productivity growth, the progressive sector. The authors suggest that the difference in this capacity for growth is due to differences in the technological structure of the industries, rather than due to specific policy of these industries or something else. In this model if wages in both sectors rise at a similar rate, which is higher than the average growth rate in the stagnant sector. Costs and prices in stagnant industries will keep rising indefinitely. Additionally if the industry does not disappear due to the rising prices, the amount of labour employed in that industry will keep growing as well. Finally, the industries that did not disappear will also consume a growing share of the total nominal output of the economy.

This theory provoked multiple responses, with many economists responding to the initial publication. But due to a lack of comprehensive data and proper testing methodology, no consensus on the validity of the theory had been reached. To resolve this, Nordhaus (2008) published an empirical model based on Baumol's theory, which employed regression analyses and industry-level data to diagnose Baumol's disease. The method was based on the identification of six syndromes which should exhibit themselves in an economy with unbalanced productivity growth. These diseases state that for low productivity growth industries:

1. Price growth is expected to be higher than average.
2. Real output change is expected *not* to be higher than average.
3. Nominal output growth is expected *not* to be lower than average.
4. Labour input growth is expected to be higher than average.
5. Wage growth is expected *not* to be higher than average.
6. The share of total nominal output is expected to be growing.

Nordhaus applied the method to US data, confirming Baumol's disease for the United States. Following Nordhaus, Hartwig (2011b) applied the model for the diagnosis of Baumol's disease to the EU, using an aggregate of ten countries. Hartwig concluded by diagnosing the EU with Baumol's disease.

The intention of this work is to perform a robustness analysis of Nordhaus (2008) and Hartwig (2011b) in order to check the validity of the results obtained previously, when using a different database with a more recent time range. First, the thesis performs the analysis on the United States, to test the results obtained for the US by Nordhaus (2008) and Hartwig (2011b), are confirmed using a different data set. Subsequently, the framework is used to analyse the EU countries in order to replicate the findings from Hartwig. And finally, the method is used to produce results for the OECD countries to find out if the diagnosis can be made for the entire OECD.

The robustness analysis was carried out using data sourced from the OECD STAN database. The STAN database contains industry data starting from 1970 ranging up to 2018. The industry aggregation level used for this thesis correspond approximately to the broad industry groups investigated by Nordhaus and Baumol, dividing all industries over 15 groups. The first five of Nordhaus' syndromes can be tested using fixed effects regression analyses. The regressions use the productivity growth rate as the independent variable, and as dependent variable respectively the change in price, real gross value added, nominal gross value added, hours employment or wages. These analyses were performed for the OECD, the EU, the US and five individual countries as an extra verification.

The OECD and EU were investigated by averaging the data over the countries, although one analysis skips this step for the OECD. Three different time-averages were used. Either the cross-section was used which takes the average of the entire time range, a cross section using the average from 1991-2017 (discarding the first two decades) or the range was divided into 5 periods, subsequently calculating the average of each period. This averaging is done to prevent short term business cycle effects from dominating larger scale effects.

The sixth disease is diagnosed using a different method. The FSGR calculates the average productivity growth rate for a certain base year, by weighting each industries' productivity growth with their respective nominal share of total output in the base year, before summing the industries. The purpose of this measure is to show growth in the nominal share of total output of industries with low productivity growth.

For both types of OECD aggregation Baumol's disease can be diagnosed. In some cases, there are differences between the results when comparing the OECD average to the set of non-averaged countries. But in either case the diagnosis holds. For the EU the results deviate from Hartwig slightly, mostly the results provide a clearer picture than Hartwig. Symptoms of the disease can be found, therefore the diagnosis of Baumol's disease is warranted. Finally, the results for the US confirm Baumol's disease in the US, similar to Nordhaus. The results mainly differ from Nordhaus' in magnitude, finding a somewhat weaker effect.

Finally, five countries were investigated separately, to make sure the heterogeneity within the OECD countries did not affect the validity of the results obtained for the aggregate. For this purpose Korea and Luxembourg were selected because these represent the highest average productivity growth rate and the lowest average productivity growth rate in the OECD data set, respectively. Finland and Italy were the highest and lowest performer in the EU country set used by Hartwig. Finally the Netherlands was selected because the average annual productivity growth rate is close to the median value, as well as the exceptionally low amount of missing data (each year contained productivity data). Despite large differences in average productivity growth rate, the countries all show symptoms, additionally it was not possible to spot a correlation between the coefficients obtained and their average growth rate. Therefore, the results for the averaged OECD set can be considered valid.

The US and the EU have both been confirmed multiple times by means of the model suggested by Nordhaus. Therefore, the particularly the EU and the US seem to likely suffer from Baumol's disease. Additionally, the OECD results add to the notion that the Baumol effect is a universal macroeconomic effect. Following the diagnosis, the question remains what the detrimental effects might be. The price increases seen in certain industries should theoretically be balanced by the decrease in prices of other goods. The growing share of the labour force employed in stagnant service industries, and the rising income inequality could be more harmful to average quality of life. If gains from productivity growth could be redistributed to also reach those employed in stagnant sectors, it might be possible to stave of these adverse effects.

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Introduction

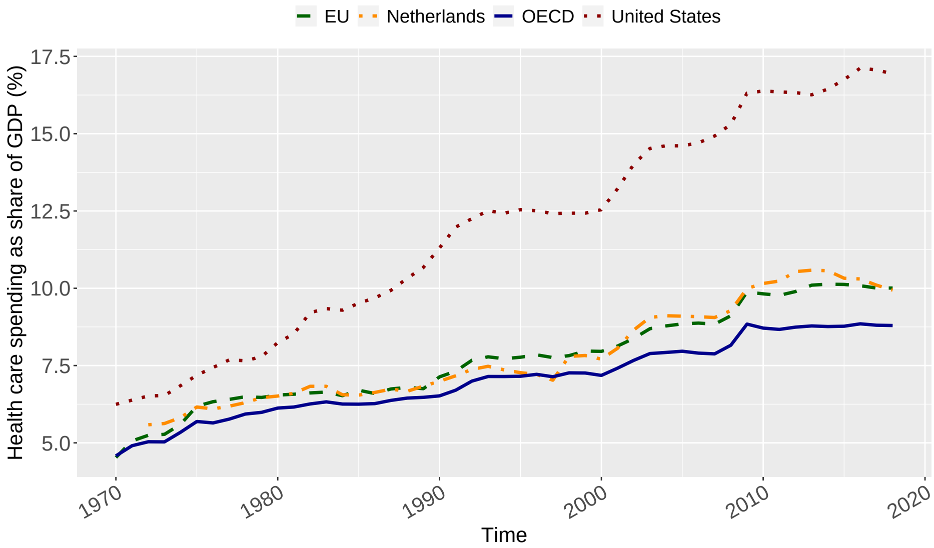
In 1987 working 9 hours a week at a minimum-wage job would be sufficient for to pay for tuition at a public university. In 2017, this would require 27 hours of work. Average tuition rose by 161% (in constant US dollars), while averages wages saw an increase of just 44% in this same time frame (Berman & Zehngebot, 2017; Insler, 2018). Looking at the real expenditure per student for primary and secondary school an increase of roughly 80% is seen. Mathematics testing scores on the other hand, have remained approximately constant (Helland & Tabarrok, 2019), indicating there was no obvious improvement in the quality of education. Expanding the view to the entire Organisation for Economic Cooperation and Development (OECD), which includes the EU and the US, a less extreme version of the same trend can be observed, average education (primary until tertiary) spending as share of the GDP (gross domestic product) increased from 1,2% to 2,2% between 1995 and 2017 (OECD, 2018). As figure 1 indicates health care spending has seen even more extreme growth. The United States showed the largest increase with the health care expenditure as share of GDP rising from 5% in 1960 to nearly 18% in 2017 (Bates & Santerre, 2013). The OECD health care expenditure increased from roughly 5% in 1970 to nearly 9% in 2017, the only OECD country where the share remained roughly constant was Latvia. Many authors have attempted to capture the price growth of education or health care, but there has been no agreement on the true origin. Additionally, most theories will explain either of the two price trends, but not both.

A series of articles published between 1965 and 1985 describe a model that provides a potential explanation for rising costs in both of these industries (Baumol, 1967; Baumol, Blackman, & Wolff, 1985; Baumol & Bowen, 1965)[1]. Development of the model starts with two important assumptions.

The first is the assumption that industries can be classified as either one of two sectors. The first of these sectors is called "progressive", demonstrating consistently high productivity growth. The other sector is "stagnant", with a constant level of productivity, or significantly lower productivity growth than the progressive sector. Low productivity growth in stagnant sectors is not due to specific shortcomings of these industries, but due to the technological structure of the sector, which does not provide opportunity for these industries to consistently grow. Technology does get adopted in low productivity industries. For instance, look at the situation of a home care provider. Advancements in technology regularly improve the quality of medical care. But there is no possibility for a home

[1] From now on Baumol (1967); Baumol et al. (1985); Baumol and Bowen (1965) will be referred to as WB, when discussing the general model and theories developed in these publications.

Figure 1: Health care spending as percentage of GDP, between 1970 and 2017. The green line (– –) shows data for the EU, the orange line (.-.-) shows data for the Netherlands, the blue line (—) shows the OECD and the red line (...) represents the United States. Source: OECD (2019)



care provider to increase the amount of patients bathed in a certain time period by a 100-fold. Yet a modern factory could be expected to produce 100 times more chairs per man-hour, than a similar factory or workplace would centuries ago. Alternatively, consider a string quartet which is employed to perform a one-hour composition by Bach. This performance will always require four hours of labour. Technological improvements can be used to practice more efficiently using online videos, and their performances can be broadcast over the entire world. But since neither the number of musicians, nor the time spent performing the piece can be reduced, the productivity of the quartet cannot be consistently improved upon.

The second assumption specified by WB is that wages in both sectors grow at the rate of productivity growth of the progressive sector. Wage growth should not occur without productivity growth to fund these from, according to the classical theory of economics. Regardless, the assumption that wages would rise despite a lack of productivity growth is not false in the real economy. Because people can move between sectors, constant wages would result in a drain of the labour in a sector and the disappearance of the sector.

WB uses these assumptions as the basis for defining a simple economic system, called the *model of unbalanced growth*. The Baumol effect[2] is the set of con-

[2]The term Baumol effect and Baumol's disease are used interchangeably in this thesis. Certain authors specifically refer to rising costs when talking about Baumol's disease, but in this case the effects of the model of unbalanced growth are referred to.

sequences that follow from this model. When wages rise in the low-productivity growth sector without productivity increases to pay for this increase, the inevitable results are higher costs and prices for services and goods in that sector. WB studies the performing arts, municipal government, artisans, haute cuisine and health care. Concluding that industries which have price-elastic demand, will be driven out of business as costs rise. Industries with price-inelastic demand, indispensable industries such as health care, will see prices grow indefinitely. Another consequence is that stagnant industries which remain in business, will take up an increasing share of the labour force, theoretically growing until all labour is employed in stagnant sectors.

To allow for a more comprehensive examination of the Baumol effect, Nordhaus (2008)[3] incorporates the Baumol model into an empirical model. WN described six diseases, each related to a separate statistical analysis. WN tests Baumol's disease empirically using US data, confirming the presence of Baumol's cost and growth disease in the United States. The newly developed method would be employed to examine multiple different countries as well as the EU (Hartwig, 2011b)[4], which also tested positive for Baumol's disease.

Any original publication should be replicable, meaning that for the same data, methods and materials the results should be the same regardless of the researcher. A commitment to reproducibility and replicability of results is what allows the public to trust the results produced in science. The idea being that results are capable of being tested and are being tested, in order to assure to their validity (Meehl, 1990; Platt, 1964). The current academic environment has a high pressure to publish (Fanelli, 2010), sometimes referred to as *publish or perish*. Replication studies and the potentially negative results which might follow from them, are less likely to be published and generally not likely to provide ground-breaking results. Therefore performing these studies are less useful for advancing the careers of scientists (Fanelli, 2012).

Despite these deterrents there has been a renewed interest in testing published results in replication studies. One of the first of these studies was in the field of psychology. Open Science Collaboration (2015) performed replications of 100 experimental and correlational studies published in three high-ranking psychology journals. Of these studies 97% of results were originally reported to be significant. Yet in the replications, only 36% was found to be statistically significant (Open Science Collaboration, 2015). Which is thought to be a result of the publish or perish environment, combined with frequent misunderstanding about the interpretation and correct use of P-values among scientists (Wasserstein & Lazar, 2016). The discrepancy in significant results sparked a larger movement

[3]From now on Nordhaus (2008) will be referred to as WN

[4]From now on Hartwig (2011b) will be referred to as JH

of replication studies in many different fields. The drive for replicable and trustworthy science is still going on, with platforms such as The Embassy of Good Science going up with European funding (Sevil, 2019).

Replication studies pose ideal candidates for master thesis projects for two reasons. Firstly, when a master student performs a replication, their thesis provides a valuable addition to their field. This is often hard to achieve when performing original research due to the short duration of a master thesis and a lack of experience by the student. Secondly, original research papers are required to include a detailed description of their methods which benefits the student significantly. The student has the freedom to question and criticise the original authors, but their research setup is not hampered by their own lack of experience. Related to replications, is the concept of a robustness analysis. A robustness analysis checks the if results still holds when varying aspects of the empirical model, such as the input data. JH performs a robustness check of the results found by WN, by using a data set that expands on the amount of countries investigated, changes the time range and uses different source data.

The aim of this thesis is to perform a robustness check of the Baumol-Nordhaus model. Specifically the approach followed by Nordhaus (2008) and Hartwig (2011b) is repeated using data from the OECD - Structural Analysis (OECD STAN) database. The benefits offered by this data set with regards to JH and WN are threefold. Firstly, WB describes the Baumol effect as an *unstoppable universal macroeconomic force.* Which means that Producing as many results reinforcing to the validity of the Baumol model will aid in confirming the truthfulness or accuracy of the model. Perhaps the theory could be universally accepted or rejected when the model has been thoroughly investigated. WN originally tested the methodology proposed with US industry data. JH used data from the EU KLEMS database to verify the results for the US, and added the results for an aggregate of ten Western European countries. The OECD database allows the investigation of a much wider selection of countries (30 countries as opposed to 10 in JH), more representative of the global economy than is the case for either WB or JH, while still containing all the countries considered by WN and JH. Secondly, it is possible that Baumol's disease was a problem which no longer applies today. Using a large time range from 1970 until 2017, it is possible to determine whether the Baumol effect is still in effect as well as confirm the universality of the model for this data set. Lastly the OECD STAN provides a new data source. Different economical and financial institutions determine economic measures in different ways. Therefore, even testing the same set of countries using a different data set can provide different results.

The main question this thesis intends to answer is: *Does a robustness check of Nordhaus (2008) and Hartwig (2011b) support or contradict the existence of* *the Baumol effect?*

To help with answering this question, some further questions have been developed. First, *how has the Baumol model been refined and adapted by the scientific community since its inception in the 1960s?* Secondly, *does the empirical evidence throughout the years support or contradict the existence of Baumol's disease?* And finally, *do cross country analyses using the methodology from Nordhaus (2008) support Baumol's disease?* These questions are answered through a literature study, combined with statistical regression analysis on an expanded data set. Through answering these questions, this thesis intends to confirm or deny the conclusions on the Baumol effect in the US and the EU. Moreover the results obtained for the OECD provide additional results for the resolution of the Baumol effect as a universal presence in developed economies.

The Baumol model is worth testing because it is a well-known model, that caused a strong response (both positive and negative), yet there is still no unanimous verdict of it's validity more than fifty years later. Producing as many results to reinforce the validity of the Baumol model will aid in confirming the truthfulness or accuracy of the model. Perhaps the theory could be universally accepted or rejected when the model has been thoroughly investigated. Accurately determining the degree to which the model applies to the real economy could benefit policymakers.

This report is structured as follows. The next chapter provides a literature review, which starts with a detailed description of the Baumol model and the adaption by WN. Following this, the evidence for the Baumol model gathered by means of a variety of methods is reviewed. Finally, the literature review studies some of the implications of the model and the problems that arise with regards to justice and fairness. After the literature review, the data and methods are discussed. The source of the data, the operations performed on these and the analyses that have been done in R are outlined and justified. Chapter 4 presents the results from the statistical data analysis, comparing the results to those found in JH and WN. The results confirm previous findings for the United States and the EU, as well as for the newly tested OECD country aggregate. Additionally, results for a set of individual countries from the OECD confirm that the variety within the OECD set does not cause problems for the aggregate analysis. The final chapter summarises the results, draws conclusions, considers policy implications and discusses the limitations of the empirical analysis.

Literature Review

The previous chapter introduced the concept of the Baumol effect. This literature review intends to provide the necessary background information and context required for the empirical analysis which follows. To start, the formal description and derivation of the Baumol model is provided. Next, the response to WB will be discussed and the evidence found to support or deny the claims made by Baumol. The defining features of the Baumol-Nordhaus model are described, as well as the evidence that was produced by application of the model. Following the description and evidence, the motivations for the robustness test are discussed. The last of this chapter starts by examining implications of the Baumol effect and the degree to which these are present in the economy. Finally, different views of fairness are discussed and how these apply to an economy suffering from Baumol's disease.

The Baumol model

Professions in the performing arts sector have been associated with low wealth throughout history. In modern times this notion has not changed, and the data confirm this assertion. Between 1970 and 2017 average wages in the *Arts and Entertainment* were 22.4%(±0,9%) lower than the total average in the OECD and 37.6%(±0,5%) lower in the United States. Numbers such as these caused Baumol and Bowen (1965) to examine the performing arts, aiming to determine the origin of the harsh economic conditions which seem to befall upon performers.

The author starts by considering two common properties of non-profit organisations. The first of these is the fact that these organisations do not earn profits on their invested capital. Secondly, they claim to fulfil a social purpose. The goal is high quality service and as such, Baumol and Bowen (1965) states that these organisations are designed to be "on the brink of financial catastrophe". Some organisations are by design incapable of being financially prosperous. And performing arts organisations show many similarities to non-profit organisations, often relying on the contributions of benefactors to stay in business.

WB proposed that all industries can be classified as (1) technologically progressive, where a rise in output per man-hour can be consistently observed due to technological progress, economies of scale and capital accumulation or (2) as stagnant, where the nature of the activity does not allow for consistent increases in productivity. Categorisation of sectors does not depend on the history of a specific activity, but rather on the "technological structure" of the activity. The technological structure determines the inherent ability of the activity to see growth in productivity. WB considers the fundamental distinction to lie in the role played by labour. In the one category, labour is merely an instrument and in the other category, labour is (part of) the product itself. It is this second category, which does not readily lend itself to increasing the output per man-hour. This distinction is not binary, within each type the degree of productivity growth potential can vary. For instance, while the performance of a two hour musical piece will not decrease the amount of labour needed, innovations in transport and technologies for more efficient rehearsing, can decrease the labour input required for the final product.

To illustrate the rising costs, WB describes a simple example. Assume a simplified economy, consisting of two sectors of equal weight, one of which has an average yearly growth rate of productivity of 4% and the other sector has a stable level of productivity, therefore the aggregate growth rate of change of productivity is 2%. Now assuming labour is perfectly mobile and wages grow at equal rates between these two sectors. In this model, the real wage grows at a rate equal to the average productivity, again 2%. When it is also assumed that there are no changes in the share of capital and labour, the money wages will also rise at 2%. Looking back at the two sectors, the sector with 4% productivity growth will be able to lower the costs of their product using the excess productivity growth. In the sector with stable productivity levels, the rise in wages will translate to rising product costs.

The performing arts are a sector which belongs in the category with a relatively constant productivity level Baumol and Bowen (1965) states. It is possible to make improvements in the output or efficiency to increase productivity, but these changes are not durable and cannot be repeated on a yearly basis. Some specific properties of the performing arts can be credited for the persistent survival of the industry Baumol and Bowen (1965) suggests. Actors are required to possess both talent and extensive training, this makes the profession relative exclusive. This exclusivity causes the *psychic returns* of being an actor to be higher than in other industries. Because being an actor grants status in society, actors are less willing to leave their occupation for a different sector. The psychic returns is worth more than a certain degree of wage increases. Because of these psychic returns, actors are less likely to immediately move into a different industry when the wages lag behind other industries. This effect explains the trope of the *starving artist* and the below-average wages reported in the first paragraph. Nonetheless, even actors require wage increases, otherwise their real income decreases with actual poverty as a result. Therefore the wages may lag behind other industries, but eventually growth is required. Another unique property of performing arts is the lack of steep price increases. Baumol and Bowen (1965) find that ticket prices grew slower than cost increases in the sector. The authors suggest that performing arts organisations have set the explicit goal of low prices, to keep cultural events accessible.

Rising costs as a result of a focus on quality, wage increases and low ticket prices, cause the performing arts to rely increasingly on donations, in addition to the lower wage growth of performers.

Baumol (1967) formally develops the model, expanding on the concept and considering other industries with a consistently low productivity growth rate such as education, municipal government and health care. The work argues that the effect should be considered a fundamental macroeconomic force (*"an unstoppable economic force"*). WB compares the force to supply and demand. In the middle ages there were attempts to thwart supply and demand, such as the failed efforts by medieval rulers to abolish usury (Moehlman, 1934). These measures seem to work in the short term, but in the longer term, the effect will inevitably overpower the countermeasures.

