CPB Netherlands Bureau for Economic Policy Analysis

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Productivity Slowdown

Evidence for the Netherlands

On request by the Ministry of Economic Affairs

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Productivity Slowdown - Evidence for the Netherlands

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Summary

The productivity slowdown is a much discussed topic. Most OECD countries have experienced a slowdown in recent decades, but show different patterns. For the US, studies find that productivity growth accelerated after around 1995, after which it slowed down again around 2000. The ICT revolution is often mentioned as an explanation for this pattern. For other countries, studies find a productivity slowdown that starts later than in the US. In addition to the ICT revolution, a number of other explanatory factors are mentioned in the literature, such as education or the age structure of the population. This paper analyses how The Netherlands compares to other countries in terms of the productivity slowdown. It also includes a comparison of different sectors and tests possible explanatory variables.

Our results show a widespread productivity slowdown. There is some variation in the timing of the slowdown, but all the countries in our datasets seem to experience historically low productivity trends in recent years. We find that labour productivity growth in the Netherlands dropped from 1970 onwards, with a notable bump around 2000. This is not caused by cyclical factors, such as business cycles, the Great Recession and bank crises. We find evidence, although no hard proof, that the slowdown of the past decade may consist of a return to a 'normal' growth rate after the ICT boom in the late 1990s. Our regression results show that before the Great Recession, highly intensive ICT sectors contributed significantly more to productivity growth than other sectors. When the period is extended until 2015, this significant effect disappears. When we include explanatory variables for this slowdown, almost none turn out to be significant, except share of women in the workforce, education level, the contribution of ICT capital services to value added growth (ITK) and the contribution of non-ICT capital services to value added growth(non-ITK intensity).

Various methods are used to study the productivity slowdown. Since observed productivity growth is subject to significant period-to-period volatility, the underlying trend should first be isolated before conclusions can be drawn about the growthrate. The methods commonly used in the literature range from simple averages to more sophisticated technical techniques (such as state space models or SSM). A much used method to separate cyclical components from structural trends is filtering, of which the Hodrick-Prescott (or HP) filter is the most well-known. We apply the HP filter and compare the results with those obtained by the more sophisticated SSM and find the results show little difference. Not only are we interested in the structural trend of productivity growth, we also would like to know whether there are structural breaks in the trend, and when these occurred. To detect these, we use the Bai and Perron, (1998) statistical methodology. We only find one significant trendbreak, in 1978.

We investigate productivity slowdown for OECD countries between 1970 and 2014. A number of datasets exist that contain labour productivity growth data. We use the KLEMS and OECD databases, which are most comprehensive. For the SSM, we use the Total Economy Database (TED). Data for the analysis on the Dutch productivity slowdown was obtained from Statistics Netherlands. We combined

several datasets to generate a complete dataset (in terms of available variables, countries, sectors and years). However, not all datasets are compatible, limiting our analysis of explanatory factors.

Samenvatting

De vertraging van de productiviteitsgroei is een veel besproken onderwerp. De meeste OESO landen hebben een vertraging ervaren in de recente decennia, maar laten verschillende patronen zien. Studies over de VS vinden dat de groei versnelde na ongeveer 1995, waarna de groei vertraagde rond 2000. De ICT-revolutie wordt vaak genoemd als verklaring voor dit patroon. De studies met meerdere landen vinden verschillende patronen voor verschillende OESO landen, maar de meeste constateren ook een daling van de productiviteitsgroei die later inzet dan de Amerikaanse. Naast de ICT revolutie wordt ook een aantal andere verklarende factoren voor de vertraging vermeld in de literatuur. Deze notitie analyseert hoe Nederland zich vergelijkt met andere landen op het gebied van de productiviteitsvertraging. Het bevat ook een vergelijking van verschillende sectoren en test mogelijke verklarende factoren.