The mathematical description of the model uses a set of assumptions to construct a simplified economical system from the theory. Wages in the two sectors are expected to rise and fall together, relying on the assumption of at least moderate labour mobility, it is assumed that while wage growth might lag in a sector, unless the sector disappears, the wages will have to rise eventually in the longer term. Finally, the money wages are taken to rise instantaneously as the productivity grows. These assumptions simplify the mathematics and while the absolute levels may not be representative, the relative costs and prices are the relevant takeaways from this derivation, therefore this should not affect the conclusions drawn. Using sector 1 to describe the sector with constant productivity, and sector 2 to describe the technologically progressive sector, where the labour productivity is expected to rise at a constant compounding rate of r, the production functions can be written as:

$$Y_{1t} = aL_{1t} \tag{B1}$$

$$Y_{2t} = bL_{2t}e^{rt} \tag{B2}$$

L_{1t} and L_{2t} represent the quantity of labour and $a\&b$ are constants. Wages are taken to be equal between the two sectors and to be fixed at a rate of W_t dollars per unit of labour. W_t as described under the assumptions, grows with the productivity of sector 2 and can be described as:

$$W_t = We^{rt} \tag{B3}$$

WB now uses this basic model of unbalanced growth, to derive a set of propositions, by studying the behaviour of this simplified economy.
The costs per unit of output for sectors 1 and 2, are:

$$C_1 = \frac{W_t L_{1t}}{Y_{1t}} = \frac{W e^{rt} L_{1t}}{a L_{1t}} = \frac{W e^{rt}}{a} \tag{B4}$$

$$C_2 = \frac{W_t L_{2t}}{Y_{2t}} = \frac{W e^{rt} L_{2t}}{a L_{2t} e^{rt}} = \frac{W}{a} \tag{B5}$$

And the relative costs will exhibit this behaviour regardless of the function for the wage increase.

$$\frac{C_1}{C_2} = \frac{L_{1t}/Y_{1t}}{L_{2t}/Y_{2t}} = \frac{b e^{rt}}{a} \tag{B6}$$

From which the first proposition follows:

Proposition 1 *"The cost per unit of output of sector 1, C_1, will rise without limit while C_2, the unit cost of sector 2, will remain constant"* (Baumol, 1967, p. 418).

With rising relative costs, generally the demand for sector 1 would decline. If the elasticity of demand for both sectors' output were 1, the relative expenditure on the commodities offered by sector 1 and 2, would remain constant.

$$\frac{C_1 Y_1}{C_2 Y_2} = \frac{W e^{rt} L_{1t}}{W e^{rt} L_{2t}} = \frac{L_{1t}}{L_{2t}} = A \tag{B7}$$

Where the ratio of output looks like this:

$$\frac{Y_1}{Y_2} = \frac{a L_{1t}}{b L_{2t} e^{rt}} = \frac{aA}{b e^{rt}} \tag{B8}$$

This function will asymptotically approach zero, which leads to the second proposition.

Proposition 2 *"In the model of unbalanced productivity there is a tendency for the outputs of the "non-progressive" sector whose demands are not highly inelastic to decline and perhaps, ultimately, to vanish."* (Baumol, 1967, p.418).

In other words, unless people are willing to pay a steeply increasing price for the product (such as health care and education), stagnant industries will be driven into a niche of luxury items or products, or the industry could disappear as a whole.

Next, the question is investigated what would happen when the magnitude of the relative outputs of the sectors are kept equal, despite their change in relative costs and prices. A situation which could be created by subsidies for instance, or if demand for the product were price inelastic or income elastic. Setting equation B8 equal to a constant H, gives $\frac{Y_1}{Y_2} = \frac{aL_1}{bL_2e^{rt}} = H$, which can be rewritten as:

$$\frac{bY_1}{aY_2} = \frac{L_1}{L_2e^{rt}} = \frac{b}{a}H = K \tag{B9}$$

Which can be rewritten to isolate L_1 and L_2.

$$L_1 = KL_2e^{rt} \qquad \text{and} \qquad L_2 = \frac{L_1}{Ke^{rt}} \tag{B10}$$

Defining the total labour supply L as $L_1 + L_2 = L$, and substituting L_1 and L_2 on the right hand sides of B10, gives the following equations:

$$L_1 = \frac{LKe^{rt}}{1 + Ke^{rt}} \qquad \text{and} \qquad L_2 = \frac{L}{1 + Ke^{rt}} \tag{B11}$$

In the limit as t approaches infinity, L_1 will approach L and L_2 will approach zero. Which then leads to the following.

Proposition 3 *"In the unbalanced productivity model, if the ratio of the outputs of the two sectors is held constant, more and more of the total labour force must be transferred to the non-progressive sector and the amount of labour in the other sector will tend to approach zero"* (Baumol, 1967, p.419)

In the final "experiment", WB considers what happens to the overall growth rate of output in the economy, when the output ratio is not allowed to vary. A weighted average of the outputs of the sectors is used as an index of output:

$$I = B_1Y_1 + B_2Y_2 = B_1aL_1 + B_2bL_2e^{rt} \tag{B12}$$

Combining equations B11 and B12, and taking the derivative, result in:

$$I = \frac{Re^{rt}}{(1 + Ke^{rt})} \qquad \text{and} \qquad \frac{dI}{dt} = \frac{rRe^{rt}}{(1 + Ke^{rt})^2} \tag{B13}$$

Finally, the percentage rate of growth of output is calculated:

$$\frac{(dI/dt)}{I} = \frac{r}{(1 + Ke^{rt})} \tag{B14}$$

From which it follows that the percentage rate of growth of output, will asymptotically approach zero. Therefore, it is senseless to artificially keep the output ratios of the two different sectors constant. Which is the idea behind the fourth proposition.

Proposition 4 *"An attempt to achieve balanced growth in a world of unbalanced productivity must lead to a declining rate of growth relative to the rate of growth of the labour force. In particular, if productivity in one sector and the total labour force remain constant the growth rate of the economy will asymptotically approach zero"* (Baumol, 1967, p.419).

Summarising the main concepts from the mathematical derivation, for an economy with a sector of industries where wages grow faster than the productivity: The costs will rise in low-productivity industries, because wages need to be paid from sources other than productivity increases; Price-elastic stagnant industries will decrease or disappear, due to decreasing demand caused by increasing prices; Surviving stagnant industries will consume an increasing share of available labour, and progressive industries will consume a smaller amount of the labour share.

Final note on the Baumol model: The mathematical model was simplified to make the mathematics more straightforward. For instance, wages between sectors are supposed to be equal and rising at the rate of productivity growth in the progressive sector. Neither of these are essential to the model. Baumol's disease manifests itself whenever wages grow faster than productivity in that industry. The wage rate does not have to be as high as the productivity in the progressive sector, not do wages have to grow at equal rates.

Reception of the Baumol model

The publication of Baumol (1967) raised attention, the following two issues of the American Economic Review contained five comments on the paper and the subsequent rebuttals by Baumol (Baumol, 1968, 1969). Bell (1968) suggests that the reason for the low productivity growth of service industries, the problem is not that these activities inherently are incapable of making use of economies of scale, capital accumulation and technological progress, but in the difficulty in measuring service industries. When looking at the activities performed by appliance repairmen, hospitals and governments, none of these services are performed in the same way they were decades earlier. Therefore the author deems it clear that it is not inherent to the service industries that no productivity growth is measured, instead the measured should be adapted to accordingly. When defining productivity as a ratio between the labour input, and the output, which is again defined in terms of labour, it is not surprising that the services will by definition remain close to one.

One particular comment argues for the notion that while costs would increase in sectors with constant output, the real cost would not (Robinson, 1969). Since according to the author the demand for services will rise once wants for commodities are satiated. Industrial labour is an inferior good and therefore the demand will decrease as real income increases. In the long run this will result in a constant or reduced cost of services. Initially, Baumol responded to this by agreeing that the real costs would not increase when measuring the cost of labour, but when measuring the opportunity costs, the costs would rise. Interestingly, Baumol (2013) seems to retract his previous rebuttal. The book does not discuss labour as an inferior good, but does argue that the real wage will not decreases. According to the author, a higher share of wages will be allocated towards stagnant services, but the total amount of goods afforded are higher.

Finally a famous counter argument is offered by Oulton (2001). The argument states that a growing nominal share of stagnant industries will only lead to a decline in aggregate productivity growth if these stagnant industries produce final products. Business and financial services most often produce intermediate products instead. In that case, despite stagnant productivity growth, the aggregate productivity would still grow. WB agreed with this notion, although Hartwig and Kraemer (2017) found not all conditions for this effect to arise were satisfied.

The most straightforward method for analysing the legitimacy of the Baumol effect is by observing whether the predicted implications, as well as the assumptions of the Baumol model can be observed. Analysing both the OECD and Switzerland separately, Hartwig (2005); Wölfl (2003) find that productivity growth is the highest in manufacturing; Wages seem to co-vary between manufacturing and the tertiary sector; The price deflators have not significantly risen or even decreased in manufacturing, but the deflators in other industries have on average increased between 1980 and 2001; The real output ratio has remained roughly constant between manufacturing and other industries. Finally, the health care expenditure share of GDP and the medical sector employment share of total employment have increased.

Supplementing the original publications, Baumol et al. (1985) introduces some modifications and additions to the model, as well as empirical evidence found in support of the model. The work starts by retracting the notion that service industries automatically equate to stagnant industries, because certain services were found to show high productivity growth. The paper also introduces a third category of industries, the asymptotically stagnant sector, which the authors show to be sectors with a fair amount of stagnant activities while showing mostly the growth pattern of a progressive industry in the short term. As time progresses, the progressive activities make up less of the industry's costs, increasing the share of the budget consumed by the stagnant activities. Eventually this leads to those sectors becoming stagnant sectors as well.

In the second part of Baumol et al. (1985) empirical evidence for the Baumol model is presented. To test the model, the authors calculate the average annual rate of productivity growth by sector between 1947 and 1976, using four different indicators for productivity growth rate. For each indicator, the sectors are classified as stagnant or progressive, based on observing the range of rates calculated and determining a cut-off. This cut-off is based on finding a point where the difference in average productivity growth rate between industries below and above the cut-off point are the largest. Various statistics are calculated for the group of stagnant and progressive industries. The average annual productivity growth rate, the average real and nominal share for the first and the last year in the range, and the share of employed persons in stagnant industries between the first and the last year. From these analyses the authors show that the average difference in productivity growth rates between productive and stagnant sectors is 2,5-2%, while the relative price difference between the two sectors grows at roughly 2%, confirming the rising costs of stagnant industries. Additionally, the nominal share of output of the stagnant sectors, rose from 6 to 12% while the real output shares of the stagnant sectors remained roughly constant. Finally, the share of employment in the stagnant sectors was found to have risen significantly, at over 10%. From these results the authors conclude that the Baumol effect can indeed be identified in the US.

In a work opposing the diagnosis of the Baumol disease (for the United States), Triplett and Bosworth (2003) analyse labour productivity growth in the United States and determine the contributions to productivity growth by several different factors. Between 1973 and 1995, the United States experienced a relatively low labour productivity growth of roughly 1,3%annually. Since 1995 productivity growth has double to 2,6% and in the same period the labour productivity growth in services has increased at roughly the same rate as the economy-wide rate. The origin of this labour productivity growth was mainly due to IT. In response to this, Hartwig (2006) reports that there is only a single service industry which is truly seeing a durable productivity growth, namely wholesale and retail trade. Stating that this sector is likely to stagnate soon as well, the paper concludes with the statement that Baumol's disease for the US has been postponed rather than cured.

Because the Baumol effect relies on the notion that wages are rising faster than the productivity growth, certain authors have proposed a "Baumol variable", which is defined as the difference between the wage growth and the aggregate productivity growth. If the Baumol variable is positive wages grow faster than productivity, requiring an increase in costs for the to fund this wage growth. In order to examine the cause of increasing health care expenditure, the relation between health care expenditure growth and the Baumol variable is tested. Employing a regression model, a significant contribution of the Baumol variable to the growth in health care spending in several OECD countries as well as the United States can be found (Bates & Santerre, 2013; Hartwig, 2008).

In another variation of this method, Colombier (2012) found that while Baumol's disease could be detected, the effect was weak. In an alternative method, Hartwig (2011a) tests the Baumol effect in health care by testing the contribution of the relative price growth in medical care, to the growth in health care expenditure. Albeit less strongly, and with mixed results by predecessors (i.e. L'horty, Quinet, and Rupprecht (1997)), the positive relation between relative price growth and health care spending growth are again confirmed.

The Baumol-Nordhaus Model

The Baumol model has generated a lot of attention, prompting many responses, but there has been little consensus on the Baumol effect. Other works diagnosing the Baumol effect often only examine part of the implications of the Baumol effect, such as only researching the effect of price variations on variations in health care spending. Such results do not necessarily confirm the Baumol effect, but rather find results that do not disagree with the implications of the effect. The method employed by Baumol et al. (1985) requires manual inspection of the productivity growth data and choosing a value to classify industries as stagnant or progressive. WN sets out to reexamine the Baumol effect, making use of recent developments in the availability of data as well as the improved measuring methods for price and output indices. Additionally WN creates a comprehensive analytical framework, which incorporates an array of implications of the Baumol effect rather than a single one.

In an economy where industries have inherently different productivity growth rates, WN first questions which implications would arise from this situation. Using the propositions of WB as a basis, the following six syndromes or diseases (named after "Baumol's disease") are identified by WN, each of which relates the change of growth of a variable to a change of productivity growth.

1. *Cost and price disease* Costs and prices in low productivity sectors are expected to increase relative to the costs and prices in high productivity sectors.

2. *Stagnating real output* The real output for stagnant sectors, does not necessarily have to demonstrate one type of behaviour. The real output growth should **not** be lower for high productivity sectors. The relation between real output growth and productivity growth, is linked to the relation between employment growth and productivity growth. WB derives the growing labour share of stagnant industries, using the assumption of a constant real output ratio between the two sectors.

3. *Unbalanced growth* What will happen to the nominal output growth depends on the type of industry the stagnant industry is. If the demand for a stagnant industry is price-inelastic, low productivity growth would lead to high nominal output growth.

4. *Impact on employment and hours* Low productivity growth industries are expected exhibit high growth in labour input, provided that the real output share is constant, or has a positive relationship between productivity growth and real output growth.

5. *Impact on factor rewards* WB assumed that low productivity growth sectors would be financially stressed, resulting in lower wage growth in stagnant industries. However, the wage rate could be equal between the productive and the stagnant sectors, in which case profits are not invested into raising wages.

6. *Impact on aggregate productivity growth* If the nominal output shares of stagnant industries rise, the expected result is that the total economy growth rate is lowered because of this.

Where previous methodologies mostly considered a simplified two-sector approach, WN instead formulates an analytical framework for many sectors. First, WN creates a system of production, cost, supply and demand equations, under the assumption of (1) Cobb-Douglas production functions in capital, labour and exogenous technology (2) Cost minimisation (which means the cost function is the dual of the production function) (3) Price is simply a markup over cost.

$$\begin{aligned}
&\text{Production} : \hat{x}_{it} = \hat{a}_{it} + \beta_{it}\hat{m}_{it} + (1-\beta_{it})\,\hat{k}_{it} + \varepsilon^{x}_{it} \\
&\text{Cost} : \hat{z}_{it} = -\hat{a}_{it} + \beta_{it}\hat{w}_{it} + (1-\beta_{it})\,\hat{c}_{it} + \varepsilon^{z^*}_{it} \\
&\text{Price} : \hat{p}_{it} = \gamma_i + \theta_i\hat{z}_{it} + \varepsilon^{p}_{it} \\
&\text{Income} : Q_{it} \equiv P_{it}X_{it} \equiv R_{it}K_{it} + W_{it}M_{it} \\
&\text{Price} : \hat{x}_{it} = \lambda_i + \eta_i\,(\hat{p}_{it} - \hat{p}_t) + \mu_i\hat{x}_t + \varepsilon^{s}_{it} \\
&\text{Demand} : \hat{x}_{it} = \lambda_i + \eta_i\,(\hat{p}_{it} - \hat{p}_t) + \mu_i\hat{x}_t + \varepsilon^{s}_{it}
\end{aligned}$$

The lower case roman letters represent the logarithmic growth. a_{it} is the productivity, c_{it} is the cost per unit capital services, ϵ^{x}_{it} is a random error for variable x in period t for industry i, k_{it} is the capital input, m_{it} is the labour input, η_i is the price-elasticity of demand, p_{it} is the price, w_{it} is the cost per unit labour x_{it} is the real output, z_{it} is the unit cost of output. Other Greek letters denote parameters. Q_{it} is the nominal output, R_{it} is the rate of profit on capital. Subscript it denotes by industry and period t. Subscript t denotes the aggregate value by period t.

WN solves the system of equations for the endogenous variables, which returns a set of reduced form equations for the first five diseases: Price, nominal output, real output, wages and profits. The reduced form equations are a function of the productivity growth and error terms. For instance the real output, gives the following reduced form equation:

$$\hat{x}_{it} = \varepsilon^{x1}_{i} - \overline{\eta}\hat{a}_{it} + \varepsilon^{x2}_{it} \tag{1}$$

In this equation the real output is expressed as a function of the productivity growth and shocks/errors from the previous equations. This specification allows WN to perform a regression analysis on the data, in order to test if the results from the estimated data correspond to the analytical model. The form of the regression equation is described below:

$$\hat{x}_{it} = \alpha_i + \gamma_1\hat{a}_{it} + \gamma_2 D_t + \varepsilon^{x}_{it}$$

The linear regression is performed by letting the labour productivity growth for each industry act as the independent variable and five variables corresponding to the first five diseases, as the dependent variable. The regression takes effects into account which vary over time, but not over industries (D_t), this parameter tries to account for external influences to the regression that do not vary between the industries and therefore are not of interest for examining the correlation between productivity growth and the dependent variable. An advantage of this method over some other methods is that the regression analysis captures the differential productivity growth between industries without the need for a specific definition of the stagnant and the progressive sector.

The Baumol-Nordhaus model has been employed by several researchers to test the Baumol effect and add to the literature on the subject. For instance, Japan was examined between 1970 and 2011, and the authors found that while before the 1990s there was significant variability in the productivity growth between industrial sectors and services. But since the 1990s the industry has taken the position of progressive sector and the authors conclude that the Baumol disease appears in Japan in recent decades (Nishi, 2018). For Korea, the effect is also observed but conclude that the effect is only weakly present. Proposing that a heavy reliance of export combined with Korea's "compressed growth", have caused a weakening of the effect (Oh & Kim, 2015).

Repeating the analysis for the United States, Helland and Tabarrok (2019) performed an analysis similar to WN, employing regression analyses between the rate of change in prices and the rate of change of productivity growth for multiple industries, while foregoing the examination of the other five diseases described by WN. Making use of more recent data ranging between 1987 and 2016, the authors conclude that the Baumol effect is the most plausible current explanation for rising costs in education, health care and other service industries. For certain other industries, the article posits that the Baumol effect is not the cause. They argue for instance that rising prices of infrastructure construction in Los Angeles and New York are caused by trade unions and a conservative legal system. Because the residential construction has seen a much lower price growth, and is also not affected by trade unions or the legal system as much.

Finally, the Baumol-Nordhaus model was used to investigate the presence of Baumol's disease on an aggregate instead of an individual country. Hartwig (2011b) used a selection of JH used the method to analyse the aggregate of a selection of ten EU countries[5]. For the analysis of the aggregate, the ten countries are averaged and treated as a single country. Due to the large inter-country heterogeneity in the set, JH also analyses the country with the lowest productivity growth (Italy) and the country with the highest productivity growth (Finland) separately. JH concludes that despite a slightly weaker presence, the Baumol effect is also observable in the EU. The specific output of the regressions by JH can be found in the *Results and Discussion* chapter, tables 5 and 6.

[5]Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Spain, United Kingdom

Robustness Analysis

An empirical model aims to predict the outcome of processes which happen in the real world. Due to the large number of potential influences on the outcome of the predicted variable, every model involves a set of assumptions. A robustness analysis provides a way to deal with the uncertainty brought forth by assumptions and sensitivity to measurement errors in a model (Morgan & Winship, 2015). In order to test if the results obtained by the original model are accurate, the input sample can be changed and varied. If the same conclusions are drawn, the model can be considered robust. The theory by WB does not specifically refer to the United States, rather the effect is supposed to manifest itself in any industrialised economy. The results from the analysis by WN were obtained by sourcing data from the United States, which should not be the only country for which the effect is detected. Similarly the time range investigated should not be the only time range for which the effects are seen.

Additionally, the Baumol-Nordhaus model also employs a number of assumptions. In the analytical framework used by WN, each function is the result of an economist's attempts to identify the most important factors which affect the outcome. In order to estimate the output from the demand equation, WN has to assume certain conditions. Significantly, the assumptions that productivity growth for each industry are independent of shocks affecting other variables; that input costs per unit for each each industry are independent from other variables; and that prices are always markup over costs. In addition to the assumptions made during the formulation, the model is sensitive to errors in measurement of price deflators. Such errors affect both the real output growth as well as the productivity growth.

JH performed a robustness analysis of WN by varying the sample data in multiple ways with respect to WN. Firstly, the United States are examined while varying only the source of the input data, using the EU KLEMS database rather than the Industry Accounts Bureau of Economic Analysis (BEA). Secondly, JH applies the methodology to EU15ex[5] data reported between 1970-2005, which means using different countries from WN, as well as using a country aggregate as the sample instead of a single country. WN and JH attempt to overcome the problem concerning the measurement errors by repeating the analysis for a "well-measured" industry subset, which discards industries that are notoriously difficult to measure (O'Mahony & Timmer, 2009) as well as a broader industry level. The broader industry classification should have less industry-specific measurement issues. Except for industry specific measurement issues, the use of different periods and subsets of the total time range can cause the measurement errors to be covered in different ways. If the results still agree with the general conclusions, the errors were likely not significant.

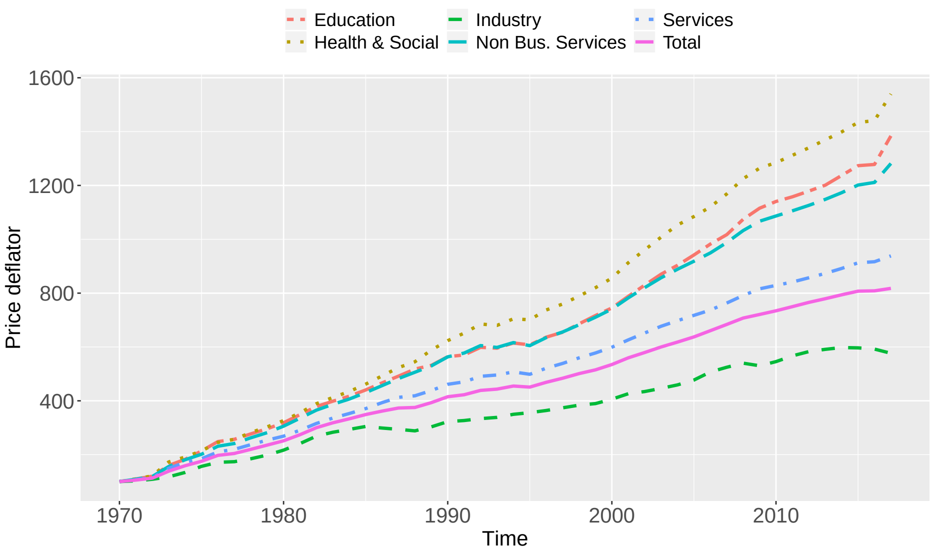
The current work carries out a robustness analysis by varying several components, the results of which can be found in the following chapters. Most importantly, the analysis is carried out on data sourced from the OECD STAN database. Different databases use different measurement standards and process data differently. Even if the US data in the STAN database is sourced from the BEA, in order to ensure the compatibility between countries the data is processes in a way that might result in different findings. Secondly, the database contains data from 1970-2017, while WN and JH used data going up to 2001 and 2005 respectively. In the past ten to fifteen years the Baumol effect could have decreased or gained in strength, by investigating the most recent data a statement can be made about the past decade and whether the effect is roughly constant over time. The different data set and time range are applied to the United States and the EU15ex, which allows for a direct comparison of the results for those specific countries. Next the results are generated for the whole OECD. The OECD STAN data contains 30 OECD countries, 19 of which were not covered by either JH or WN. The analysis of the OECD provides additional information on whether the Baumol effect is as universal as stated by WB.

Justice under Baumol's disease

In case the Baumol model is indeed a valid model for the real economy, it is worth considering what the implications would be, if these can indeed be observed and finally what this could mean for the future. Under the Baumol effect, the first implication which has been discussed extensively already, is the cost and price disease. Most often the expectation is that certain industries, such as many services, will show significant increases in costs. As mentioned earlier, initially Baumol (1967) roughly equated the stagnant sector and the service sector of the real economy. In their later work that assertion is modified, because their results show that not all services are stagnant. For instance, the communication and broadcasting sector showed an average annual productivity growth rate of over 5% between 1947 and 1976, and the wholesale and retail trade has shown significant growth between 1995 and 2005 (between 3,9% and 4,2% annually). These progressive services behave similar to highly productive good producing industries. Nonetheless, many stagnant industries are service industries.

Figure 1 shows the increasing expenditure on health care as a share of the GDP, from which can be gathered that more money is being spent on health care. And upon reviewing the time progression data of the price deflator of several industry groups in figure 2, the increasing prices are evident as well. Health care has prices have grown the fastest and education comes in after that. Not just these

Figure 2: The time evolution of the price deflators of several sectors, as the mean of the OECD. The magenta line (—) shows data for average of all industries, the green line (- - -) shows goods producing industries, the blue line (.-.-) shows all services, the teal line (— —) depicts the non-business services, the red line (- – -) represents Education and the ochre line (...) shows health care and social work. Source: OECD (2010, 2016b)

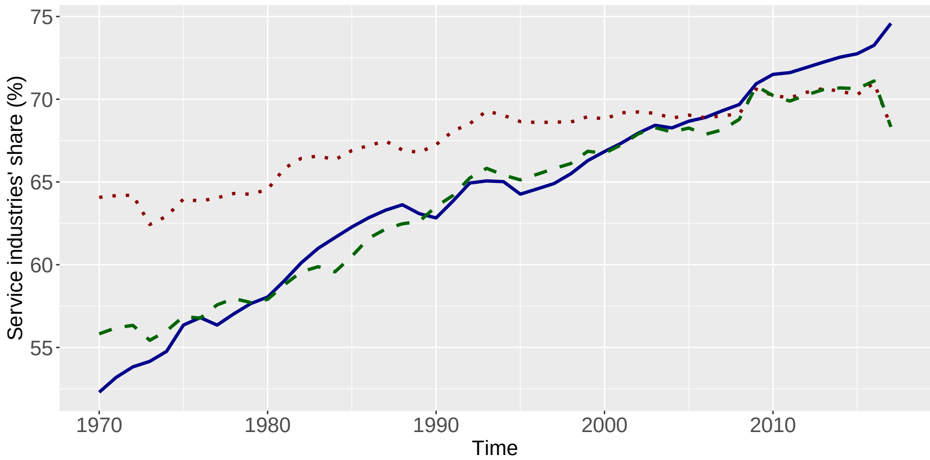


two services show growth, although they are most often cited because of their low price elasticity of demand. Which could also explain why costs are rising fastest in those industries, while other more elastic industries might try to compensate for their decreased demand by keeping price growth artificially lower. The figure also shows that the price index of goods-producing-industries grows slowly with respect to the average, while in the services it grows faster than the average.

Industries that do not succumb to the increased price pressure, are expected to increasingly absorb more of the available labour, theoretically eventually employing all labour. Because the progressive sector has durable productivity growth which is not expected to decline (significantly), these industries should require less labour over time. Figure 3 shows that the share of labour in services has been steadily rising since 1970, employing nearly 75% of people in the OECD in 2017.

Despite the fact that not all services are stagnant, the largest growth of employment happens in stagnant services rather than high productivity services (Baumol et al., 1985). Mostly these are low-skilled and low-income jobs (Autor, 2014; Deming, 2017; Goos & Manning, 2007; Saint-Martin, Inanc, & Prinz, 2018). With the prospect of the majority of workers employed in these types of jobs, significant income inequality could be expected. One measure of income equality is the Gini index, which represents the inequality in a country with a single value,

Figure 3: The growing weight of the service industries in the total economy of the OECD. The dark-blue (—) line represents the ratio of people employed in the service sectors to total people employed. The dark-red (...) line represents the share of the real value added of service industries of the total real value added. The dark-green (– –) line represents the share of the nominal value added of the service industries. Source: OECD (2016b)

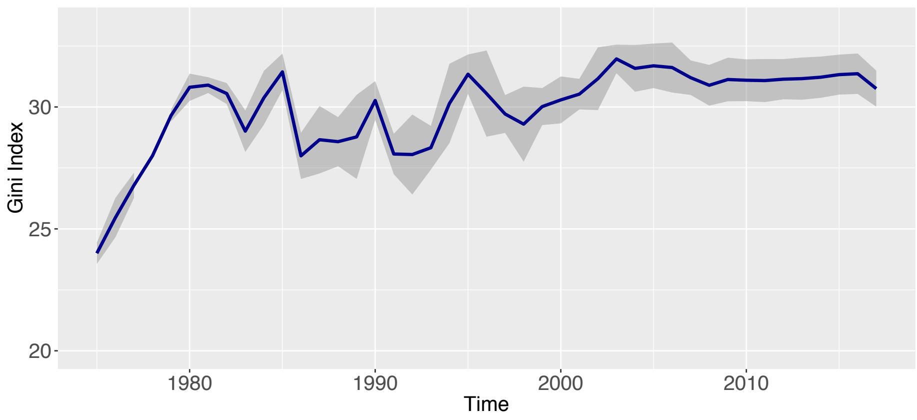


0 being perfectly equal and 100 being perfectly in-equal. Figure 4 shows the Gini index for the OECD which shows a noticeable increase since 1975, although not by much. Still, many authors find that the inequality is rising. For instance Atkinson, Piketty, and Saez (2011) finds a growing share of the total income is going to the top 10% and figure 5[6] shows the development of employment share in jobs ranked by their skill percentile. In the 1980s the middle and highly skilled jobs were growing, and the low-skilled jobs were decreasing. The 1990s show job polarisation with growth of both low and high skilled jobs, while middle skill declined. Between 1999 and 2007, there was almost no growth of medium and highly skilled jobs, nearly all growth concentrating around the bottom 40% of skill percentiles.

When nearly all labour is located in stagnant industries there is no guarantee the majority of people will actually see an increased quality of life, regardless of the growth in the aggregate productivity rate (Gordon, 2017). Increased prices of education combined with lower chances of finding employment despite college education are causing a decline in the number of university registrations (OECD, 2018). Lower education levels, in addition to lower relative wages, are correlated with lower life expectancy, amongst other things (Murtin, Mackenbach, Jasilionis, & D'ercole, 2017). Therefore, the results of wage inequality are further reaching than purely financial means. If the development of the labour market does indeed follow the predicted pattern, a growing share of people will be "disadvantaged".

[6] Adapted from (Acemoglu & Autor, 2010)

Figure 4: Gini Index quantifying income inequality in the OECD between 1975 and 2017. A Gini index of 100 means perfect inequality (a single person receives all income), whereas a value of 0 means perfect equality (each member of the population receives an identical income. The shaded area shows the standard error. Source: OECD (2016a)

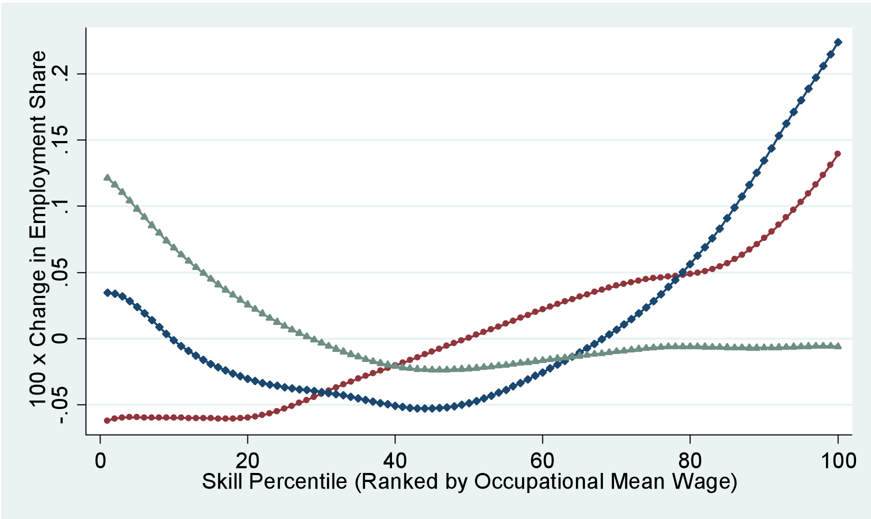


Because even if people are willing to put in the effort, the amount of jobs available in the progressive sector is only decreasing, with computers for instance performing former low-to-medium skilled tasks more productively. These predictions raise questions of fairness. Would it be fair for people to be significantly disadvantaged with respect to a very few, and would it be just to redistribute wealth in order to benefit disadvantaged people.

To a certain degree, most people agree that differences in income are fair. It might be considered fair for instance for a CEO to earn more than an administrative employee, due to the higher amount of skills and education required as well as the additional liability and responsibility. But is it still considered fair when the average CEO in 2017 earns 221 times as much as the typical worker at that company, compared to 20 times as much in 1965. Or is it fair that the life expectancy at birth for a baby in South Africa is 63 years old, while a baby born in Japan has a life expectancy of 84.

Distributive justice deals with the question of how goods can and should be allocated in a socially just manner. This question can be approached from many different angles. Some philosophers believe in *justice as equality* which states that it would be most fair if each person receives exactly the same. But different people need different things. Most people would not want or need a large amount of what they are allocated under this principle. But they might need more of one particular thing. Based on this argument is the principle of *need based justice*, the idea that certain people have greater needs than others. Therefore it is fair for the people with greater needs to receive more. *need based justice* can be countered by the argument that it is unfair to people who do not have greater needs. Less needy people are should not be "punished" for having fewer needs. Yet another

Figure 5: The log changes in employment shares by 1980 occupational skill percentile rank using a locally weighted smoothing regression (bandwidth 0.8 with 100 observations), where skill percentiles are measured as the employment-weighted percentile rank of an occupation's mean log wage in the Census IPUMS 1980 5 percent extract. The mean log wage in each occupation is calculated using workers' hours of annual labour supply times the Census sampling weights. The red line (circles) depicts the change in employment between 1979-1989. The blue line (diamonds) represents 1989-1999. The green line (triangles) represents 1999-2007. Figure adapted from Figure 10 in Acemoglu and Autor (2010)



movement is utilitarianism. This theory aims to obtain the highest total sum of utility, which could be considered as happiness or satisfaction. The result of this theory might be the redistribution of wealth to benefit people that are worse off, which would alleviate inequality. But if a wealthy person desires a certain good more than a less fortunate person – therefore achieving higher happiness as a result – the good would be distributed to the wealthy person. This situation would result in an increase of inequality in society, therefore adherence to this theory requires accepting whichever the final outcome of wage (in)equality would be. Furthermore, finding a reliable measure for utility is not straightforward.

A specific theory worth discussing is the theory of justice as fairness, by Rawls (2009). In this work, Rawls enumerates two key principles.

- *The first principle* "Each person is to have an equal right to the most extensive total system of equal basic liberties compatible with a similar system of liberty for all"
- *The second principle* "Social and economic inequalities are to be arranged so that they are both:"
  - "To the greatest benefit of the least advantaged, consistent with the just savings principle, and"

- "Attached to offices and positions open to all under conditions of fair equality of opportunity"

Additionally, these two are connected by a rule. This rule states that the two principles are ordered, such that the first always takes precedent over the second.

To arrive at the first principle, Rawls suggests a thought experiment. Rawls placed a group of people, in the so-called *original position.* The original position implies that the people in this group are placed behind a *veil of ignorance.* This veil causes the people in this group to forget everything about their origin, and other factors that are not required for the determination of justice. Under this veil, people do not know anything about their gender, race, country of birth, family, possessions, skills or motivation. About everything else, they are not ignorant. Rawls posits that if this group of people, had the challenge of drawing up a set of institutions. They would naturally arrive at granting the most extensive set of equal basic liberties. When granting rights to people, the problem might arise that these rights collide. For instance, it would not be possible to simultaneously grant people the right to do construction work at 4 am, and to sleep throughout the night. Only the liberties that can be granted without possibly colliding with other's liberties, would be included. The set of liberties the group would arrive at according to Rawls would consist of rights such as: Freedom of speech, the right to vote, the right to be treated according to the law, etc.

For the second principle, Rawls notes that people are in a situation where there is no telling what the results will be for each individual. Once the veil of ignorance is lifted, the individuals will be placed somewhere that they have no knowledge of. Therefore, Rawls argues that any reasonable person would choose a *maximin* strategy in this case. Maximin means maximising the outcome for the worst possible scenario. In other words, improving the situation the most, for the people who are the most disadvantaged. Finally, the rule about ordering the two principles is involved. If the least advantages group would be better off when for instance another group's right to be treated according to the law would be taken away, this scenario should not be chosen. Liberties are always more important than the benefits for the least advantaged. As an example, imagine that the richest man alive was asked about whether rich people should be taxed 1% more to provide health care for homeless people. There is no reason this person should agree to this (other than general kindness), nor would it be justice to force this man to pay the tax. Yet, if this man was asked the same question behind the veil of ignorance, he would have to agree, according to Rawls, because nothing is known about whether he himself might be homeless once the veil is lifted.

When Rawls' principle is applied to the inequalities faced as a result of Baumol's disease, there is no doubt that Rawls would argue that this does indeed constitute an unjust situation. Rawls would then argue that the inequalities should be addressed in such a way that the least well of, for instance people who lost their jobs altogether, are the most benefited by aggregate productivity gains. For instance in the form of higher taxes for highly productive industries and subsidies for stagnant industries.

Rawls theory has been criticised by philosophers mainly due to Rawls' assumption that it would be inevitable that people would do as he describes in the original position. Because such a situation is so foreign to people, that it cannot be reasonably expected from them to know what they would do in a position where they are essentially a different person (Wolff, 2006). In another counter argument, few people would disagree that people who are willing to work hard, deserve more than people who do not work at all and only want to hang around all day. But Rawls does not make a distinction between poverty due to unfortunate circumstances or poverty due to laziness. People under the veil of ignorance could still agree to situations where people are rewarded for their effort, even without knowing if you are inherently lazy in real life. Finally, Sen (1999) disagrees with the ordering of the two principles. While agreeing that it is important for liberties to take precedence over the second principle. This should not be completely set in stone, because there are situations where economic inequalities can be life or death situations, which might warrant breaking certain liberties. Rawls avoids this problem by placing the original position in a situation where there are no such life or death situations, which makes the theory less applicable to real world scenarios.

A different concept of justice is offered by Nozick (1974). Nozick follows libertarian philosophy. Libertarianism seeks the maximum amount of freedom and autonomy for people. Nozick developed the *entitlement theory of justice*. Which starts from three basic principles.

- The principle of Justice in Acquisitions
- The principle of Justice in Transfers
- The principle of Rectification of Injustice

Nozick believes that any distribution of wealth is just, as long as each person is entitled to the holdings they possess. The three principles specify when a person is entitled to property. The property has to have been acquired in a just manner, transferred in a just manner or obtained as part of retribution for past injustices. Although Nozick considers it a fundamental right to retrieve property from someone that is yours, he agrees there would be anarchy if everybody would take the law into their own hands. Therefore, Nozick says, the only possible just state is a *night-watchman* state, the only purpose of which is to retrieve property that belongs to someone else. The only taxation is to pay for this activity. Any other taxation is unjust, because it involves appropriating property from one person, to give to some other person.

To justify the *night-watchman* as the only possible just state, Nozick argues that there are two types of theories concerning for distributive justice. The first is the theory by Nozick, where any distribution is just as long as the property was obtained in a just manner. The second type of theory is a *patterned theory*, which means wealth is redistributed according to a certain pattern. For instance egalitarian theories believe the only just distribution is perfectly equal distribution, but most taxation is also a form of pattered theory. Arguing against pattered theories, Nozick describes a situation where all property is collected and redistributed according to an arbitrary pattern. Suppose in this state with redistributed wealth, people want to pay a famous basketball player, Wilt Chamberlain, to play. In this situation, in order to prevent the pattern from being broken, the state would have to intervene to stop people from paying Wilt Chamberlain to play basketball. Otherwise, Wilt Chamberlain would become wealthier than the pattern dictates. The state would have to intervene not a single time, but every single time a transaction is made. Such a state that continuously infringes upon peoples rights by wrongfully taking their justly owned property, Nozick equates to a dictatorship. Therefore the night-watchman state the only just type of state.

The results for the wage inequality caused by the Baumol effect are straightforward, because the higher wages were not acquired in an unjust manner, the distribution is fair as is. There is no way to interfere in the situation without being unjust to people who happen to have been born in a wealthier family or have higher natural abilities. Certain people are lucky which results in higher wages and a higher standard of living. But it is unjustified to ask or force these people to give up their wealth as long as their wealth was obtained fairly.

Some of the criticisms of Nozick's theory focus on the following aspects of the theory. Firstly, Sen (1999) remarks that it is possible for bad scenarios, such as famine, to occur in situations where Nozicks rights are all satisfied. Therefore more is required of a theory of justice than a set of rights. Secondly, the requirement of knowing the entire history of property makes just ownership complex. If property was at some point in history obtained unjustly, any subsequent owner owns this property unjustly. Despite the fact that the unfair transfer might have happened a single time, three generations before the eventual buyer was born. Since there is no method of amending injustices that have occurred in the past, this poses a significant hurdle for the theory (Hausman, 1992). Finally, although some disagree with taxation, most people would not consider contemporary democracies dictatorships.

By presenting these two diametrically opposed views of justice, the aim is to illustrate the difficulty in deciding on a solution to seemingly unfair situations. While an individual reader might still end up with a feeling of injustice when considering one of the theories, the fact that both are logically reasoned and both can be criticised, should indicate there is no clear-cut solution. It is also interesting that many modern states incorporate notions from both theories. It is illegal to take property from someone else unless this is actually your property. On the other hand, there are many countries with welfare systems funded by taxes, through which governments provides support for disadvantaged individuals. Finding a solution that satisfies everyone is likely not possible, therefore it is important to consider different points of view.

Data and Methods

Wherever possible, this thesis will adhere to the methods as applied in the original WN and JH papers. Due to the relatively limited amount of information given in these papers, but in a few cases liberties have to be taken with regards to specific details in the analysis. The source data from the OECD STAN is publicly accessible. All analyses performed in this thesis were done in the statistical programming language R, with the use of a selection of open-source packages and libraries[7]. The code and custom functions written for this project can be found in the git repository[8].

NB When this paper omits to specify the type of mean calculated, geometric or arithmetic, it can be assumed that the geometric average was used if rates of change are discussed. The geometric mean is calculated as the n-th root of the sample values multiplied by each other. The geometric mean of values x_1 through x_n is $\sqrt[n]{|x_1 \times \cdots \times x_n|}$

Data used by Nordhaus and Hartwig

WN used data sourced from the Industry Accounts by the Bureau of Economic Analysis (BEA) or the National Income and Product Accounts (NIPA). The data set constructed by WN contained data for the United States, ranged from 1948-2001 and covered 67 detailed industries and 14 major industry groups.

The time range was either fully employed (1948-2001), or the range from 1977-2001 was chosen, WN found that the number of missing observations declined steeply after 1977. Additionally, the data was compressed by either calculating the cross-section (a single average of the whole time range) or four sub-periods, where the range was split into four roughly equal subsets and each of these were averaged. The data set was also analysed at different levels of industry detail. The most detailed level listed 67 distinct industries. But this level of detail often leads to a lot of missing data points. It can be difficult to obtain accurate measurements for certain industries, most notably service industries. Therefore WN made a selection of 28 industries (out of the 67 detailed industries), which is supposed to contain more accurate data. The third industry selection contained 14 major industry groups. Especially for earlier years there is often data available at this coarse level, without data at the detailed level.

JH uses the EU KLEMS database (march 2008 release). This database contains industry level data spanning from 1970-2005 and covering the EU15 coun-

[7] ggplot2, ggridges, matrixStats, plm, pxR, readr, stargazer, tidyr
[8] https://github.com/omul/baumol

tries[9] as well as the United States. The selection of countries was further narrowed down to ten countries, which JH calls the EU15ex[10]. This selection was made due to the availability of multi-factor productivity data. The MFP data coverage starts in 1980, and covers fewer industries than the labour productivity data. JH uses a similar selection procedure for industries as Nordhaus, ending up with 46 detailed industries with 30 of those well-measurable, and 16 broad industry groups. No separate subset is used with a reduced time range, but the range is divided into three (or four) periods based on business cycle cut-off years. Finally, JH also uses a separate data set from the EU KLEMS which subdivides the labour costs and hours employed for each industry by skill level (low, medium or high skill).