Onze resultaten laten een wijdverspreide vertraging zien. Er is enige variatie in de timing van de vertraging, maar alle landen in onze datasets lijken historisch lage productiviteittrends te ondervinden in de afgelopen jaren. We zien dat de groei van de arbeidsproductiviteit in Nederland vanaf de jaren zeventig is gedaald, en na een opvallende hobbel rond 2000 verder vertraagde. Dit wordt niet veroorzaakt door conjuncturele factoren, zoals de conjunctuurcycli, de Grote Recessie en de bank crises. We vinden aanwijzingen, hoewel geen harde bewijs, dat deze vertraging komt door een terugkeer naar 'normale' productiviteitsgroei na de ICT boom in de late jaren negentig. Hierbij zien wij als 'normale' groei de gemiddelde productiviteitsgroei sinds het begin van de jaren tachtig, waarbij productiviteitsgroei vrij constant is met ups (ict-boom) en downs (financiële crisis).

Onze regressie resultaten tonen aan dat vóór de Grote Recessie, zeer intensieve ICT-sectoren beduidend meer aan productiviteitsgroei bedroegen dan andere sectoren. Wanneer de termijn wordt verlengd tot 2015, verdwijnt dit significant effect. Wanneer we andere verklarende variabelen meenemen, lijken er geen significant te zijn, met uitzondering van het aandeel van vrouwen op de arbeidsmarkt, onderwijsniveau, de bijdrage van ICT-kapitaaldiensten aan groei van toegevoegde waarde (ITK) en de bijdrage van niet-ICT-kapitaaldiensten aan groei van toegevoegde waarde (niet ITK intensiteit).

Verschillende methodes zijn in gebruik om productiviteitsgroei te meten. De waargenomen productiviteitsgroei laat aanzienlijke periodieke volatiliteit zien. Daarom moet eerst de onderliggende trend geïsoleerd worden voordat er conclusies kunnen worden getrokken over de groeivoet. De methodes die in de literatuur worden gebruikt variëren van het nemen van gemiddelden tot geavanceerde technische technieken zoals *state space models* of SSM. Een veelgebruikte methode om cyclische componenten uit de trendmatige groei te halen is een filter, waarvan de Prescott-Hodrick (HP) filter de meest bekende is. We passen de HP filter toe en vergelijken de resultaten met die verkregen door de meer geavanceerde SSM, waarbij we weinig verschil zien. We zijn niet alleen geïnteresseerd in de structurele trend van productiviteitsgroei, maar willen ook weten of er omslagpunten zijn in de trend, of

structurele trendbreuken. Om deze te detecteren gebruiken we de Bai and Perron, (1998) statistische methode. We vinden slechts een sigificante trendbreuk, in 1978.

Er zijn een aantal datasets die gegevens bevatten over de groei van de arbeidsproductiviteit. Wij gebruiken voor de regressie analyses de KLEMS en OESO-datasets, die het meest uitgebreid zijn. Voor de SSM gebruiken we de Total Economy Database (TED). De data voor de Nederlandse productiviteitsvertraging is verkregen van het CBS. We hebben verschillende datasets gecombineerd om een complete dataset te hebben (in termen van beschikbare variabelen, landen, sectoren en jaren). Omdat de datasets niet geheel compatibel zijn, is onze analyse van verklarende factoren beperkt.

1 Introduction

The productivity slowdown is a much discussed topic. Several studies have found that productivity growth in the developed countries decelerated in recent years (OECD (2016, Syverson (2016, Mas and Stehrer (2012, Connolly and Gustafsson (2013). Various recent studies are available for the large European economies and the US, but not the Netherlands itself. The Ministry of Economic Affairs requested the CPB to investigate the evidence for a trend productivity slowdown in the Netherlands. To understand the slowdown, we analyse whether the trends in productivity growth are driven by country or sector-specific factors, focusing on the development of labour productivity.[1] We test a few specific factors that may explain the reasons behind the slowdown.