Data used in the present study

This thesis uses data from the OECD Structural Analysis (STAN) database. The latest list of OECD members contains 38 countries, covering between 40 and 60 % of the global GDP (IMF, 2018). The OECD STAN database provides industry data starting from 1970 and has seen a number of revisions in the industry classifications (ISIC) as well as the Standard of National Accounts (SNA). To cover the largest possible time range and to fill in as many missing observations as possible, the constructed data set draws from a combination of two data sets. The first and oldest is the OECD STAN ISIC Revision 3 SNA93 (OECD, 2010), and the other more recent database is the OECD STAN ISIC Revision 4 SNA08 (OECD, 2016b).

The OECD STAN database does not offer MFP data for any of the countries in their database. Due to the discussion around the use of MFP as a productivity measure, which involves the difficulty in accurately measuring and interpreting the data (Van Beveren, 2012), this lack of MFP data is not considered a disadvantage in this thesis. Lastly, the labour compensation by skill level by industry is unavailable in the OECD STAN database. JH shows there is a stronger correlation between wage growth and labour productivity growth for higher skilled jobs. When available this data provides some extra substance for certain conclusions, but it was not used in WN and not considered necessary for a robustness check of the main objective of the JH paper.

Despite the drawbacks, the OECD STAN database also offers advantages. Firstly, the data used in WN only involved the US, which means the validation of

[9] Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom

[10] Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Spain, United Kingdom

Baumol's disease in that case, would not necessarily apply to other developed economies. JH adds data for Western European countries. But the OECD database allows the investigation of a much wider selection of countries, more representative of the global economy than is the case for either WB or JH. Secondly, more recent data is available. The OECD STAN database Rev. 4 goes up to 2017, which is more than a decade of data with regards to JH. This can provide information on the time progression of the Baumol effect. The effect might be weakening or gaining in strength. Finally, it allows the assessment of the existence of Baumol's disease using another set of data altogether. Databases measure and process data differently, which can lead to different results. The EU KLEMS database could have been used for the analysis of more countries than the EU15ex. For instance, Japan and Australia are also included in that database. The drawback would be that the results for the original EU15ex countries would most likely be identical to those found by JH. Using a different data set, results for the same country set can still provide additional knowledge.

Industries

The main set of industries selected for this thesis was based on the broadest level of industry aggregation found in WN and JH. The industry groups used in this work were selected to reflect approximately the same level of broadness and scope of the industry groups as defined by WN and JH. The resulting list of industries counts 15 sectors, which can be found in the appendix (table A7).

In order to merge the two data sets, the industry lists were carefully, manually curated with concordance tables for reference (Both ways for Rev. 3 to Rev. 3.1, and both ways for Rev. 3.1 to Rev. 4). The difficulty in merging Rev. 3 and Rev. 4 of the OECD STAN data stems for a large part from the fact that between industry classification Rev. 3 and Rev. 4, there was another revision (3.1), which was never utilised by the OECD. This also means that merging the data between the two data sets requires more than a single concordance table. Groupings have been merged and separated to such a degree that it is no longer possible to accurately merge the industries at the 2-digit level (JH's detailed industries). Although it might have been possible to create a selection of well-measured industries that could still be fairly accurately merged because the industries included there have not seen large changes.

As an example of the actions that were applied to the industries, take a look at the Information and Communication industry group. In the most recent revision of the ISIC (Rev. 4), at approximately the "broad" level of aggregation, Information and Communication (I & C) was placed in a separate category to reflect the strong upswing of this field in recent years. Previously, this group was split up over Post and Telecommunications and Computer and Related activities. In the estimated data set I & C group has been placed in a category merged with postal services. Merging industry groupings in Rev. 3 data to represent the I & C sector without including postal services, would be more complex and inaccurate than to group Information and Communication and Postal Services in Rev. 4.

Data formatting and merging

Before performing the data analysis, it is necessary to format the data to make sure the Rev. 3 and Rev. 4 data sets are conform to each other, and are ready to be used in the regression analysis. The data was retrieved from the OECD statistics website. The website offers a variety of export formats, of which the PC-Axis format proved to be the most useful in this case. PC-Axis files were imported most easily in addition to being imported in a long data format. Long form data refers to a type of data organisation where each combination of year, country, industry and variable represents a separate observation, rather than using one of these variables as columns.

Having imported the data into data frames in R, it is necessary to rename variable values such that these are conform between the data frames. Furthermore, indices in Rev. 4 use an index of 100 as base value, whereas Rev. 3 uses 1 with the occasional use of 100. Finally, Rev. 4 reports values in millions of currency and Rev. 3 does not. Next, there is a small difference in the countries available for the Rev. 3 and the Rev. 4 data sets, countries that were only present in Rev. 4 were excluded because the data available in the Rev. 4 database was generally less complete. The only country available in Rev. 3 which was not in Rev. 4, West-Germany, was excluded because of the dissolution of West-Germany in 1990.

The next step performed was extending the years available for Rev. 3 data to 2017, adding NA values for each data entry, this was to simplify the merger later. Having now achieved conformity between the two data sets on all facets except for the industries, the industries were merged using the previously composed industry groups. Something which needs to be kept in mind are the price deflators, which are presented as an index value. These values have base year which is set to 100. The base year used for Rev. 3 is 2000, while for Rev. 4 this year is 2010 and the same applies to the volumes ("real" value added). Therefore, the index numbers have to be accurately chained and the base year is recalculated to be 100 in 2010 for both data sets. Next, the missing variables need to be calculated. For the methods suggested by WN, labour productivity and labour compensation are required in addition to those variables directly in the data set (Value added deflators, the price index; Value added volumes, the real value added; Value added current prices, the nominal value added; Hours worked by total engaged; Compensation of employees). The labour productivity is calculated as the real gross value added per hour worked (value added volumes / hours worked by total engaged). The labour compensation is the amount of labour costs spent per hour worked (compensation of employees / hours worked by total engaged).

The final action before merging the two sets, is calculating the log differences of the levels in the data set. If the observation at the current and the previous time points are close to each other, the log difference is an approximation of the percentage change. To calculate this the natural logarithm is taken for each value and the difference with the previous time value is taken, which results in the percentage change values for all the variables.

The data sets have been formatted and standardised, now it is possible to merge the two revisions. The ISIC Rev. 4 data set has been chosen as the "base set" because it is the most up to date, employing the most recent measurement techniques. The Rev. 3 data is used to supplement the data if there are observations available that are not available in the Rev. 4 data set. Between the two data revisions, a certain difference in the levels of variables can be expected. For instance when a small industry is merged with a larger industry in the new revision, or simply due to measurement differences. When the revision 4 data set would be supplemented with level-data from revision 3, these differences in level would result in sudden spikes in the growth rate, whenever the time series incorporates one value from a different revision. When the growth rate data are merged, such spikes do not occur. Now that the data estimate has been constructed, the data set is complete to be used for the statistical analysis. Care has been taken to ensure the conformity of the industries, time range, economic measures and countries. The following section contains a description of the data with general statistics.

Description of the data

After the process of industry selection, data formatting and data merging, the result is a single data set containing the estimated rate change of 7 variables, for 15 industries in 30 countries, spanning the period of 1970 until 2017. The countries Japan, Mexico and Chile were dropped because there were no productivity data available.

Table 1 and figure 9 report on the statistics of the entire data set. For each variable the lowest value, the highest value, the median, the mean and the standard deviation are reported. Figure 9 shows the probability density functions of the variables. The limits of the x-axis were chosen as the 1st and the 99th percentile, because as can be seen in the table, the actual extremes are so far from the centre, the plots become very stretched out. Additionally, together with

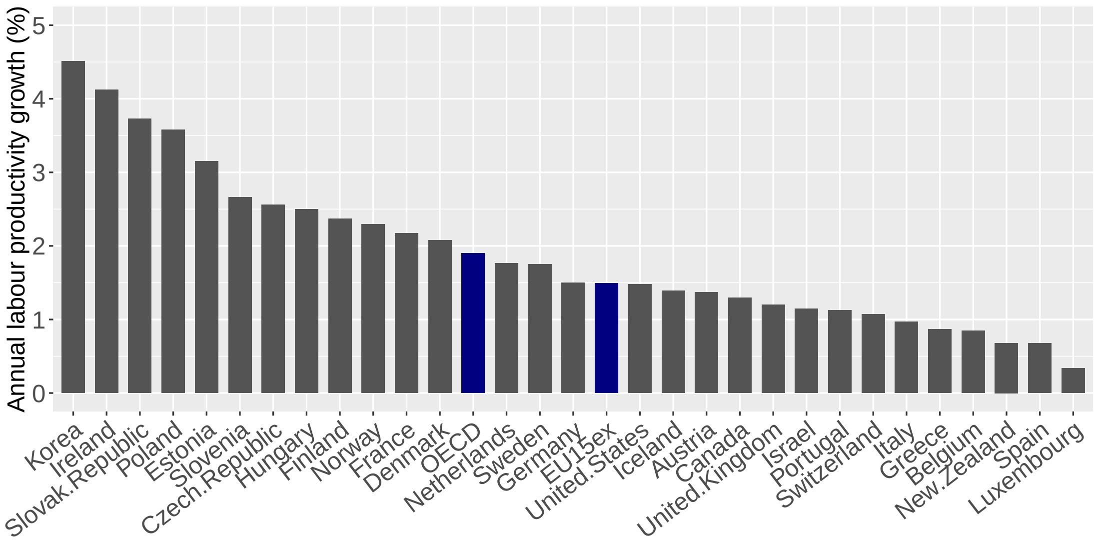
Table 1: The minimum value, 1st quartile, median, mean and standard deviation, 3rd quartile, the maximum value and the number of observations in the estimated data set as constructed for this paper. The main analyses for the data set were performed on growth rates, therefore this table summarises these. The values are reported as percentages.

	Min	First Quartile	Median	Mean	Std	Third Quartile	Max	No. of Obs.
Value Added, Nominal	-98.26	2.48	6.13	7.55	11.41	11.40	242.58	17456
Value Added, Volumes	-97.81	-0.20	2.36	2.32	6.61	5.10	98.01	16687
Value Added, Deflators	-78.30	0.67	3.42	4.72	8.75	7.39	116.16	16463
Labour Costs	-93.81	2.56	5.85	7.14	8.38	10.45	91.38	16034
Hours Worked	-211.72	-1.45	0.80	0.59	5.57	2.90	103.24	10953
Labour Productivity	-119.69	-1.46	1.10	1.46	7.37	4.19	206.58	10804
Labour Compensation	-94.48	1.73	4.01	4.89	6.67	7.48	236.73	10787

the data from the table the rarity of growth rates of 200% can be understood. In fact, even the 99.9th percentile still only yields a maximum value which is roughly 96% lower than the maximum value of the entire set. The density plots show the data is generally reasonably distributed, the curves showing relatively neat Gaussian shapes, with only moderate kurtosis and skewness. If industries were in fact easily separable into two discrete categories, the expected results for these density plots would be that there were two separate Gaussian curves (with peaks for the productive and the stagnant sectors) contained in the single plot.

More interesting perhaps, are the heat maps in figures 7 and 8. Figure 7 reports the average (geometric mean) taken over the entire period, for each combination of country and industry. The x-axis lists all the industries analysed here, and looking at the general picture, it seems like there is a trend of lower productivity change as we move up the industries. Approximately, the third of the industries on the right, more generally seem to be orange. This region is where the services are grouped, the highest numbers reserved for non-business services such as government, health care, education and others. D68T82, "Real estate, renting and business activities", seems to perform particularly poorly. Finally, the second column from the left portrays some interesting results. This is the mining industry group, and for most countries the performance in this sector is quite high, but the UK, Luxembourg and Iceland show the industry as bright red.

Figure 6: The average annual labour productivity growth for all countries included in the analysis, between 1970 and 2017 as well as the averages for the OECD and the EU15ex, highlighted in blue (dashed stroke). The averages are calculated by taking the geometric means of the growth rate for each year. Source: OECD (2010) & OECD (2016b)



Perhaps this can be explained by particularly strong effects of the financial crisis of 2008 in these countries.

Figure 8 shows the same type of heat map, but this time the average has been calculated over the countries, rather than over the years. Again referring to the mining sector, it is interesting to see how this sector generally seems to be a high performer, with some odd years showing high losses. The financial crisis seems to be visible in the red-orange bands in 2008 and 2009, although the public and personal services (three rightmost industries) do not seem affected in their general pattern of low growth. Generally this figure shows a similar trend as the previous figure: Performance drops when moving to the right and the "Real estate, renting and business activities" sector is a poor performer. Only the first decade for this industry shows decent productivity growth. Finally another trend can be observed, this time moving upwards on the figure, or forwards in time. The last decade or so seems to have more instances of low productivity growth in generally well performing sectors.

From these figures we can see there are no clear signs for universally poor performing countries. Moreover, no industry is immune to bad results with the possible exception of although agriculture (first from the left) where low productivity growth is rarely seen. It would be possible to categorise sectors as stagnant or non-stagnant, but the figures slow there is no way to make a completely unambiguous choice about which sector falls where.

Figure 7: Heat map showing all permutations of countries and the industry groups. The colour depicts the average annual labour productivity growth rate as a percentage. The scale runs from −3% and everything below that as bright red, to the median of 1.13% as yellow and 3% and everything above that as bright green. Grey values depict an absence of data.
Source: OECD (2010, 2016b)

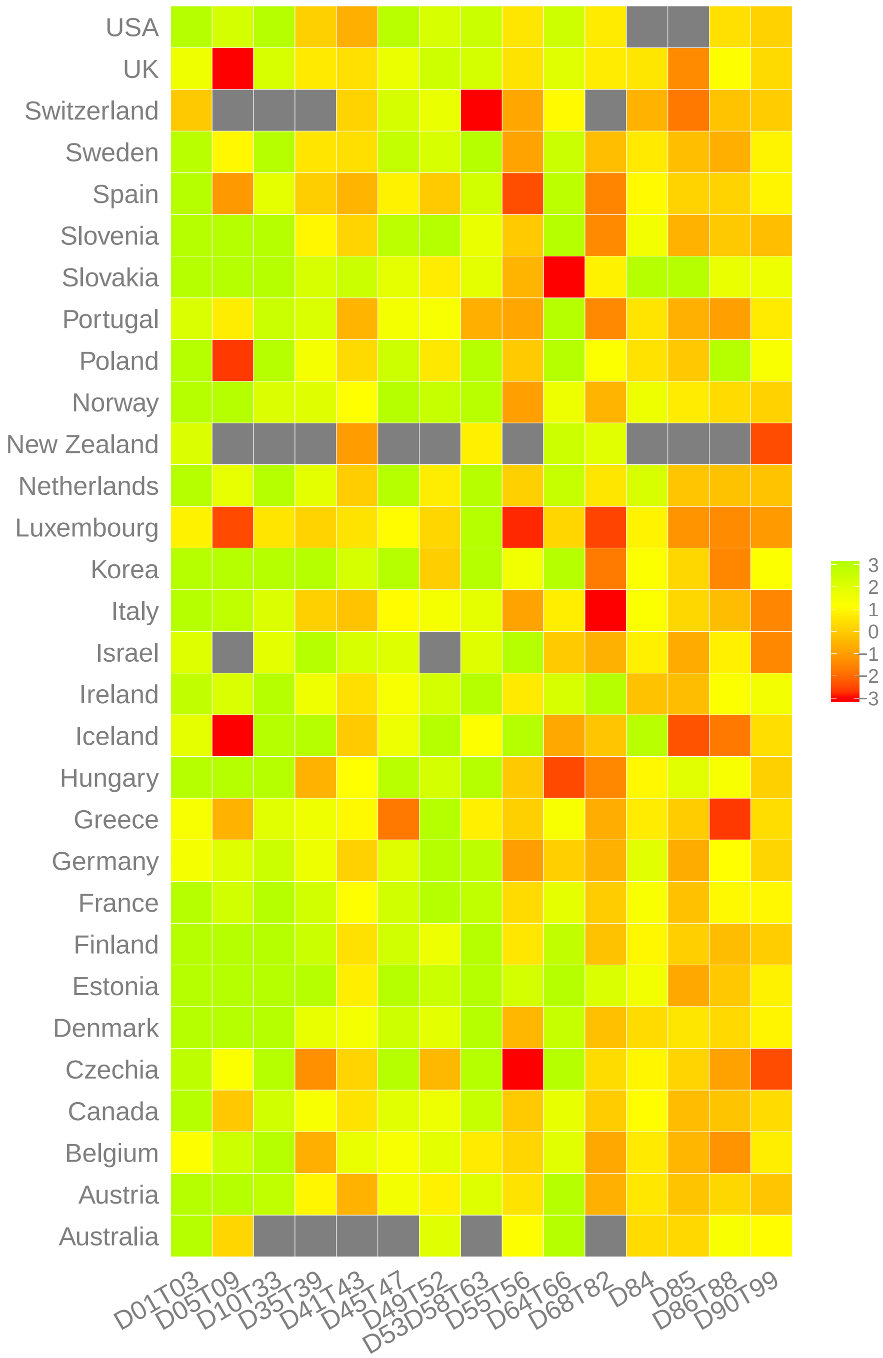


Figure 8: Heat map showing all permutations of years and the industry groups. The colour depicts the average labour productivity growth rate as a percentage, averaged over the countries in the estimated data set. The scale runs from −3% and everything below that as bright red, to the median of 1.35% as yellow and 3% and everything above that as bright green.
Source: OECD (2010, 2016b)

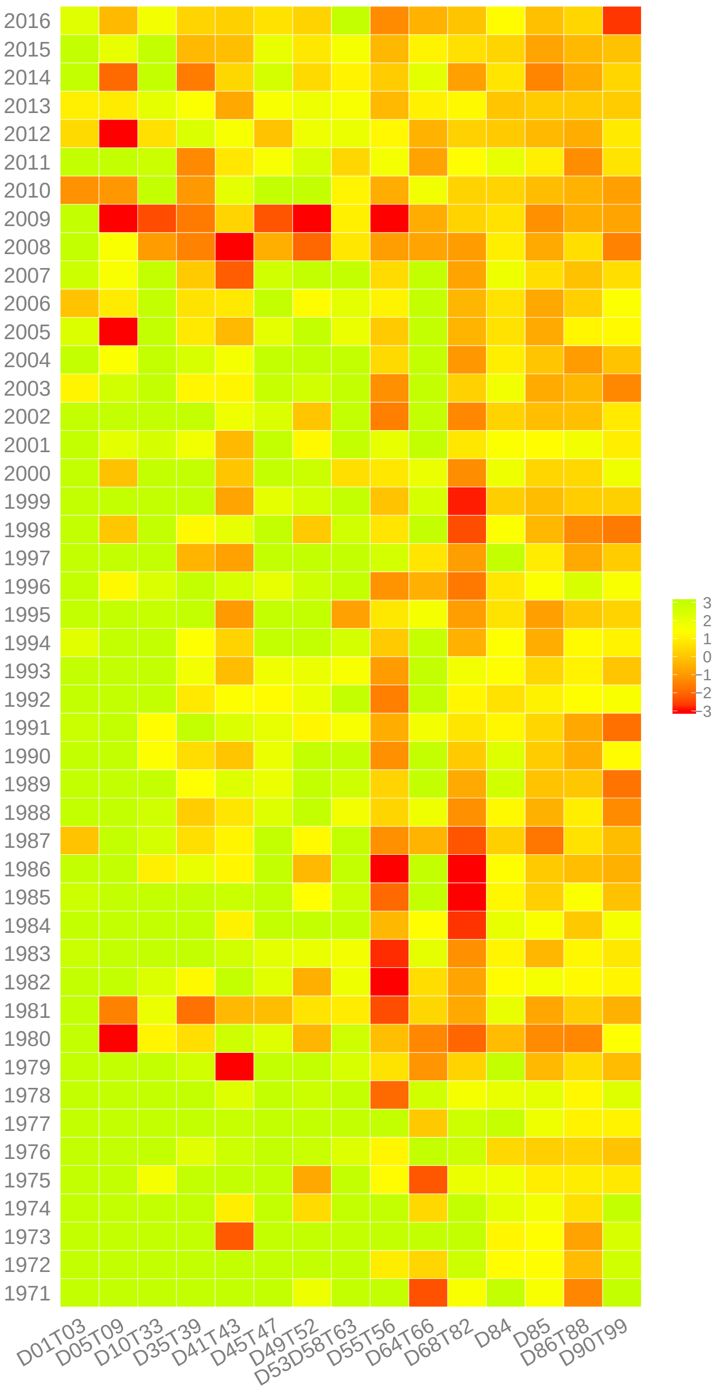


Table 2: The minimum value, 1st quartile, median, mean and standard deviation, 3rd quartile, the maximum value and the number of observations of the aggregated (in both time and countries) data for industries. The summarised data are calculated from the productivity growth rates from the estimated data set. The values are reported as percentages. Sources: OECD (2010, 2016b)

	Min	First Quartile	Median	Mean	Std	Third Quartile	Max	No. of Obs.
Agriculture, forestry and fishing	-57.72	-0.91	3.75	3.83	9.72	9.21	53.38	764
Mining and quarrying	-119.69	-5.75	1.82	2.45	17.26	9.04	206.58	725
Manufacturing	-26.34	0.98	3.21	3.61	5.07	5.98	62.48	712
Electricity, gas and water supply; Sewerage and waste	-40.07	-2.29	1.46	1.50	7.66	5.37	37.29	710
Construction	-36.09	-2.06	0.44	0.57	5.91	3.19	39.99	739
Wholesale and retail trade; Repair of motor vehicles	-22.61	0.06	2.51	2.31	4.27	4.65	19.97	719
Accommodation and food service	-22.08	-1.14	1.76	1.86	5.65	4.57	30.03	699
Transportation and storage	-25.93	-0.08	2.78	2.76	5.93	5.50	43.13	709
Information and communication; Postal services	-27.89	-2.82	0.02	-0.12	5.65	2.64	25.23	731
Financial and Insurance	-61.35	-1.82	1.94	1.93	7.82	5.90	53.87	752
Real estate, renting and other business activities	-22.53	-2.45	-0.36	-0.35	3.94	1.69	18.60	721
Public administration and defence; Compulsory social security	-19.54	-0.25	0.99	1.11	3.79	2.23	36.21	688
Education	-19.91	-1.68	-0.12	-0.01	3.34	1.38	27.26	688
Human health and social work	-28.98	-1.39	0.15	0.08	4.12	1.64	39.75	707
Other community, social, and personal service activities	-63.94	-1.83	0.39	0.20	5.68	2.42	58.58	740

Table 2 reports the same statistics as table 1, for each individual industry. The data as presented in this table are summary statistics on the data set used for the regressions on OECD cross-section data (see the following section). Country variation has been mitigated by averaging over the countries in the OECD and the time dimension has been removed by calculating the average annual productivity growth rate for each industry. Taking the average over all rows of either figure 7/8 would result in the data presented in table 2.

Regressions

Most results for this thesis are produced by running linear regression analyses. In a linear regression the goal is to find a line which accurately predicts a correlation in the data from which your sample was gathered. WN showed that the first 5 diseases of the Baumol-Nordhaus model can expressed as reduced-form equations that fit the following regression equation:

$$\hat{x}_{it} = \alpha_i + \gamma_1 \hat{a}_{it} + \gamma_2 D_t + \varepsilon^x_{it} \tag{2}$$

Here $\hat{x}_{it}$ represents one of several variables, $\hat{a}_{it}$ represents the productivity, α_i are time-constant entity effects, D_t are the entity-constant time effects, γ_1 & γ_2 are regression coefficients and finally ε^x_{it} are random disturbances for variable p.

This regression is a fixed effects with time effects regression. Compared to the most basic type of linear regression, ordinary least squares (OLS), a fixed effects with time effects regression accounts for two types of unobservable factors in the data. The first are variables that vary over industries, but remain constant over time. And the second are variables that vary of time, but remain constant over industries. There are two methods to calculate such a regression. The first is to simply perform the OLS with an additional two variables, that represent the two unobservable factors. This method requires the calculation of the regression coefficients for each industry as well as for each time point. This method can be implemented in R by means of the lm() function.

A second method is by using the entity-demeaned version of the original model, which gets rid of time-constant effects by subtracting the time-averaged version of equation 2, from itself.

$$\begin{aligned} \hat{x}_{it} - \bar{x}_i &= \gamma_1(\hat{a}_{it} - \bar{a}_i) \ + \gamma_2(\hat{D}_t - \bar{D}) + (\varepsilon^x_{it} - \bar{\varepsilon}^x_i) \\ \tilde{x}_{it} &= \gamma_1(\tilde{a}_{it}) + \gamma_2(\tilde{D}_t) + \tilde{\varepsilon}^x_{it} \end{aligned} \tag{3}$$

Repeating this process, the second time demeaning by variables averaged over the industries, time effects can also been eliminated. The demeaned model can be performed in R using the plm() function. The main difference between these functions is the fact that the lm() function will calculate all the dummy variables while plm() will only calculate the main variable. Additionally, lm() is more versatile because it is a more general function for linear regressions. It allows the addition of any number of additional variables, rather than requiring a time-constant and an entity-constant variable. Although the lm() function is more versatile, a drawback is computational inefficiency. When using 15 industry groups and 5 time periods the function will calculate 20 separate coefficients, whereas plm() will calculate one.

Specific regressions

The tables reported in the *Results and Discussion* chapter contain multiple variations and specifications of the generalised regression as described in equation 2. Below, the differences between these variations are outlined and the associated equations are described.

For each of the first five diseases, a different variable is regressed against the productivity growth rate. The correlations investigated in the first five diseases are as follows:

1. *Cost and price disease.* How does the price growth rate (deflator of the value added) vary with productivity growth rate?
2. *Stagnating real output.* How does the real output growth rate of industries (real gross value added) vary with productivity growth rate?
3. *Unbalanced growth.* How does the nominal output growth rate of industries (nominal gross value added) vary with productivity growth rate?
4. *Impact on employment and hours.* How does the change in the input of hours of labour vary with productivity growth rate?
5. *Impact on factor rewards.* How does the wage rate (labour costs per hour labour) vary with the productivity growth rate?

Aggregation over countries The most important results in this paper are for the OECD, which is not a single country or a single market. The OECD consists of many countries, but equation 2 does not vary over countries. JH performs a the analysis for a selection for countries (EU15ex), solving this by taking the geometric mean over the values of the different countries. Starting with panel data consisting of values over countries, industries and time. Taking the average over the countries, will reduce the data set to panel data which with observations for variable in each industry in every year.

Following the example of JH, this thesis mostly uses the same principle. But averaging over the countries also comes with the effect of smoothing changes, and discarding information on heterogeneity in the data. The heat map in figure 7 illustrates that no industry performs perfectly consistently over countries. This variation in the labour productivity growth is lost by taking the country average. The advantage on the other hand is that averaging should makes sure that outliers do not impact the data as strongly, and inter-country effects do not affect the results too strongly. Since the Baumol effect should present itself in every developed country.

For completeness, equation 2 could be written as follows when describing the regressions for the OECD/EU15ex, where N_j represents the number of countries. Note that this is not necessary because the country-averages are calculated before performing the regression analysis.

$$\frac{1}{N_j}\sum_{j=1}^{N_j}\hat{x}_{ijt} = \alpha_i + \frac{1}{N_j}\sum_{j=1}^{N_j}\gamma_1\hat{a}_{ijt} + \gamma_2 D_t + \frac{1}{N_j}\sum_{j=1}^{N_j}\varepsilon^x_{ijt} \tag{4}$$

Because equation 2 allows for additional variables to be added. The equation is also extended to take into account differences over countries, shown in equation 5. The present work also uses this equation to calculate the results for the OECD without averaging the countries. In tables 3 & 4 the row called "OECD (panel)" displays the results when regarding the individual country data as a co-parameter. The observations for this row are much higher, with roughly 30 times (30 countries) as many observations as those for the average over the countries. The exact number of observations depends on the data available for each country/industry/year combination. This type of regression was not done for the EU15ex (only the average data was used).

The equation describing the regression account for industry-constant and time-constant country effects, would look as follows, with index j representing the countries, and C_j are time-constant country effects.

$$\hat{x}_{ijt} = \alpha_i + \gamma_1\hat{a}_{ijt} + \gamma_2 D_t + \gamma_3 C_j + \varepsilon^x_{ijt} \tag{5}$$

Aggregation over time WN and JH perform a certain level of time-averaging for each every regression that is performed. The Baumol effect considers progressive industries to show consistent productivity improvements, therefore taking the average over time should not affect if the industry presents itself as progressive or not. Additionally by averaging over time, short-term business cycle effects are mitigated.

One option for time-averaging is to calculate the mean over the whole time period available. The average is the geometric mean, no rolling average is applied.

The whole time range of growth rates is reduced to a single average annual growth rate. This is referred to as the cross-section in the tables (second column). When averaging over time, the data set consists of a single average annual productivity growth rate value for each industry. Two different cross-section values are reported in each table, the "cross-section 1970-2017" and the "cross-section 1991-2017". The former means the average over the entire time range is calculated. The latter data set takes the average over the entire time range, but this time the first 21 year have been discarded from the data before calculating this average. Because the available data in the first two decades is significantly lower than in the later decades, this cross-section might contain more accurate growth rates.

The seemingly low number of observations in some tables in the *Results and Discussion* chapter (for instance the first three rows of table 3) can be understood as follows. To start off, countries are averaged (except for the OECD (panel)), which decreases the number of observations from 30 Countries * 15 Industries * 48 Years = 21600 , to 15 Industries * 48 Years = 720. In the cross section this is further reduced to 15, by dividing by the number of years. The equation for this set of data, a cross-section data set, has changed because the time component has dropped:

$$\hat{x}_i = \alpha_i + \gamma_1 \hat{a}_i + \varepsilon_i^x \tag{6}$$

This equation has a variable for the time-constant industry effects (α_i), but it not longer accounts for industry-constant time effects. Likewise, the cross-section regression equation can be drawn up for the OECD (Panel), i.e. the regression will account for country-specific as well as industry-specific time-constant effects, while discarding any variables that vary over time only.

$$\hat{x}_{ij} = \alpha_i + \gamma_1 \hat{a}_{ij} + \gamma_3 C_j + \varepsilon_{ij}^x \tag{7}$$

Another option for averaging over time is by dividing the set into period. The time parameter is still reduced, but this time multiple time points are still left. In regressions where the second column mentions 5 Periods, the 48 years, are reduced to 5 periods, but taking the geometric average over the following: 1970-1979, 1980-1988, 1989-1998, 1999-2007, 2008-2017. These years approximately correspond to business cycles, while also keeping roughly equally spaced periods. This way the business cycles are also taken into account, while retaining a sense of variation over time. In this case the number of observations left to perform the regression on is 15 Industries * 5 Periods = 75. Finally, the regression equation for this data set is the same as the original, equation 2.

The Growth Disease

The last of Baumol's diseases according to WN is the growth disease. WB states that unbalanced productivity growth will lead to stagnant industries taking up a rising share of the economy. If this is the case, the productivity growth rate should fall over time, as the weight of progressive sectors declines. In order to examine this WN suggests a new measure dubbed the *fixed shares growth rate* (FSGR), which is based on the calculation of a Törnquist index. The Törnquist index for the aggregate productivity growth is defined as:

$$\hat{a}_t = \sum_{i=1}^{n} \hat{a}_{it} S_{it} \tag{8}$$

The S_{it} term is the Törnquist shares of nominal output, which is the share of the nominal output for each industry, taking the arithmetic mean between the previous and the current period.[11]

The formula for the FSGR is:

$$\text{FSGR(T)} = \sum_{i=1}^{n} \overline{\hat{a}_{it} S_{iT}} \tag{9}$$

The important difference between the Törnquist index and the FSGR is the fact that the Törnquist share of nominal output (S_{it}) is used as a time-constant factor here, e.g. when the goal is to calculate the FSGR for 1971, the equation looks like this:

$$\text{FSGR(1971)} = \sum_{i=1}^{n} \overline{\hat{a}_{it} S_{i1971}} \tag{10}$$

When the Törnquist share of nominal output is considered as a matrix with rows i (for industries) and columns t (for time points), the FSGR does does not use the whole matrix like the Törnquist index does. Instead, the calculation is done using a single column (all industries, a single year).

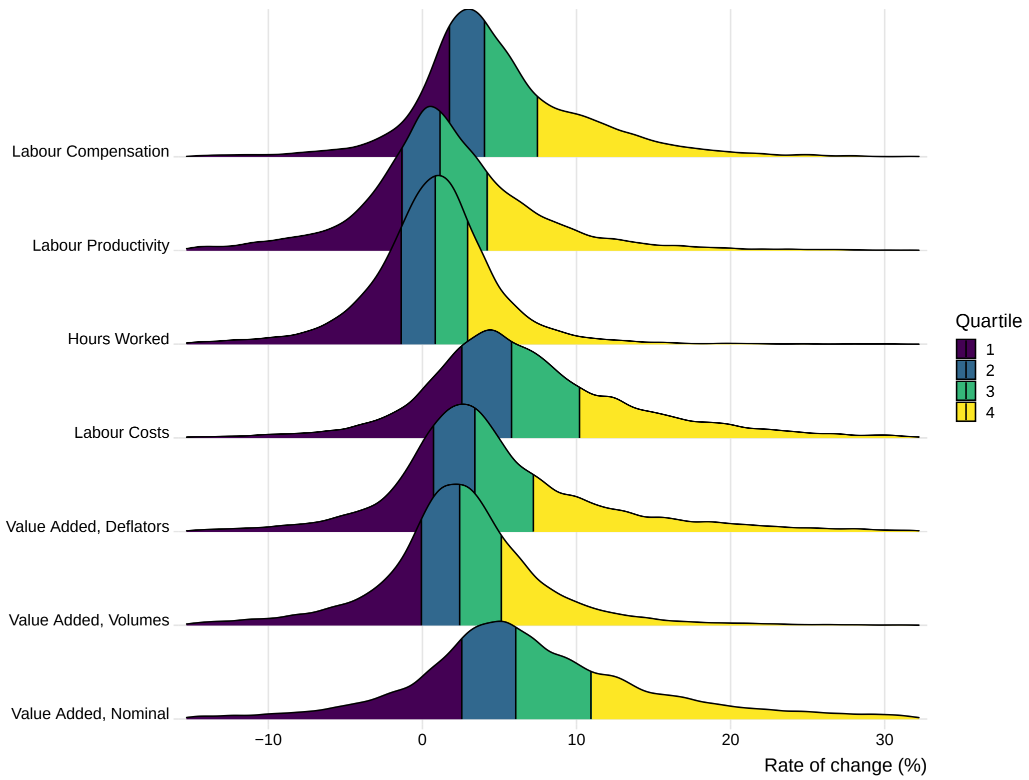
To calculate the FSGR, first the average productivity growth rates for each industry in the OECD or the EU15ex are calculated. Subsequently, the productivity for each industry and each year is multiplied by that industry's nominal output share in one particular "base year". Then these are summed over the industries. Finally, the geometric mean of the resulting vector is taken, to provide a single aggregate value[12]. To examine the growth disease according to WN, the

[11] $S_{it} = \frac{1}{2}\left(\frac{Q_{it}}{Q_t} + \frac{Q_{it-1}}{Q_{t-1}}\right)$ Where Q_{it} is the nominal output and Q_t is the aggregate nominal output

[12] In the derivation for the FSGR by WM, their description of the concept and the results and in the discussion by JH, one issue with the formula for the FSGR was not addressed. The

FSGR is calculated for a range of years. When the share of an industry increases over time, this industry will gain a higher weight. If the industries that gain in weight over time have below-average annual productivity growth, the aggregate productivity growth rate will fall. Since the productivity growth rates for each industry stay the equal and only their nominal shares change, the FSGR can be used to determine if the nominal output share of stagnant industries is rising.

Figure 9: Seven separate density distributions for each variable contained in the estimated data set. The quartiles are illustrated by using four different colours, indicated in the legend. The values of these quartiles as well as the mean can be found in the accompanying table. The limits on the y-axis are chosen from the 99th percentile of the entire data set (not separated into different variables).
Source: OECD (2010, 2016b)



formula multiplies a matrix (2 dimensions, i and t), with a vector which varies with i, but not with t (the subscript is T, which is an input for the formula, therefore a single constant value when calculating). Then the sum is taken over this product, summing over the subscript i. This still leaves the subscript t of the productivity, unaccounted for (leaving the result to be a vector, varying with time). From the description and handling of the results, it seems highly unlikely the intention is to do anything other with that remaining t than to average this number.

Results and Discussion

The following section will deal with the presentation of the results as obtained in this thesis. Additionally, the results will be compared to those obtained previously, to determine how well the different results conform. Based on the results an attempt will be made to determine whether the OECD countries can be considered to be suffering from the diseases as defined in the Nordhaus-Baumol model. The next question is whether this would be sufficient to state that the OECD is suffering of Baumol's disease and finally these answers might be able to contribute towards validation of the claimed universality of the cost disease, as originally stated in WB.

The methods used here are described in the *Data and Methods* chapter. These are all based on the methodology as developed by WN. Due to the unambiguous nature of the suggested tests, it is possible to draw conclusions directly from the results of the data analysis. This is opposed to the older methodologies, such as those employed in Baumol et al. (1985), where after the calculation of average productivity growth rates and such, industries had to be manually classified as stagnant or progressive. A laborious and error-prone process. Additionally,

The Five Costs diseases

The OECD

The primary objective of this study is the investigation of an expanded data set, covering a larger time range and a larger set of countries than the JH study. The results discussed in this first section are those for the OECD. Below follows a short introduction on what the symbols and names in the table mean.

Table Columns Tables 3 through 7 (odd numbers) all have the same column headers, as well as tables 4 through 8 (even numbers). The top headers refer to which the dependent variable was that was used for the specific regression. For diseases 1 through 5 as described in WN, the regressions are performed in the exact same manner. $\hat{x}_{it}$ in equation 2 is a placeholder for the dependent variable, and for each of these the data used were the log difference values. When reading the table, the regression equation associated to it can be found by substituting $\hat{x}_{it}$, with the symbol in the header. The price $\hat{p}$, the real gross value added $\widehat{rgva}$, the nominal gross value added $\widehat{ngva}$, the hours worked by all engaged $\widehat{hemp}$, and finally the compensation paid to employees $\hat{w}$. The labour productivity is $\hat{a}_{it}$ for each case.

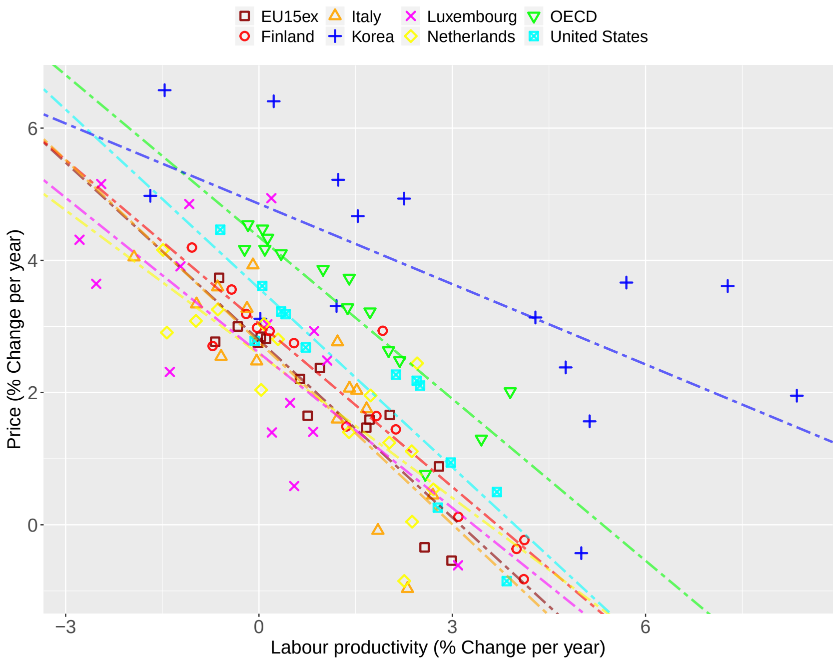
The result for a single regression consists of four parts, firstly the coefficient obtained. Secondly, the standard error belonging to this coefficient reported in brackets. Thirdly, the P-value, reported as between 0 and 3 asterisks. The P-value is important for the significance, and values with no asterisk are not significant, or in other words, no significant relationship has been found between the dependent and the independent variable. This does not necessarily mean there is no relationship, it could also be due to a lack of data or particularly extreme outliers. Finally, the number of observations is reported, the amount of data points used to calculate the coefficient.

To reiterate what was mentioned in the *Data and Methods* chapter; There are a total of six different sets of values for the OECD. Tables 3 and 4 display these results, and the list below can be used for straightforward identification of the regression framework used.

- *OECD* The average growth rates over all countries in the OECD has been taken. The data therefore does not vary over countries anymore.
  - *Cross-Section 1970-2017* The average growth rates over the whole time range is taken. The data therefore does contain time information any more. This regression corresponds to equation 6.
  - *Cross-Section 1991-2017* The average growth rates over the time range 1991-2017 is taken. The data therefore does contain time information any more. This regression corresponds to equation 6.
  - *5 Periods* The average growth rates is calculated for each period. The data is left with 5 time points. This regression corresponds to equation 2.
- *OECD (Panel)*
  - *Cross-Section 1970-2017* The average growth rates over the whole time range is taken. The data therefore does contain time information any more. This regression corresponds to equation 7.
  - *Cross-Section 1991-2017* The average growth rates over the time range 1991-2017 is taken. The data therefore does contain time information any more. This regression corresponds to equation 7.
  - *5 Periods* The average growth rates is calculated for each period. The data is left with 5 time points. This regression corresponds to equation 5.

Using the discussion of the results for the OECD as a guideline for the entire results section, the interpretation of the sign, magnitude and significance of the results will be considered in detail for each of the five variables. In the sections after this, covering the EU15ex, US and a selection of individual countries, the discussion of interpretation will not be repeated in as much detail each time.

Figure 10: The average annual change in price vs. the labour productivity growth, for the 15 industry groups for the Netherlands, Korea, Luxembourg, the US and the aggregates EU15ex and OECD. The values are obtained by calculating the geometric time average of the growth rates of the industries. For the OECD and the EU15ex the averaged growth rates are averaged again over the countries contained in the respective aggregates. In corresponding colours, the modelled linear regression lines are shown for each country/aggregate, these are estimated by performing and OLS-regression, with price as the dependent variable, labour productivity as the independent variable and the industries as co-regressors. Source: OECD (2010) & OECD (2016b)



(1) The cost and price disease hypothesis The first investigated disease is the cost disease. In an economy with differential productivity growth, the expectation is that the prices will rise faster in industries with lower productivity growth. To investigate if the empirical data shows the same trends, a regression is performed to assess the amount of correlation between the growth in prices and the growth in labour productivity. Confirming the cost and priced disease means that when the labour productivity rises more slowly, prices rise more quickly which corresponds to a negative regression coefficient.