We find that labour productivity growth in the Netherlands has slowed down after a bump around 2000. This is not caused by cyclical factors, such as business cycles, the Great Recession and bank crises. We find evidence, although no hard proof, that this slowdown may consist of a ’return to normal’ after the ICT boom in the late 1990s. We assume that the ’normal’ productivity growth is the average growth since the eighties, which is more or less constant, with ups (the ICT boom) and downs (the financial crisis).

Our regression results show that before the Great Recession, highly intensive ICT sectors contributed significantly more to productivity growth than other sectors. When the period is extended to include the Great Recession, this significant effect disappears. When we include explanatory variables for this slowdown, almost none turn out to be significant, except share of women in the workforce, education, the contribution of ICT capital services to value added growth (ITK) and the contribution of non-ICT capital services to value added growth (non-ITK intensity).

Most evidence cited in the literature of a productivity slowdown is based on five-year averages, linear trend estimations or filtering techniques. However, there are a few methodological issues that spur concerns about the validity of the evidence. Multiple negative shocks, such as the Great Recession and double dip recessions, may have led to indications of a productivity slowdown while the underlying productivity growth rate may have remained unchanged. It is therefore important to filter out these effects to determine the actual trend productivity growth rate. We do so by running a battery of testing procedures that aim to pick up changes in the productivity growth rate and trend. In addition, we use an innovative approach by applying a structural space model to detect changes in the trend productivity growth.

In section 2, we outline the literature concerning the productivity slowdown and likely explanations. In section 3 we describe the methodology used in the analyses. Section 4 reviews the data used. The subsequent sections present the results of the different methodologies. Section 5 presents and discusses the

[1] measured as Gross Domestic Product (or GDP) per hour worked.

estimation of the growth trend of Dutch labour productivity. Section 6 delves deeper into the sectoral data. Section 7 presents and discusses the panel regressions for the periods 1996-2005 and 1997-2014. Section 8 concludes.

2 Overview of the productivity slowdown literature

Key message: For the US, studies find in general that productivity growth accelerated after around 1995, and slowed down again around 2000. The ICT revolution, which started around the mid-1990s, is often mentioned as an explanation for this pattern. The multi-country studies find various patterns for different countries. However, most find also a productivity slowdown in OECD countries, but later than the US. In addition to the ICT revolution, a number of other explanations for the slowdown are mentioned in the literature.

2.1 Empirical evidence

2.1.1 Studies of the US

US studies, in general, show a rise and fall of productivity growth in the last two decades. A prominent example is the work of Fernald (2015). When analysing quarterly labour productivity growth of the business sector, he uses results of Bai-Perron break tests to distinguish sub-periods.[2] During a sub-period that spans from 1973 to around 1995, the mean growth rate was around 1.5%. In the following short sub-period from 1995 to 2003, the growth rate was an exceptional 3.4%. After 2003, i.e. well before the Great Recession, the mean growth rate returned to its older level (1.6% during 2003-2007 and 1.8% during 2007-2013). Fernald claims that the productivity surge after 1995 was fuelled by widespread IT adoption. Once its benefits were reaped, productivity started to slow down, mainly in industries that produced ICT or that used ICT intensively. Using industry and regional data, he rejects that developments in the housing and financial sector are driving the productivity slowdown.

This pattern in productivity growth is supported by Kahn and Rich (2007) who estimate a Markov switching model with two regimes, using quarterly data from 1947 to 2002. They find that the difference of the annual growth rate of (nonfarm) output per hour between the high- and low-growth regimes is around 1.4%. The estimated duration is 100 quarters for the high-growth regime and 59 quarters for the low-growth regime. They find two clear regime switches in this period. The high-growth regime lasted until the early 1970s, after which a low-growth regime followed. The US returned to the high-growth regime around 1997. The sample was too short to assess the fall in productivity growth after mid 2000s.