Results for the OECD can be found in the top three rows of columns one and two of table 3. All results indicate the confirmation of the price and cost disease, results are all significant and negative, although the 5 Periods regression is less steep (-0,34). Comparing the results with figures 10 and 11, this difference in slope can indeed be observed as well. The first 2 periods seem to have a high spread, which could be causing some problems, but the removal of the first 2 decades with the second Cross-section plot would then be expected to increase

Table 3: Effect of rate of change of productivity on several different variables in the OECD

	$\hat{p}$		$\widehat{rgva}$	
	Coeff.	No. of Obs.	Coeff.	No. of Obs.
OECD				
Cross-Section 1970-2017	$-0{,}816^{***}$ (0,132)	15	0,251 (0,262)	15
Cross-Section 1991-2017	$-0{,}599^{***}$ (0,143)	15	0,131 (0,24)	15
5 Periods	$-0{,}342^{*}$ (0,175)	75	0,02 (0,084)	75
OECD (Panel)				
Cross-Section 1970-2017	$-0{,}435^{***}$ (0,053)	427	$0{,}508^{***}$ (0,055)	427
Cross-Section 1991-2017	$-0{,}327^{***}$ (0,089)	427	$0{,}525^{***}$ (0,062)	427
5 Periods	$-0{,}363^{***}$ (0,047)	1369	$0{,}608^{***}$ (0,058)	1369

Notes: p = price level (deflator of gross value added), rgva = real gross value added (million US$), ngva = nominal gross value added (million US$). The value in parentheses represents the standard error. The significance levels are as follows: P-value $\leq$ 0,01 = ***, P-value $\leq$ 0,05 = **, P-value $\leq$ 0,1 = *. The label OECD refers to the case where the labour productivity growth rates were averaged before performing the regression, whereas the OECD (panel) results were created by using the raw, non averaged data for the regressions, instead incorporating the potential variations between countries in the regression model (Equation 5). Cross-Section implies the time data in the panel was reduced to a single observation by taking the geometric mean over the growth rates of all years specified in the line below it. Therefore these regressions don't incorporate time-effects. Source: OECD (2010) & OECD (2016b)

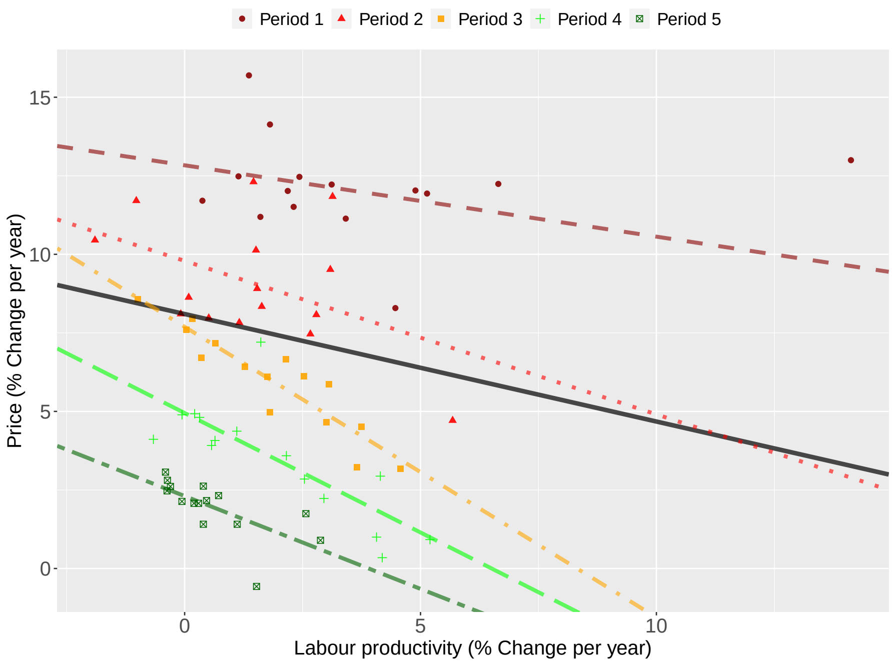
the coefficient with regards to the full time period. It might also be simply related to the weakening of the relationship as time progresses.

The OECD (panel) results agree with the above, although the magnitude of the coefficients are not as high (between -0,33 and -0,44) as the OECD cross-section results. Regardless of the specifics, the data clearly indicate the presence of the cost disease in the OECD countries or at least a heavily weighed majority of countries. Comparing the OECD results to the EU results from JH these are quite similar, ranging between -0,49 and -0,63.

(2) The "constant real share" hypothesis While not necessarily relying on them, the model as described in Baumol (1967) examines a situation in which the ratio of the real output of the stagnant and the high-productivity growth sectors,

Figure 11: Scatter plot of the labour productivity and the price changes for OECD countries, with the range of time from 1970-2017 divided into 5 periods. The regression line obtained using a fixed effects with time-effects model is shown in black (—). The regressions were also run for each period separately. Period 1: – –, Period 2: ... , Period 3: .-.- , Period 4: — —, Period 5: — - —

Source: OECD (2010) & OECD (2016b)



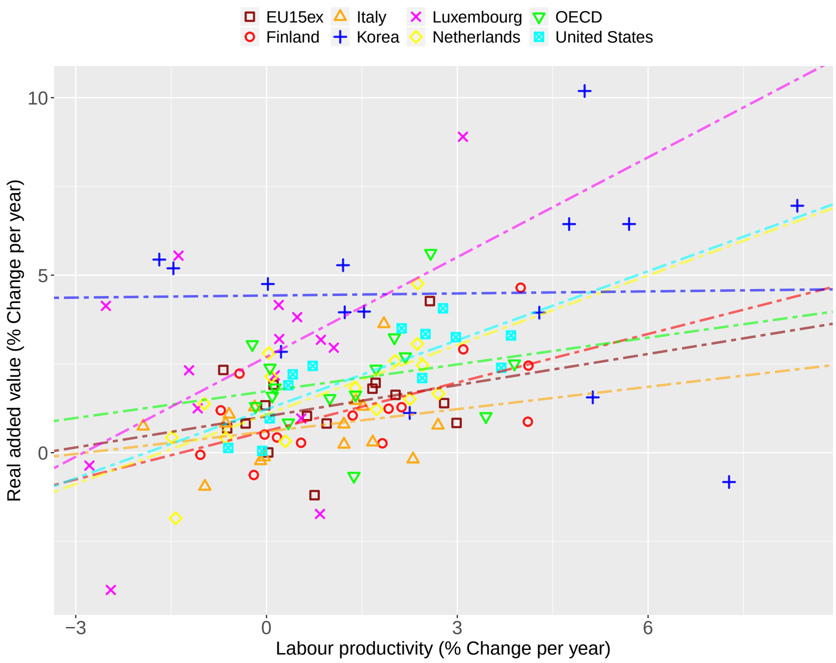
remains approximately constant. Starting from this assumption the model goes on to propose an increase in the labour force of the stagnant industries as well as the futility of trying to balance this phenomena, which would only lead to stagnating growth.

The second disease does not rely on the sign of the relationship necessarily. In the model Baumol finds that if the real output share of the two sectors remains constant, the amount of labour used by the stagnant sectors will rise without limit. Extrapolating from that idea, the expectation is for the coefficient of disease four to be lower than that of disease two. Because if a constant real value added, causes a negative relationship between productivity and employment growth, it would be expected that a slightly positive slope for disease two would result in a less steep negative slope for disease four.

Looking at the results for disease two, columns three and four of table 3 show the results for this regression and the OECD data do not show any significant relationships. The coefficients are slightly positive (between 0,02 and 0,25), which seems to agree with the scatter points on figure 12. For the OECD (Panel), the result are all significant, showing a relatively strong relationship of roughly

0,5. Therefore the results for the OECD (panel) indicate, and the results for the OECD hint at, a higher real output growth for progressive industries. The results also agree with the relationship between disease two and disease four. The OECD (Panel) results have a steeper positive slope than those of the OECD for disease two, and OECD (Panel) has a more shallow slope than the OECD for disease four. This means that if the positive relationship between real output growth and productivity growth is stronger, the negative relationship between employment growth and productivity growth is stronger. The constant real share hypothesis is not overwhelmingly confirmed, although the results fit into the analytical framework well. JH finds coefficients of 0,63 and a non significant -0,04 for the EU, which is a similar spread as between the OECD and OECD (panel) results obtained here. These differences are further discussed in the EU section.

Figure 12: The average annual change in real gross value added vs. the labour productivity growth. The data and the regressions are identical for those described in figure 10, except for using the real gross value added as the dependent variable. Source: OECD (2010) & OECD (2016b)



(3) The unbalanced nominal growth hypothesis For the third disease, the data is presented in columns one and two of table 4. This disease considers to the nominal output of businesses, rather than the real output. Baumol recognised the difficulty in forecasting the fate of the stagnant economic activities. The reason for this is because there is not a single fate laid out, which direction the activity goes depends on the price elasticity of demand. Certain industries will disappear

Table 4: Effect of rate of change of productivity on several different variables in the OECD

	$\widehat{ngva}$		$\widehat{hemp}$		$\hat{w}$	
	Coeff.	No. of Obs.	Coeff.	No. of Obs.	Coeff.	No. of Obs.
OECD						
Cross-Section	$-0{,}539^{*}$	15	$-0{,}733^{***}$	15	$0{,}22^{*}$	15
1970-2017	(0,257)		(0,212)		(0,113)	
Cross-Section	$-0{,}235$	15	$-0{,}826^{***}$	15	$0{,}246^{**}$	15
1991-2017	(0,257)		(0,205)		(0,108)	
5 Periods	$-0{,}111$	75	$-0{,}494^{***}$	75	$0{,}147^{***}$	75
	(0,144)		(0,145)		(0,035)	
OECD (Panel)						
Cross-Section	0,059	427	$-0{,}305^{***}$	427	$0{,}268^{***}$	416
1970-2017	(0,057)		(0,06)		(0,064)	
Cross-Section	$0{,}186^{*}$	427	$-0{,}242^{***}$	427	$0{,}268^{***}$	416
1991-2017	(0,106)		(0,066)		(0,06)	
5 Periods	$0{,}242^{***}$	1369	$-0{,}235^{***}$	1369	$0{,}242^{***}$	1357
	(0,08)		(0,042)		(0,044)	

Notes: The notes are identical to those accompanying 3 except for the dependent variables, hemp = total hours worked by persons engaged, w = labour compensation per hour (million US$ per hour). Source: OECD (2010) & OECD (2016b)

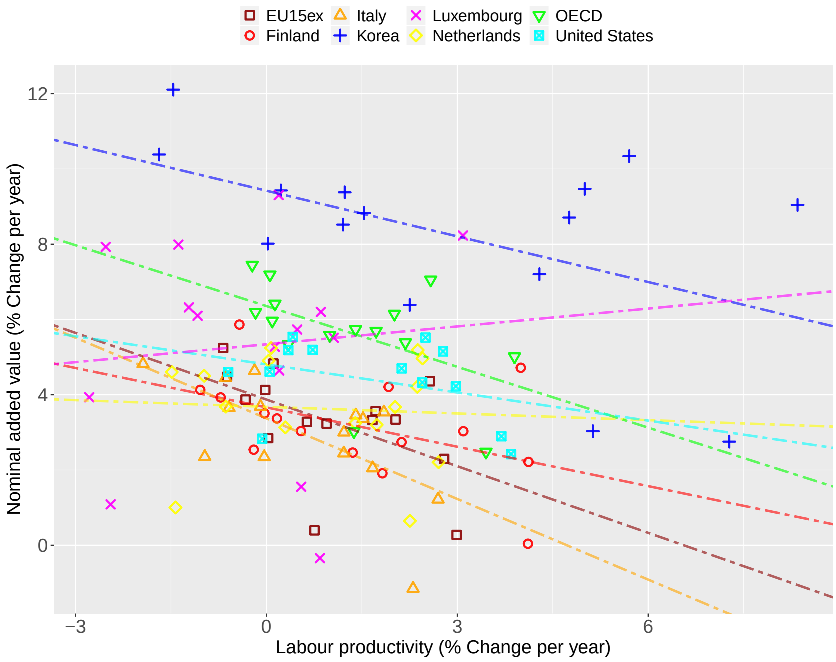
under the pressure of the rising costs, other industries might survive in their own niche for the wealthy for instance, and finally certain industries will simply see rising costs and not disappear which is a trend that seems to be manifesting itself in education and health care (Archibald & Feldman, 2008; OECD, 2019).

In the scenario where both sectors maintain similar real shares in the economy, while the costs are rising in stagnant sectors, this should mean that progressive sectors see a decrease in their added value to the nominal GDP level. With both the conditions roughly confirmed by hypotheses one and two, the unbalanced nominal growth should have a negative slope. The results for the OECD are not very strong due to insignificant coefficients, the only significant coefficient is -0,54 which agrees with the results of figure 13. The OECD results agrees with the EU results from JH, which finds a significant -0,68 for the cross-section. These results indicate that the nominal share of stagnant industries are rising, or that price-inelastic stagnant industries dominate the results.

For the OECD (panel) the only significant coefficient is 0,24, which is not in line with what was described above. In this case, the price-elastic stagnant industries seem to dominate, causing a slower growth of the nominal output. This result is the only result from all results obtained in the present work, as well as WN and JH, that finds a significant positive slope for the nominal output growth.

Theoretically, the sum of the coefficients of the first two hypotheses should add up to the coefficient of the third, therefore the more positive the real output growth coefficient is, the less steeply negative the nominal output growth coefficient should be. Especially the results for the OECD (Panel) conform quite well. The weak cost and price disease (-0,36) combined with a strong positive coefficient for the real output growth (0,61), result in a weakly positive nominal output growth (0,24). For the OECD, the second disease did not obtain a significant coefficient, although the relationship is still not far off (coefficients sum to -0,57 but should sum to -0,54).

Figure 13: The average annual change in nominal gross value added vs. the labour productivity growth. The data and the regressions are identical for those described in figure 10, except for using the nominal gross value added as the dependent variable. Source: OECD (2010) & OECD (2016b)



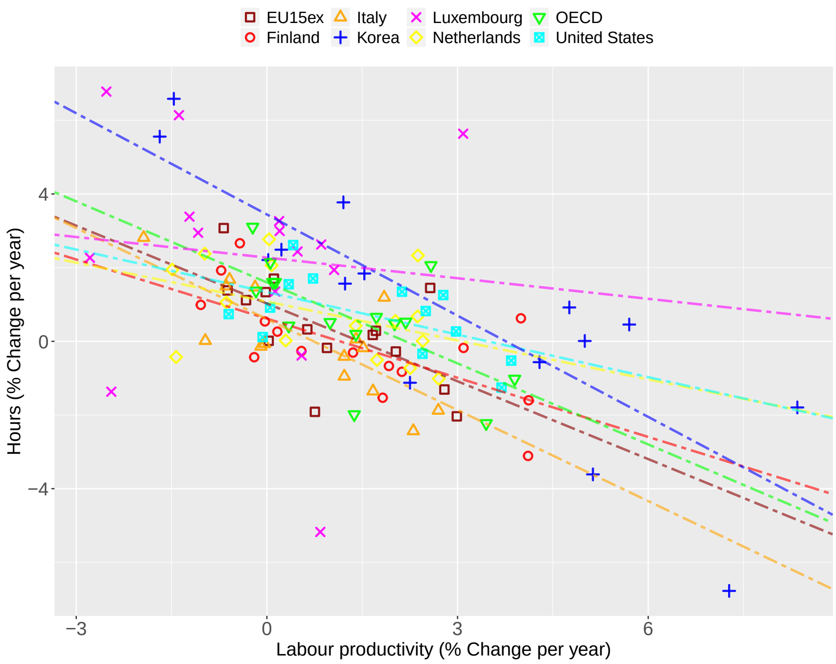
(4) The declining employment shares of progressive industries hypothesis This hypothesis deals with the proposition that as productivity increases in the progressive sector, more and more of the labour force would move into the service sector. As discussed under disease two, this is only the case though when the real share is roughly constant. Although not directly incorporated in the model, confirming this effect in the context of Baumol's disease, could allow some careful hypotheses to be drawn up with regards to income inequality for instance.

To confirm this hypothesis, the relation between employment and productivity should be negative, where the progressive sectors employ fewer workers as they become more productive.

Looking at figure 14, in general high productivity sectors have low employment growth, and the results presented in 4 columns three and four confirm the suspicion. A significant negative relationship is found for each regression (between -0,5 and -0,73 for the OECD and between -0,24 and -0,31 for OECD (panel)). Therefore these results confirm that stagnant sectors are utilising more of the workforce. Hartwig (2011b) found a slope of -1 for the cross-section and -0,34 for the periods. Matching the pattern of the OECD results, while covering a slightly larger range.

The results for the OECD are at least a factor 2 higher than those for the OECD (Panel), but looking back at disease two, the much stronger relationship between the real output and the labour productivity found for the OECD (Panel) data, agrees with this. Theoretically, without any other factors influencing the situation, for stagnant real shares, the expectation would be a slope of -1 for the employment growth and the observed differences get quite close to this. In conclusion, the fourth disease can be confirmed, for both cases, stagnant industries are hiring workers at a higher rate than productive industries.

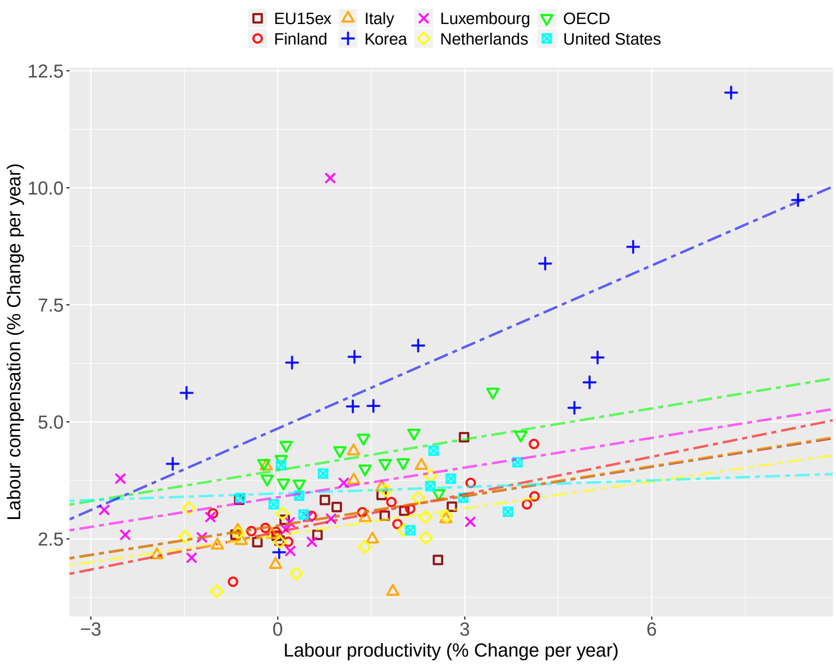
Figure 14: The average annual change in hours employed added vs. the labour productivity growth. The data and the regressions are identical for those described in figure 10, except for using the change in hours employed as the dependent variable. Source: OECD (2010) & OECD (2016b)



(5) The uniform wage growth hypothesis The last of the five diseases diagnosed by regressions, the *uniform wage growth hypothesis* relates to two somewhat intertwined effects tested by the relationship between productivity growth and labour compensation rates. On the one hand, Baumol and Bowen (1965) suggested that the financial stress in the performing arts could be due to the stagnant productivity growth in the sector. Industries with high productivity growth would increase the wages of their workers faster. On the other hand, the Baumol model relies on the notion that stagnant sectors have a wage growth that is comparable to the progressive sector, otherwise the cost disease would not manifest itself. Therefore, the expectation is that the coefficient van be positive, but not strongly. Finding a negative relationship would be surprising and not agree with the Baumol effect.

The results in table 4 shows all coefficients to be statistically significant for the regression between wage rate and labour productivity growth. The magnitude of the coefficients are between 0,15 and 0,27 and the scatter plot in figure 15 shows a shallow positive trend as well. These results indicate that some of the productivity gains of progressive sectors are going towards increasing workers wages at a faster rate. For the EU, JH does not find significant values, although the slope is approximately the same.

Figure 15: The average annual change in labour compensation vs. the labour productivity growth. The data and the regressions are identical for those described in figure 10, except for using the change in labour compensation as the dependent variable. Source: OECD (2010) & OECD (2016b)



Summary of the OECD Although they can seem confusing and conflicting, the interrelation between the different regressions results in a rather straightforward manner for drawing conclusions. Which are summarised in the list below.

1. *Price* The slope of the price regression must be negative, if there is no cost disease present, there could barely be any Baumol disease.

2. *Real output and employment* A constant real share should lead to the employment regression being roughly -1. If there is a slightly positive slope in the real output regression, the employment regression should respond by becoming less steep.

3. *Price, real output and nominal output* For the theoretical model, the coefficients of the price and the real output regressions should sum to the nominal output coefficient. $\hat{p} + \widehat{rgva} = \widehat{ngva}$

4. *Wages* Whether wages grow at similar rates, or if they grow faster in productive sectors. Most importantly, under the Baumol effect, the regression between the wage growth and productivity growth should never have a negative coefficient (i.e. higher wage growth in low productivity growth sectors).

For the OECD and the OECD (Panel) data, the results all point in the direction of the Baumol effect. All five diseases are confirmed, albeit with varying degrees of confidence. The cause of the differences between the OECD and the OECD (panel) are not directly apparent, but the differences can all be accounted for. Quite importantly, there is no ambiguity with regards to the rising costs of the stagnant sectors. Because the cost and price disease is essentially the most important proposition put forth by Baumol (1967), the proper foundation is present for the other effects to manifest themselves. Additionally, employment growth shows a significantly positive relationship for each regression. Which is another important, potentially detrimental symptom of Baumol's disease.

The EU15ex

Because the EU15ex countries[5] were investigated by JH and the fact that the full set of EU15ex countries is included in the OECD countries, repeating the analysis for these countries allows for a direct comparison between the results from the OECD STAN database and the EU KLEMS database. JH concludes that the EU15ex countries are suffering from the cost and growth diseases, although there are some differences with the strength of the effect and the specific relationship between the productivity growth and the different variables.

When using the OECD STAN database, the obtained results for the EU15ex are very similar to those found for the OECD. This might not be surprising due to the inclusion of the EU15ex in the OECD, although the OECD countries contain approximately twenty other countries (amongst which some of the largest economies outside of the EU, such as the US, Korea, Japan and Australia).

Table 5: Effect of the rate of change of productivity on the change price level and the change real gross value added, for the EU15ex aggregate

	$\hat{p}$		$\widehat{rgva}$	
	Coeff.	No. of Obs.	Coeff.	No. of Obs.
EU15ex				
Cross-Section	−0,895***	15	0,293	15
1970-2017	(0,129)		(0,267)	
Cross-Section	−0,801***	15	0,085	15
1991-2017	(0,127)		(0,242)	
5 Periods	−0,386*	75	0,085	75
	(0,208)		(0,074)	
EU15ex (JH)				
Cross-Section	−0,628***	16	−0,037	16
1970-2005	(0,139)		(0,208)	
4 Periods	−0,492***	64	0,633***	64
	(0,141)		(0,085)	

Notes: p = price level (deflator of gross value added), rgva = real gross value added (million US$), ngva = nominal gross value added (million US$). The values in parentheses show the standard error. The significance levels are as follows: P-value $\leq$ 0,01 = ***, P-value $\leq$ 0,05 = **, P-value $\leq$ 0,1 = *. Cross-Section implies the time data in the panel was reduced to a single observation by taking the geometric mean over the growth rates of all years specified in the line below it. Therefore these regressions don't incorporate time-effects. JH means the data comes from Hartwig (2011b). Sources: Hartwig (2011b); OECD (2010, 2016b)

(1) The cost and price disease hypothesis For the first disease, the results for the cross-sections are roughly -0,90 and -0,80, but the periods result is only half as large at -0,39. All data are significant though, therefore the cost and price disease can be diagnosed. JH finds the same conclusion, and also has a higher magnitude in the cross section -0,63, while the periods have a slope of -0,49.