[2] See his Figure 1. It is not always clear whether he refers to an observed or to a trend growth rate. Trend values seem to be calculated by means of a bi-weight kernel.

2.1.2 Multi-country studies

OECD (2016) discusses trends in productivity growth in the OECD, focusing on the G7-countries. Trend values are calculated using the HP-filter (see section 3.3 for more on the HP filer) with $\lambda = 54$ for the period 1970–2014. They conclude that the slowndown is a common feature among advanced economies and that it is not a recent phenomenon, as it started before both the Great Recession and the ICT revolution.

The rich analysis of labour productivity by Bergeaud et al. (2015) covers the long period 1890-2012 for an extended set of 13 countries, including the Netherlands.[3] The study uses both HP-filtered series (with $\lambda = 500$) and Bai-Perron break tests. When taking a long term view, they distinguish two main productivity waves. The first big wave is linked to the second technological revolution, which started in the US during the 1930s and the 1940s and spread across Europe and Japan only after the Second World War. The second, smaller and shorter, wave originated from the ICT revolution. The corresponding productivity acceleration was first observed in the US during the 1980s and the 1990s, while other countries (except the UK) again benefited with a lag. The productivity slowdown in the UK started only after the Great Recession (see also Cette et al. (2016)). They attribute this diffusion lag to a lower average education level of the working age population and to higher labour and product market regulation. The break tests result in country-specific productivity breaks. For the Netherlands significant breaks are found for 1928 (1978 and 2008 (while the change in productivity was not significant in 1973 and 1983). They note that the results on recent break dates might not be robust due to the impact of the large contraction in economic activity during the Great Recession.

A comparable analysis is performed by Wegmuller (2015) using quarterly data from 1960 to 2013 for 15 countries (unfortunately without the Netherlands[4]). In addition to the Bai-Perron break tests, he applies the time-variation methodology in trend labour productivity growth. First, he finds substantial evidence of structural breaks in 10 out of 15 countries, mainly around the first and second oil price shock. A break in the early 2000s is only found for four countries, all European. The analysis does not explain why this is the case. Second, time-varying parameters are detected for 13 countries. In particular, evidence strongly suggests a collapse in trend productivity growth in the Eurozone countries. Finally, the two approaches give mixed results for the US. In contrast to other studies, significant breaks are not found. However, in line with US-studies, the approach based on time-varying parameters shows an acceleration of (median) productivity growth starting in the mid-1990s

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[3] The set of countries include the G7, Spain, the Netherlands, Australia, Finland, Norway and Sweden. Results for the Netherlands are presented in their Appendix.

[4] Compared to Bergeaud et al. (2015), the set of countries (listed in the previous footnote) is extended with Austria, Ireland and Korea, while the Netherlands is dropped.

(from 1.5% to 1.9% in 2002Q2), followed by a reversion to a ’normal’ level (1.6% in 2013Q4).

2.1.1 Proposed explanations of the productivity slowdown

Many explanations are put forward to explain the productivity slowdown. An overview is provided by a recent OECD publication (see OECD (2016, p.16)). In our subsequent analysis, we test the following explanations put forward by the literature on productivity slowdown:

1. Current technological breakthroughs are less transformative than previous innovations. ICT is less useful than electricity for productivity growth (Cowen (2011); Gordon (2012)). This theory would be consistent with productivity growth being slower across all countries and sectors.
2. The slow productivity growth is simply a reflection of low demand (see McGowan et al. (2015)). In response to low demand with flexible labour markets, wages have fallen rather than employment making measures of productivity fall. Again, this theory places the slowdown as starting after 2008 and should be more visible in those sectors where output is more elastic with respect to GDP. It should also be more evident in those countries where unemployment rose less since it relies on the available work being spread amongst more workers who accept lower pay.
3. Some, like Fernald (2015), have argued that the slowdown in the US is simply a return to normal after the ICT fed growth boom of the late 1990s and early 2000s. In the US there was a boom of expenditure on ICT which led to rapidly rising labour productivity. This boom happened to a smaller extent in other countries and sectors, hence their slowdown should be smaller. The extent of the slowdown should be related to extent of ICT investment in the boom years.
4. Recent innovations may have been winner takes all (Brynjolfsson and McAfee (2011)). The EU market for services is not complete limiting the scale achievable by European firms in those sectors. This implies that the slowdown should be most visible in those sectors that are least tradeable, since tradeability implies a larger possible market (Eaton et al. (2011); Breinlich and Criscuolo (2011)).
5. Demographic changes may have played a role. Feyrer (2007) shows that the proportion of workers between 40 and 49 is associated with productivity growth across a sample 87 countries. As people age, their productivity follows an inverse U shape. In the early stages of someoneâ€™s working life, productivity increases as new skills are learnt and their experience increases. Eventually, though, these improvements are counteracted by reduced physical and cognitive abilities brought on by ageing. Furthermore, Kogel (2005) finds a relationship between the dependency ratio and total factor productivity. The demographic processes are not the same in all countries; if this is the major cause behind the slowdown there should be observable differences between countries.
6. Differences in education levels may explain different patterns in productivity growth (see, for instance, Bergeaud et al. (2015)).

Other explanations are mentioned in the literature that we do not take into account, mainly due to a lack of appropriate variables or proxies in the available data. See section 8 for proposals for future research.

Services, including personal services, make up an increasing share of GDP and they are not so obviously able to profit from productivity gains as manufacturing. Countries that have seen the largest shifts to services should see the largest slowdowns. The shift-share analysis in Elbourne and Grabska (2016) suggests this is not the case for the Netherlands.

Others have argued that adoption of new technology requires changes to organisational structures, which take time to fully realise (Brynjolfsson and McAfee (2011), Baily et al. (2013)). This view suggests the slowdown should be greatest in industries and countries that are spending the least on intangible investment in management and organisational capital.

Andrews et al. (2015) report that frontier firms are still growing strongly but the lagging firms in each industry are falling further behind. In other words, technology diffusion has slowed. Different countries have leading firms in different sectors. This theory suggests that the slowdown should be most visible in sectors in which that country is not a leader.

Others have argued that the latest ICT innovations may, instead of increasing the quantity of output possible for all, simply be enabling economies of scale for a few (McGowan et al. (2015)). This view suggests the productivity slowdown should have been the greatest where rents of previously inefficient producers have been eliminated by the economies of scale of large foreign producers.

The financial crisis in 2008 reduced the availability of external finance, which slowed the available financing for innovative activities (Aghion et al. (2014); Nanda and Nicholas (2014)). This implies that the slowdown should take place during or after 2008 and that sectors with the largest need for external finance should have been hardest hit.

There might also have been misallocation due to low real interest rates (Cette et al. (2016)). This implies that the slowdown should be visible in the early 2000s when real interest rates started to fall. Furthermore, real interest rates have fallen more in some countries than others, heightening their risks of misallocation (see also Hsieh and Klenow (2010)).

Furthermore, firm size may determine productivity growth, although conclusions on the effects are divided. Some find that large firms are typically more productive than small firms (see Criscuolo et al. (2014)). Others, for instance Kox et al. (2007), find an inverse U relationship, with small and large firms being least productive.

Finally, there is some debate whether measurement problems are a likely explanation (see also McGowan et al. (2015)). However, many recent papers argue this is not the case (see for instance Cette et al. (2016) or Byrne et al. (2016)).