(2) The "constant real share" hypothesis For the second disease, none of the results are significant, and the values of the coefficients of the 1991 cross-section and the periods are both small at 0,09, while the 1970 cross-section is not significant but the magnitude is quite high at 0,29. It seems like there is a tendency for a slightly positive relationship between the real output growth and the productivity growth. The values of of the nominal output growth are slightly lower than the slope of the price regression. This would correspond to a slightly positive real output slope, which we also seem to detect from visual inspection. JH finds conflicting results. The cross-section result is not significant, and small enough at -0,04 to ignore the negative sign. The periods result is strongly positive, with a significant coefficient of 0,6. This result does not necessarily provide evidence against the Baumol effect, because in the first case the real output is roughly constant (-0,037 (0,208)), and the employment coefficient is -1,007 (0,203), roughly -1. In the other case the real output is significantly positive 0,633 (0,085), and the employment coefficient is -0,340 (0,084), in both cases the difference is approximately 1.

Table 6: Effect of the rate of change of productivity on the change in nominal gross value added, change in hours of labour employed and wage rates, for the EU15ex aggregate

	$\widehat{ngva}$		$\widehat{hemp}$		$\hat{w}$	
	Coeff.	No. of Obs.	Coeff.	No. of Obs.	Coeff.	No. of Obs.
EU15ex						
Cross-Section	$-0{,}59^{**}$	15	$-0{,}704^{**}$	15	0,209	15
1970-2017	(0,268)		(0,249)		(0,172)	
Cross-Section	$-0{,}658^{**}$	15	$-0{,}862^{***}$	15	0,249	15
1991-2017	(0,238)		(0,218)		(0,17)	
5 Periods	$-0{,}344^{*}$	75	$-0{,}55^{***}$	75	$0{,}184^{***}$	75
	(0,206)		(0,093)		(0,052)	
EU15ex (JH)						
Cross-Section	$-0{,}679^{**}$	16	$-1{,}007^{***}$	16	0,118	16
1970-2005	(0,276)		(0,203)		(0,117)	
4 Periods	0,140	64	$-0{,}340^{***}$	64	0,188	64
	(0,164)		(0,084)		(0,120)	

Notes: The notes are identical to those accompanying 5 except for the dependent variables, hemp = total hours worked by persons engaged, w = labour compensation per hour (million US$ per hour). Sources: Hartwig (2011b); OECD (2010, 2016b)

(3) The unbalanced nominal growth hypothesis The results for disease three are reported in table 6. All results are negative and significant, with the value for the periods (-0,34), somewhat lower than the value for the cross sections (-0,59 & -0,66). Hartwig finds a significant value of -0,68 for the cross section, and a non significant value (0,14) for the periods. These results fit with seemingly conflicting results for the real output, when looking at the sum of the coefficients.

The price and real output coefficients add up to -0,665 & 0,141, while the nominal output coefficient is -0,679 and 0,140.

(4) The declining employment shares of progressive industries hypothesis In table 6, the values of the employment regressions are all negative and significant. This clearly confirms the fourth disease. JH finds even a larger difference between the two, at -1 for the cross-section and -0,34 for the periods. This does fit with the results for the real output though.

(5) The uniform wage growth hypothesis In the last of the cost diseases, only the periods regression is significant at 0,18 and the cross-section coefficients are not significant, but in the same region at 0,21 and 0,25. So, the wages rise at a slightly higher rate in progressive sectors. JH finds both values non significant but in the same area again at 0,19.

Summarising the EU To summarise, both the data in the present study and the data found by JH confirm the rising costs and rising employment share. The other diseases are confirmed too insofar that they match the theory well. JH does find a remarkable difference between the periods and the cross-section, but this does not matter much because both cases can exists under the Baumol effect. The results from the cross-section match quite well with the situation for price-inelastic demand industries, but maybe this industry showed larger irregularities on shorter time periods.

The United States

The United States have been studies rather extensively before, and therefore a nice comparison can be made between results from different sources and different time ranges. Initially the United States were the point of focus for WB, and while the methodology of Baumol et al. (1985) differs significantly from the one applied in this paper, the basic conclusions on the presence of the Baumol effect can be compared. Additionally, WN performed their newly developed framework on the US, and JH also considered the US for comparison reasons.

Tables 7 & 8 present the results produced in this work, as well as the corresponding results from WN and JH. In the appendix (Table A7), the list of industries used for the analysis can be found, the 15 industries correspond approximately to the 14 industries used by WN and the 16 industries used by JH. Unfortunately, JH did not report their results for the 16 industry grouping of the U.S. data, therefore tables 7 and 8 instead shows the results for the detailed industry classification.

Table 7: Effect of rate of change of productivity on several different variables in the United states, comparing several results obtained by different data sets in this paper and Hartwig (2011b); Nordhaus (2008)

	$\hat{p}$		$\widehat{rgva}$	
	Coeff.	No. of Obs.	Coeff.	No. of Obs.
This paper				
Cross-Section	$-0{,}902^{***}$	13	$0{,}648^{***}$	13
1970-2017	(0,118)		(0,16)	
Cross-Section	$-0{,}851^{***}$	13	$0{,}521^{**}$	13
1991-2017	(0,136)		(0,168)	
5 Periods	$-0{,}427$	51	$0{,}206^{**}$	51
1970-2017	(0,263)		(0,096)	
Nordhaus				
Cross-Section	$-0{,}921^{***}$	14	$0{,}673^{***}$	14
1948-2001	(0,097)		(0,167)	
Cross-Section	$-0{,}1000^{***}$	14	$0{,}682^{***}$	14
1977-2000	(0,145)		(0,231)	
4 Periods	$-1{,}073^{***}$	42	$0{,}610^{***}$	42
1948-2001	(0,277)		(0,136)	
Hartwig				
Cross-Section	$-0{,}600^{***}$	55	$0{,}941^{***}$	55
1977-2005	(0,021)		(0,034)	

Notes: p = price level (deflator of gross value added), rgva = real gross value added (million US$), ngva = nominal gross value added (million US$). The value in parentheses represent the standard error. The significance levels are as follows: P-value ≤ 0,01 = ***, P-value ≤ 0,05 = **, P-value ≤ 0,1 = *. Cross-Section implies the time data in the panel was reduced to a single observation by taking the geometric mean over the growth rates of all years specified in the line below it. Therefore these regressions don't incorporate time-effects. Nordhaus used data derived from the BEA, Hartwig from the EU KLEMS database and this paper uses OECD STAN data. Sources: Hartwig (2011b); Nordhaus (2008); OECD (2010, 2016b)

(1) The cost and price disease hypothesis The results for the U.S. can be found in the top four rows of columns one and two of table 7. For the United States, there is no question about the presence of the cost and price disease. Each result shows a highly significant (P-value ≤ 0,01) coefficient with a negative sign, except for the Periods which is negative but not significant. The results suggest that for each percentage point difference in labour productivity growth, the price level changes between 0,85 and 0,9 percentage points. Figure 10 shows a scatter plot of the rate of change of prices and the productivity growth rate, the negative relationship is clear.

The results from both WN and JH correspond to those found here. WN finds the largest values, reporting significant values between -0,92 and -1,1. JH finds a lower magnitude of 0,60. Although there are differences in the magnitude of the effect, these too conclude that the United States are suffering from the cost disease. This result implies that the source for the majority of price trends in the long term, are the trends in productivity. Another interesting takeaway noted by WN is the fact that this implies that nearly all the gains from technological progress are passed on to the consumer.

(2) The "constant real share" hypothesis Columns three and four of table 7 show the results for this regression and generally the trend seems rather clear, all coefficients were positive and all three are statistically significant. Slightly curious is the fact that for the Periods regression, the coefficient is much lower.

The results from the Cross-sections correspond to the value found for disease four, but the shallow slope from the Periods should result in a steep curve for disease four. The coefficient for the Periods regression of disease four though, is very shallow, and although it is non significant, there is a very large difference with the expected value (around -0,7/-0,8).

The results found by WN and JH also agree with those found here, although their results have steeper positive slopes. JH finds a very steep slope of 0,94. While WN reports values of 0,67/0,68 for the cross-section, and 0,61 for the periods. Most notably the 5 periods regression found a slope which seems to fall outside the range suggested by WN and JH. Perhaps productivity growth trends in the first two decades were somewhat erratic, with non-monotonic behaviour causing some artefacts.

(3) The unbalanced nominal growth hypothesis In table 8, the findings for the cross-section data are not significant, but for the regressions using both three and five periods, the results are non significant but do all show a negative curve, which figure 13 seems to support, implying that there is a tendency of low-productivity sectors to see a rise in their nominal output share.

The results found by WN for this regression also indicate a negative relation, although this value is not significant. JH has a coefficient value of approximately 0, although the slope is non-significant. From summing the price and real output, the slope of the nominal output in JH's data, should be approximately 0,3, which the standard error does not seem to really support. But the non significant result still means no real conclusions ought to be drawn from the result in any case.

(4) The declining employment shares of progressive industries hypothesis Figure 14 offers a pretty solid a negative relationship between productivity growth and employment growth. The results presented in 8 columns three and four confirm this as well. A significant negative relationship is found for both cross-sections, with values of -0,39 and -0,45. The results confirm that more

Table 8: Effect of rate of change of productivity on several different variables in the United states, comparing several results obtained by different data sets in this paper and Hartwig (2011b); Nordhaus (2008)

	$\widehat{ngva}$		$\widehat{hemp}$		$\hat{w}$	
	Coeff.	No. of Obs.	Coeff.	No. of Obs.	Coeff.	No. of Obs.
This paper						
Cross-Section	−0,249	13	−0,385**	13	0,047	13
1970-2017	(0,213)		(0,174)		(0,085)	
Cross-Section	−0,33	13	−0,446**	13	0,085	13
1991-2017	(0,206)		(0,184)		(0,136)	
5 Periods	−0,232	51	−0,125	51	−0,198	51
1970-2017	(0,215)		(0,136)		(0,174)	
Nordhaus						
Cross-Section	−0,272	-	−0,327***	14	0,019	14
1948-2001	(0,195)		(0,267)		(0,062)	
Cross-Section	-	-	−0,317***	14	0,017	14
1977-2000	-		(0,213)		(0,125)	
4 Periods	-	-	−0,392***	42	0,013	42
1948-2001	-		(0,136)		(0,11)	
Hartwig						
Cross-Section	−0,007	55	−0,041	55	0,029	55
1977-2005	(0,035)		(0,033)		(0,016)	

Notes: The notes are identical to those accompanying 7 except for the dependent variables, hemp = total hours worked by persons engaged, w = labour compensation per hour (million US$ per hour). Sources: Hartwig (2011b); Nordhaus (2008); OECD (2010, 2016b)

productive sectors are utilising less and less of the workforce. Although the relationship is confirmed, the magnitude of the coefficient is not particularly high, which is caused by the relatively unbalanced real share growth (average slope at least 0,5). The results from WN correspond to this quite well, their coefficients ranging between -0,32 and -0,39, whereas JH on the other hand finds a non-significant coefficient of -0,041.

(5) The uniform wage growth hypothesis The results in table 8 shows not a single coefficient to be statistically significant for the regression between wage rate and labour productivity growth. The Periods regression coefficient is given to be negative, although with a standard error nearly equal in size, not too much should be observed from this. The magnitude of the other coefficients are all very low and correspond well to those found by WN and JH, 0,02 and 0,03 respectively. The scatter plot in figure 15 seems to show a very slightly positive trend, although, as the regressions indicate, there is no clear linear relationship between the two variables. The most important aspect here is that the wages are found to grow uniformly over stagnant and productive industries, or productive industries exhibit higher growth. This is confirmed for the US.

Summarising the US The results for the five costs diseases, or symptoms, as described by WN allow for the diagnosis of the US with Baumol's cost disease. Generally, the results from the analysis here corroborate those obtained in WN, the slopes are often not quite as steep but generally the same trends are observed, and the diagnosis of the diseases is mostly concerned with the sign of the coefficient. A comparison with the results from JH shows some key differences, the most important being the results on the *unbalanced nominal growth hypothesis* and the *declining employment shares of progressive industries*, and of these especially the employment shares surprises. The nominal output shares deals with some ambiguous concepts as well as different potential outcomes for stagnant activities depending on their price elasticity. The share of the labour force employed by the stagnant versus the progressive sector on the other hand should show a relatively straightforward trend at least. Perhaps the fact that for comparison the industry level data from JH was used here introduced some discrepancies, although the detailed industry results for the employment share regressions by WN corresponded to his results on the broad industry level.

Individual countries

When performing a robustness analysis of the WN and JH papers there are two possible approached. The first is more rigid, following steps taken (especially those by JH) literally. In the other approach, the original article is used as a guideline for the analyses to be done. For most analyses, these two approaches overlap. But in the following section there are two different options, both of which could be useful. In JH, the author performs a robustness check of their own work, by applying the analysis for the EU15ex on the two countries with the lowest and highest productivity growth rates. JH finds that Italy has the lowest labour productivity growth rate over the period of 1970-2005, 1,8%. Finland on the other hand shows the highest rate, at 3,0%. If the results of these countries with the largest possible difference in aggregate productivity growth in the set, confirm the results found for the EU15ex. Then the heterogeneity between countries can be regarded as inconsequential for diagnosis of Baumol's disease.

To avoid choosing either direction, and because of low amount of added work, the analysis has been performed for five individual countries (in addition to the US). In order to perform the most comprehensive analysis, the current paper performs the analysis on the countries chosen by JH, Italy and Finland. Additionally, the top and bottom performers of the OECD countries are chosen. Figure 6 shows these countries are now Korea (4,5%) and Luxembourg (0,3%) respectively, with Italy and Finland located around the 1st and the 3rd quartile.

The results for Italy and Finland can be found in Tables A1 & A2. The results for Korea and Luxembourg can be found in Tables A5 & A6. Finally, the Netherlands was one of three countries which had productivity data available for each year and for each industry measured, additionally the aggregate productivity growth rate for the Netherlands is near the median value of the OECD, which means the entire spectrum is covered by these five countries. The results for the Netherlands can be found in Tables A3 & A4.

The Netherlands, as might be expected for a near-median country, shows results very similar to those for obtained for the OECD and the EU15ex. In fact, none of the countries examined disagree with the results obtained for the aggregates. There are some different effects visible, such as Korea with a nearly constant real share, whereas Luxembourg has a nearly 1 tot 1 relationship between real output and growth. Still, these are limiting cases, both allowed in the scope of the Baumol model. It is also interesting how Italy, located at approximately the bottom quartile of figure 6 has a very low / constant real share, while Korea, the maximum of figure 6, also has near a near constant real share. Granted, these values are not significant, but figure 12 corroborates the fact that changes in productivity growth do not cause variation in the real output growth for these two countries. The level of aggregate productivity growth does not significantly impact the Baumol effect. In conclusion, the results for the aggregate can be sufficiently confirmed by limiting cases, under significant heterogeneity.

The Growth Disease

The Growth Disease as WN calls it, is different from the other examined diseases. Firstly, the analysis performed is not a regression analysis like the first five diseases. Secondly, in personal correspondence between Baumol and Nordhaus, Baumol mentioned that in the original model, the intention was not to imply Baumol's disease would slow down economic growth, the disease was purely intended as a cost disease (Nordhaus, 2008).

In the Nordhaus-Baumol model, the sixth part of the method for testing the Baumol effect is the growth disease. WN asks the question whether the stagnant industries have rising shares of total nominal output and if this is the case, would this result in lower productivity growth and living standards? How does the changing composition of output of the economy, implied by the Baumol model, affect the productivity growth rate of the entire economy. The method introduced

Table 9: Fixed-Shares Growth Rates: Average Fixed-Weight Labour Productivity Growth with Different Base Years for OECD and EU15ex Countries

	EU15Ex		OECD	
Base Year	All Industries	Without Business Activities	All Industries	Without Business Activities
1971	2,35%	1,61%	2,99%	2,08%
1976	2,27%	1,54%	2,93%	2,04%
1981	2,22%	1,50%	2,89%	1,98%
1986	2,17%	1,41%	2,85%	1,90%
1991	2,09%	1,32%	2,75%	1,78%
1996	2,01%	1,25%	2,71%	1,71%
2001	1,87%	1,19%	2,65%	1,63%
2006	1,89%	1,11%	2,59%	1,55%
2011	1,87%	1,04%	2,55%	1,47%
2016	1,84%	1,02%	2,53%	1,45%
Regression coefficient	0,0175***	0,0139***	0,0107***	0,0155***

Notes: The FSGR is calculated as the average annual industry growth rates, weighted by nominal share in the base year. Repeating this calculation for successive base years, results in the rows shown above. The declining percentage indicates that the nominal shares of industries with low productivity is increasing. In the bottom row the results of an OLS-regression are shown, confirming a significantly negative relationship. When excluding the business activities, the trend still persists. Source: OECD (2010) & OECD (2016b)

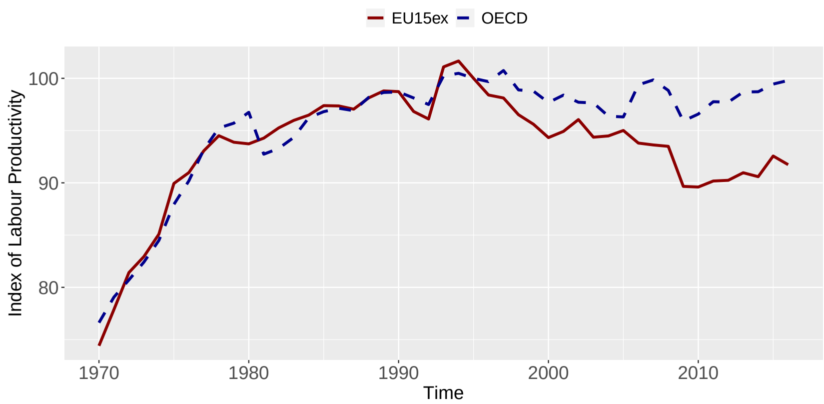
by WN to test for the growth disease is by a measure dubbed the FSGR, the Fixed Shares Growth Rate, the mathematical derivation of which is discussed in the *Data and Methods* chapter.

Table 9 presents the results found from the OECD STAN database, aggregating the full set of countries examined or the subset of the EU15ex countries, to allow for comparison with the results from Hartwig (2011b). The results obtained seem to paint a very clear picture, for both the OECD and the EU15ex, the average fixed shares productivity growth rate clearly declines as the weighting year is increased from 1971 to 2016, in steps of 5 years. To reiterate, since the average productivity growth rate is declining as the years are increased, this means the nominal share of the industries with a lower productivity growth rate are gaining more weight in later years than in earlier years. Therefore, the OECD countries as well as the EU15ex countries can be diagnosed with the growth disease according to this model. The same conclusions were drawn in WN and JH, and the decline found happens at a remarkably similar rate.

The coefficient found in the bottom row of table A7 are the results of an OLS regression run on the calculated FSGR values to check for a significant relationship, all of which are significant with P-values below 0,01.

The second and fourth column of table 9 show the productivity growth rates calculated while excluding the business activities (D68T82), which was done for two reasons. Firstly, JH reported these results. The reasoning for the exclusion of the business activities by JH mainly drew from the fact that upon encountering some anomalies, the business activities sector was identified as potentially disruptive to the results. *Business activities* showed the largest increase in the nominal share (from 4,0% to 11,6%) between 1970 and 2005, and a largely stagnant productivity increasing at an average annual rate of 0,7% during this same period. Yet, when looking at annual productivity year by year, a steeply rising productivity can be observed in the first 13 years of the period, after which the productivity levels off. Moreover, looking back at figure 7 the productivity growth rate for this industry group shows fluctuating behaviour. Finally, figure 16 is based on a figure from JH[13]. And the results are similar as well. In the first decade measured, this industry has a relatively high rate of productivity growth, after this though the sector stagnates, falling even for the EU15ex (using OECD STAN data). The nominal share increase for the sector were not as high as those found by JH, but the fact that the OECD STAN data has the volume index in the EU15ex falling since 2000, rather than stagnating, means the industry could certainly throw off results obtained using time-averaged data. Getting back to table 9, when excluding the business activities, there are no changes with regards to the conclusions drawn from the results.

Figure 16: Volume Index of Productivity of the Industry Group "Real estate, Renting of Machinery and Equipment, and Other Business Activities" (1995 = 100). The red (—) line and the blue (– –) line represent the EU15ex and the OECD, respectively. Source: OECD (2010) & OECD (2016b)



[13]The figure shows the same data as figure 2 in Hartwig (2011b), using the OECD STAN data. The figure was not copied or adapted from that work.

Conclusion and Reflection

The overarching goal of this thesis was to provide a robustness check of the Baumol-Nordhaus model. This was done by analysing data from the OECD STAN database and comparing the results to those found previously by Nordhaus (2008) and Hartwig (2011b) for the United States and the EU, respectively. The results described here mostly agree with their findings, although there are some differences. Notably, the results for the United States found by Hartwig (2011b) and the current work both were weaker than those found by Nordhaus (2008). Nevertheless, all results fit into the framework provided by the Baumol-Nordhaus model, and therefore this thesis also confirms the A summary of the results for the six diseases Nordhaus (2008) described is presented below.

Summary of results

The Cost and Price disease is strongly confirmed, regardless of which different data set is used, the coefficient is always negative and nearly all results are significant. These results indicate that prices in low productivity growth industries are indeed rising faster than in high productivity growth industries, the results for the OECD and the EU agree with those for the United States, although the cost disease is experienced more strongly in the US.

For the second disease, the results are variable with respect to those found by Hartwig (2011b); Nordhaus (2008). WN finds significant positive correlations for each regression, and the OECD STAN results for the US confirm these. As such, stagnant industries are found to exhibit a slower growth in their real output. For the EU and the OECD, the results have less statistical significance, but the coefficients are moderately positive. Due to the lack of statistical significance, stagnating real output hypothesis cannot be confirmed, but the results do not conflict with the other results.

The nominal output growth is not affected by the productivity growth in a straightforward manner. Nominal output growth depends on the price elasticity of the industry. Inelastic industries should exhibit a negative coefficient, whereas elastic industries should show positive coefficients. Considering the diverse mix of industries included, variability in the results is not surprising. For the OECD results gave showed a significant negative relation when all countries were averaged, and a significant positive relation when they countries were not averaged. The EU results are more coherent, with significant negative coefficients, indicating a growth of the nominal output of stagnant industries. This is in line with the OECD results, because the EU was only tested with all countries averaged. Finally, theoretically the coefficient for the price disease and the real output growth should add up to the nominal output growth, which is approximately confirmed.

For each regression WN, JH and this paper find the growth in employment to be negatively related to the productivity growth. As expected, stagnant industries consume an increasing share of the labour force.

The final regression was between the wage growth and productivity growth, both WN and JH do not find any significant relationship, although the coefficients found are slightly positive. This paper does find a weakly positive relationship (<0,25) for the OECD, and one significantly positive result of the EU. This indicates that in the OECD the growth of wages is slightly higher in sectors with higher productivity growth. Which would mean that not all of the productivity increases are put into lowering prices, but some are put into raising wages.

The final results is the on the growth disease, which finds that the nominal share of total output of stagnant services has increased in the past decades. This means that a growing share of the economy consists of low-productivity growth industries, this increased nominal share of output has the effect of lowering aggregate productivity growth.

For the OECD, the most important figures were (pp = percentage point):

- **Price vs Productivity** Approximately a 0,6 pp decline in the price growth, for each 1 pp increase in productivity growth.
- **Real output vs Productivity** None to a very slight real output growth for each 1 pp increase in productivity growth.
- **Nominal output vs Productivity** Approximately a 0,3 pp decline in the nominal output growth for each 1 pp increase in productivity growth.
- **Hours worked vs Productivity** Approximately a 0,7 pp decline in the rate of change of employment for each 1 pp increase in productivity growth.
- **Wage rate vs Productivity** Approximately 0,2 pp wage growth for each 1 pp increase in productivity growth.
- **Nominal share growth** Low-productivity growth sectors have gained more weight in terms of nominal output since 1970.

Baumol's disease

Baumol's disease has existed for over five decades, it was already more than forty years old when Nordhaus (2008) formulated his version. Some of the evidence in favour of the model and the relatively small amount of evidence against the model has been discussed in the literature review[14]. Most earlier work on the

[14] The lack of evidence against the model does not mean there is none to be found. This could be due to the unwillingness of authors to publish negative results, the old age of the model, or because it is not considered to have real potential for explaining macroeconomic effects.

Baumol disease tested the model using methods that did not necessarily rule out other explanations. For instance, Hartwig (2011a) tests the correlation between the change in relative price of medical care and the change in total health care expenditure. By finding a positive coefficient the authors conclude in favour or Baumol's disease, yet the results do not necessarily rule out other explanations. The Baumol-Nordhaus model encounters a similar problem. Because it is an empirical model, it cannot analytically validate the model, it can only find data that supports or contradicts the Baumol model. But by examining six diseases, the model creates a redundancy. Therefore more alternative explanations can be ruled out, since the chances of other explanations fitting six results are significantly smaller than fitting a single result.

Certain predictions and implications follow from the Baumol effect that can be observed in real world economies. As noted before, the most prominent effects are rising health care costs and rising education costs. More generally the paradox of services, which is the phenomenon that in services are rising but they still maintain a relatively constant or growing share of the economy, and employ an increasing share of labour (Ten Raa & Schettkat, 2001). Finally, job inequality has risen in developed economies in recent years (Acemoglu & Autor, 2010; David & Dorn, 2013). These separate phenomena can be explained by the Baumol model, but this does not mean this is guaranteed to be the real or only explanation. The Baumol effect does not rely on specific properties of industries affected by rising prices or inequality, rather by the common property of stagnant/service industries that wage growth outpaces productivity growth. But, identifying the unique characteristics of industries affected by problems, in order to find the underlying cause is also valid. Additionally, because of the different focus of those approached, the results do not necessarily exclude the Baumol effect. A number of alternative explanations are presented below.

Rising costs in health care has been noticed by researchers for years, but conclusive answers have been difficult to obtain. The only assured relation that has been found, is a positive relationship between health care spending and GDP (McCarthy & Hoffmeyer, 1994). Despite the lack of conclusive findings, the theory of Newhouse (1992) has been relatively well received. According to the author, the most important drivers of health care spending are an ageing population, rising incomes, new medical technologies and an overly high insurance coverage. Pauly (2003) considers the price of labour an important driver of health care spending, and does so without placing this in the context of the Baumol model.

Increases in costs and spending on education were addressed by Bowen (1980). He introduces the *revenue theory of costs*. This theory is based on the idea that the educational institutions (especially in the US) have a strong interest in prestige and excellence, due to the strong competition for students and prominent scientific results. Combined with the difficulty in determining the educational output of money that is put into the institute, the result is that all revenue is always spent. As more money is provided, more money is spent as well. Archibald and Feldman (2008) finds that most data favours Baumol over Bowen, but does not rule out the coexistence of both effects.

Another important and often cited factor in explaining rising costs of services is the difficulty in measuring these industries. For instance, there are indications that the price indices of medical care are consistently upward biased (Berndt et al., 2000), because these measurements do not consider the improvement of the quality of medical care (Boskin, Dulberger, Griliches, Gordon, & Jorgensen, 1996). There are more authors that note that the rising costs of services are the product of flawed measurements of their productivity, for instance the fact that services often have no time between the production of the product and the consumption of the product can cause problems in determining their value added. Furthermore, labour productivity can be considered a poor measure of output when labour is inherently part of the product provided by services (Bell, 1968; Brynjolfsson, Rock, & Syverson, 2017; Cowen, 1996; Griliches, 1998; Syverson, 2017).

Finally, the growth of the service sector, rising job polarisation and wage inequality have been of interest for a long time. In modern times the rise of computers, robots and in the near future AI (artificial intelligence) are sometimes suggested as the cause for these effects. These technologies are increasingly capable of replacing people at routine-task jobs. The lower costs for these machines decreases wages and causes workers to be forced to seek employment in services which are more difficult to automate (Acemoglu, 2002; David & Dorn, 2013), causing a significant growth of the service industries. By replacing human workers and therefore labour input, productivity can be improved significantly. This means that it is very likely these technologies are part of progressive industries, but surprisingly, there have been few productivity improvement attributed to improvements in IT up to now (Brynjolfsson et al., 2017), which could be because the technology enhances the productivity at people rather than replacing them altogether. The most recent wave of technologies lead by AI, have the potential to replace workers at complex mental tasks as well (for instance pattern recognition), whereas most previous technologies replaced more physical or simpler tasks. This could mean that workers with a higher skill level would also be at risk of automation (Arntz, Gregory, & Zierahn, 2017; Furman & Seamans, 2018).

This thesis does not provide an final answer for Baumol's disease. There are several questions that require further research before an unambiguous statement on the model can be made. An important question which is still unanswered is whether the implications of the Baumol effect will in fact come true. It is true that prices in sectors which could be classified as stagnant are rising, services are growing and wage inequality has risen in the past decades. But there is still no guarantee these are caused by the Baumol effect, to what degree these could be impacted by other effects and if these trends will persist. It is also interesting to consider what would happen when the Baumol effect reaches the limits. As the effects of the Baumol model manifest themselves, the nominal and labour share of the progressive sector will decrease up to a point where the progressive sector has nearly vanished. As the growth of the total economy slows down, the Baumol effect should also taper off. Would this result in a cycle of an increasing and decreasing degree of the Baumol effect? What would be the result? Furthermore it would be interesting to find out if all industrialised countries exhibit Baumol's disease or whether some countries are exempt? Even if all countries exhibit signs of the disease, some countries exhibit the Baumol effect to a weaker degree than others. By finding the cause for this, it might be possible to slow down the Baumol effect in the worst suffering countries.

Implications for economic policy

The results obtained by this work as well as previous publications provide evidence in favour of the Baumol effect. Assuming this model correctly describes a critical determinant for rising costs and a growing stagnant sector, it is worth considering if policy could help diminish the effects. Baumol (1967) stated that any measures taken to try to stop the Baumol effect, would be futile in the long run. This can be understood by noting that the origin of the Baumol effect lies in the fundamental discrepancy in productivity growth between industries, and the inevitable wage increases required in both for as long as both sectors continue to exist. This poses a problem, because it seems like there are no options. Regulations in the form of price controls can be tempting, but considering the underlying problem and the fact that wages will not stop rising, price controls are likely to decrease the quality of the output of the industry or bring them into severe financial trouble. For instance in the performing arts, where the goal of keeping ticket prices affordable causes a type of self imposed price control. These price controls put increasingly larger strain on their supporters, and the financial troubles are not solved, nor expected to change (Baumol & Bowen, 1965).

Nevertheless, some suggestions are offered by Helland and Tabarrok (2019) and Archibald and Feldman (2008). Productivity is defined as the output per unit of labour that is put in. To improve productivity, either labour can be reduced or output can be increased. For education, increasing the use of computers and IT seems to offer a straightforward solution. Computers could replace labour input by professors, and in the form of online or digital courses the output can be increased from teaching a hundred students in an hour, to teaching potentially thousands. Additionally, further improvements in computations, will directly increase the productivity of these digital courses. In a way this allows the coupling of a stagnant industry, to a progressive. In health care similar technologies can be employed, such as the promise shown by AI in diagnosing cancer and other diseases for instance (Wrzeszczynski, 2017).

On another note, it is not certain that something actually has to be done. In his most recent work on the cost disease Baumol (2013), WB stands by the argument made by Robinson (1969), which states that as long as there is aggregate productivity growth, rising costs of services will not matter much, because less money is spent on non-services. Therefore, spending more on essential services is no problem, everything else got cheap enough that in the net result is still that more goods and services can be bought. The designation of the Baumol effect as a disease is actually a misnomer, since there is nothing wrong that should or could be fixed. The economy is not diseased and it is still growing and specifically because of the aggregate growth of the economy, the Baumol effect manifests itself. If there was no growth, there would be no cost disease, but the future of the economy would certainly be worse (Baumol, 1967).

A potential objection to these solutions stems from the fact that neither Baumol (2013), nor Helland and Tabarrok (2019) address the implied inequality. In fact, the solution offered to increase productivity in these sectors involves displacing human labour. This labour, would potentially be forced to move into lower skilled jobs, increasing inequality. Additionally, the positive outlook described by Baumol (2013) does not address the issues the United States faces with student debt, the fact that medical debt is the number one cause of personal bankruptcy in the USA, or other factors that several limit the standard of living (Gordon, 2017; Himmelstein, Thorne, Warren, & Woolhandler, 2009). This could be an oversight, but this could also be because the price increases are not completely explained by the Baumol effect and other factors come into play as well. Another explanation might be that this debt is the result of overspending on goods that have become relatively more affordable. For instance, if the price of phones has decreased by 30%, but the consumer now buys two new phones, in total more money is spent and less money is left for services.

If a society sets the goal of decreasing inequality or maximising the average quality of life, a certain degree of redistribution of wealth could be required, since other measures cannot be guaranteed to work. Taxing extremely wealthy individuals and providing a basic income to assure a minimum standard of living for the least well of could be a solution. This would suppose a basic level of appropriation of goods in an "unjust" manner, according to Nozick for instance. But the concept of taxes and welfare are already employed in most states, therefore this would not require a significant deviation from the status quo. Differences in the strength of the Baumol effect between countries are present, for instance Korea shows a weaker manifestation of the Baumol effect than the USA (Oh & Kim, 2015). This might indicate there are specific institutions and regulations in place in Korea that act as successful countermeasures or retardants of Baumol's disease. Although it might be that Baumol's disease will gain in strength there as well. Finally, policymakers should strive to increase education levels. Because of the increase in the college premium, and the high utilisation of highly skilled workers in highly productive industries, ensuring a basic level of education could lead to levelling the playing field for chances of getting jobs in high productivity sectors (Allen, 2017; Vivarelli, 2014). The high school movement in the United States in the early 20th century is attributed to a significant improvement of the standard of living (Allen, 2011).

Limitations

The final section of this thesis details some of the limitations regarding the empirical study that was performed. Firstly, a general remark: A robustness check is not a guarantee for a valid model. Despite the advantages offered, performing a robustness check does not assure the validity of the model. Therefore, some reservations regarding the results should be held.

Next two limitations with regards to the source data are considered. The measure used for all calculations was the value added, which is not the ideal measure for final goods and some errors could be introduced as a result. Secondly, certain industries are notoriously difficult to measure. Mostly service industries. Due to the broader industry aggregation, these problems should not be as persistent, but they could skew results (O'Mahony & Timmer, 2009).

Continuing with limitations of the data selection and formatting, the analysis here only used a single level of industry grouping. Using different industry aggregations could provide a more rounded view of the results. Both WN and JH used three different levels of industry aggregation which would occasionally result in different data. Related to the industry aggregation level, is the low number of observations for the cross-section regressions. These only contain 15 observations, one for each industry. Had the most detailed level of industries been used, then those cross-sections would still consist of 50+ observations. WN and JH do both also use the results from regressions with 14 to 16 observations. Finally a consideration on industry merging between the third and the fourth revision of the STAN database, which required manually checking two concordance tables. This leaves room for error and the different industry classifications are not perfectly compatible. Therefore, this could have an impact on the estimated data set. Although the Rev. 4 data set was only supplemented by Rev. 3 data where necessary, to minimise this issue.

Finally, not all of the methods were as clearly mentioned as others in JH and WN. Therefore, there were times when an educated guess had to be made about which method was most likely to be applied. Most notably, the equation for the FSGR would result in a vector with a time dimension, instead of a scalar as required by the expected results. Taking the average to deal with this is quite straightforward, but sit does require an additional assumption. Another thing missing is the specification of which type of mean has been calculated. Generally speaking, growth rates are averaged using a geometric mean, however the lack of specification could cause some differences.

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Appendix

Table A1: Effect of rate of change of productivity on several different variables in the some member countries of the OECD

	$\hat{p}$		$\widehat{rgva}$	
	Coeff.	No. of Obs.	Coeff.	No. of Obs.
Finland				
Cross-Section 1970-2017	$-0{,}824^{***}$ (0,064)	15	$0{,}455^{**}$ (0,201)	15
Cross-Section 1991-2017	$-0{,}638^{***}$ (0,087)	15	0,327 (0,189)	15
5 Periods	$-0{,}666^{***}$ (0,081)	75	$0{,}398^{***}$ (0,101)	75
Italy				
Cross-Section 1970-2017	$-0{,}919^{***}$ (0,158)	15	0,21 (0,209)	15
Cross-Section 1991-2017	$-0{,}864^{***}$ (0,245)	15	$-0{,}02$ (0,124)	15
5 Periods	$-0{,}613^{***}$ (0,105)	58	0,109 (0,117)	58

Notes: p = price level (deflator of gross value added), rgva = real gross value added (million US$), ngva = nominal gross value added (million US$). The value in parentheses represents the standard error. The significance levels are as follows: P-value ≤ 0,01 = ***, P-value ≤ 0,05 = **, P-value ≤ 0,1 = *. Cross-Section implies the time data in the panel was reduced to a single observation by taking the geometric mean over the growth rates of all years specified in the line below it. Therefore these regressions don't incorporate time-effects. Source: OECD (2010) & OECD (2016b)

Table A2: Effect of rate of change of productivity on several different variables in the some member countries of the OECD

	$\widehat{ngva}$ Coeff.	No. of Obs.	$\widehat{hemp}$ Coeff.	No. of Obs.	$\hat{w}$ Coeff.	No. of Obs.
Finland						
Cross-Section	$-0{,}349$	15	$-0{,}535^{**}$	15	$0{,}268^{***}$	15
1970-2017	(0,228)		(0,195)		(0,086)	
Cross-Section	$-0{,}293$	15	$-0{,}633^{***}$	15	$0{,}185^{**}$	15
1991-2017	(0,182)		(0,174)		(0,076)	
5 Periods	$-0{,}272^{***}$	75	$-0{,}513^{***}$	75	$0{,}144^{**}$	75
	(0,095)		(0,083)		(0,058)	
Italy						
Cross-Section	$-0{,}714^{**}$	15	$-0{,}824^{***}$	15	0,212	15
1970-2017	(0,259)		(0,189)		(0,137)	
Cross-Section	$-0{,}623^{***}$	15	-1.02^{***}	15	0,224	15
1991-2017	(0,148)		(0,113)		(0,162)	
5 Periods	$-0{,}508^{***}$	58	$-0{,}884^{***}$	58	$0{,}438^{***}$	58
	(0,117)		(0,126)		(0,088)	

Notes: The notes are identical to those accompanying A1 except for the dependent variables, hemp = total hours worked by persons engaged, w = labour compensation per hour (million US$ per hour). Source: OECD (2010) & OECD (2016b)

Table A3: Effect of rate of change of productivity on several different variables in the Netherlands

	$\hat{p}$ Coeff.	No. of Obs.	$\widehat{rgva}$ Coeff.	No. of Obs.
Netherlands				
Cross-Section	$-0{,}725^{***}$	15	$0{,}652^{**}$	15
1970-2017	(0,144)		(0,222)	
Cross-Section	$-0{,}849^{***}$	15	$0{,}595^{***}$	15
1991-2017	(0,137)		(0,156)	
5 Periods	$-0{,}227$	75	$0{,}487^{***}$	75
	(0,235)		(0,144)	

Notes: p = price level (deflator of gross value added), rgva = real gross value added (million US$), ngva = nominal gross value added (million US$). The value in parentheses represents the standard error. The significance levels are as follows: P-value $\leq$ 0,01 = ***, P-value $\leq$ 0,05 = **, P-value $\leq$ 0,1 = *. Cross-Section implies the time data in the panel was reduced to a single observation by taking the geometric mean over the growth rates of all years specified in the line below it. Therefore these regressions don't incorporate time-effects. Source: OECD (2010) & OECD (2016b)

Table A4: Effect of rate of change of productivity on several different variables in the Netherlands

	$\widehat{ngva}$ Coeff.	No. of Obs.	$\widehat{hemp}$ Coeff.	No. of Obs.	$\hat{w}$ Coeff.	No. of Obs.
Netherlands						
Cross-Section	−0,059	15	−0,352	15	0,192	15
1970-2017	(0,298)		(0,221)		(0,109)	
Cross-Section	−0,278	15	−0,401**	15	0,256***	15
1991-2017	(0,215)		(0,153)		(0,057)	
5 Periods	0,247*	75	−0,458***	75	0,102**	75
	(0,147)		(0,112)		(0,045)	

Notes: The notes are identical to those accompanying A3 except for the dependent variables, hemp = total hours worked by persons engaged, w = labour compensation per hour (million US$ per hour). Source: OECD (2010) & OECD (2016b)

Table A5: Effect of rate of change of productivity on several different variables in the some member countries of the OECD

	$\hat{p}$ Coeff.	No. of Obs.	$\widehat{rgva}$ Coeff.	No. of Obs.
Korea				
Cross-Section	−0,405***	15	0,019	15
1970-2017	(0,115)		(0,252)	
Cross-Section	−0,427***	15	0,071	15
1991-2017	(0,14)		(0,329)	
5 Periods	−0,242**	41	−0,099	41
	(0,099)		(0,187)	
Luxembourg				
Cross-Section	−0,782***	15	0,937	15
1970-2017	(0,147)		(0,55)	
Cross-Section	−0,877***	15	0,857	15
1991-2017	(0,131)		(0,511)	
5 Periods	−0,431***	45	0,395	45
	(0,148)		(0,315)	

Notes: p = price level (deflator of gross value added), rgva = real gross value added (million US$), ngva = nominal gross value added (million US$). The value in parentheses represents the standard error. The significance levels are as follows: P-value ≤ 0,01 = ***, P-value ≤ 0,05 = **, P-value ≤ 0,1 = *. Cross-Section implies the time data in the panel was reduced to a single observation by taking the geometric mean over the growth rates of all years specified in the line below it. Therefore these regressions don't incorporate time-effects. Source: OECD (2010) & OECD (2016b)

Table A6: Effect of rate of change of productivity on several different variables in the some member countries of the OECD

	$\widehat{ngva}$		$\widehat{hemp}$		$\hat{w}$	
	Coeff.	No. of Obs.	Coeff.	No. of Obs.	Coeff.	No. of Obs.
Korea						
Cross-Section 1970-2017	−0,404 (0,229)	15	−0,916*** (0,193)	15	0,58*** (0,147)	15
Cross-Section 1991-2017	−0,387 (0,265)	15	−0,916*** (0,193)	15	0,58*** (0,147)	15
5 Periods	−0,367*** (0,135)	41	−0,945*** (0,118)	41	0,8*** (0,143)	41
Luxembourg						
Cross-Section 1970-2017	0,158 (0,472)	15	−0,186 (0,611)	15	0,211 (0,263)	15
Cross-Section 1991-2017	−0,024 (0,463)	15	−0,186 (0,611)	15	0,211 (0,263)	15
5 Periods	−0,054 (0,285)	45	−0,583* (0,305)	45	0,201 (0,192)	45

Notes: The notes are identical to those accompanying 3 except for the dependent variables, hemp = total hours worked by persons engaged, w = labour compensation per hour (million US$ per hour). Source: OECD (2010) & OECD (2016b)

Table A7: List of 15 broad industry categories

	2-digit industries	
Industry	Rev. 4	Rev. 3
Agriculture, forestry and fishing	D01T03	C01T05
Mining and quarrying	D05T09	C10T14
Manufacturing	D10T33	C15T37
Electricity, gas and water supply; Sewerage, waste management and remediation activities	D35T39	C40T41 + C90
Construction	D41T43	C45
Wholesale and retail trade; Repair of motor vehicles and motorcycles	D45T47	C50T52
Accomodation and food service activities	D55T56	C55
Transportation and storage	D49T52	C60T63
Information and communication; Postal services	D53 + D58T63	C64 + C72
Financial and Insurance	D64T68	C65T67
Real estate, renting and other business activities	D68T82	C70T71 + C73T74
Public administration and defence; Compulsory social security	D84	C75
Education	D85	C80
Human health and social work activities	D86T88	C85
Other community, social, and personal service activities	D90T99	C91T99