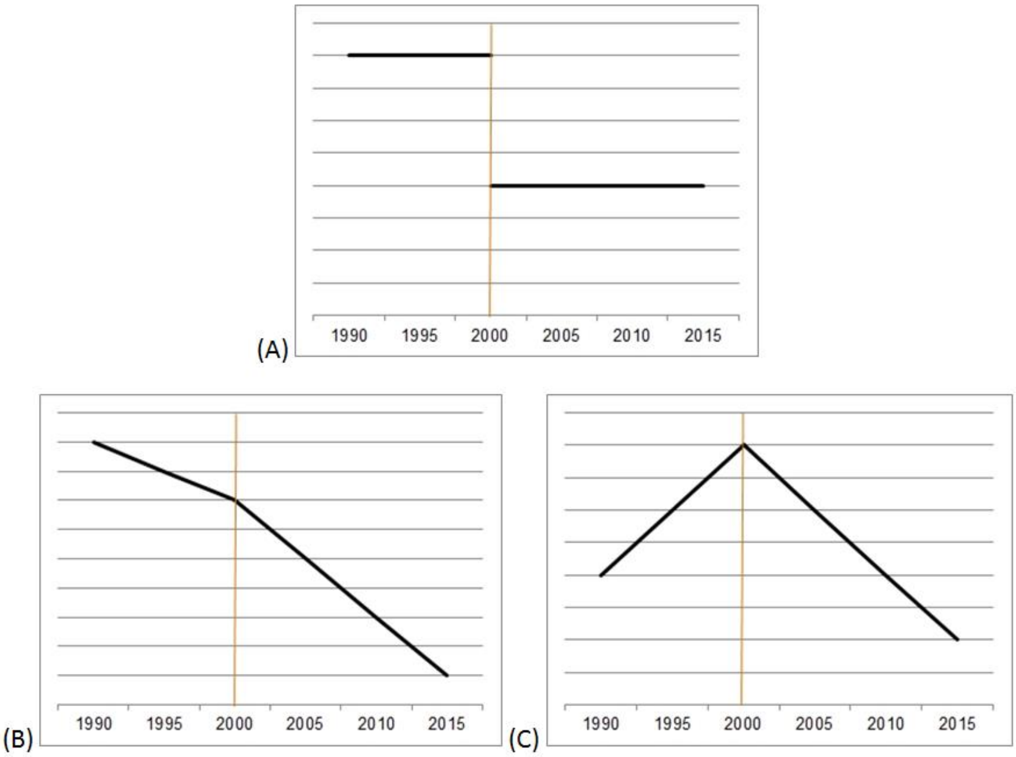
3 Methodology

Key message: A number of methods are used to study the productivity slowdown. Since observed productivity growth is subject to significant period-to-period volatility, some method for isolating the underlying trend is necessarybefore conclusions can be drawn about the growthrate. The methods that are commonly used in the literature range from simple averages to more sophisticated technical techniques (such as state space models). The HP filter is often used, but has several drawbacks. This is why we also apply the state space model. To detect productivity trend breaks, we use the Bai and Perron (1998) statistical methodology.

3.1 Measuring productivity slowdown

Before we describe the various methodologies, we highlight that the pattern of a slowdown may have implications for how it is measured. Panel (A) in Figure 1 shows the case in which the slowdown is identified as a sudden fall in productivity growth. This case is best measured by statistical techniques that test for a structural break in the data. Panel (B) illustrates the case in which productivity growth is gradually reduced. To measure this type of slowdown, the analysis has to allow for a smooth development of the productivity growth. The pattern of an acceleration, followed by a period of deceleration, as depicted in panel (C), is typical for the slowdown driven by the ICT-revolution (see e.g. Fernald (2015)). It is difficult to capture this type of pattern by a simple indicator.

Figure 1: Three patterns of a slowdown



3.2 Averages

One of the simplest techniques is to take multi-year averages of the growth rate of labour productivity. Typically a window of 5 to 10 years is used. If the average growth rate in recent windows is lower than in previous windows, the conclusion is drawn that there has been a productivity slowdown. The most obvious problem with this technique is that a sub-period may have a low average growth rate due to the fact that it includes a recession or a substantially negative shock (such as the Great Recession). An example of this approach is Fernald (2015).

3.3 Bandpass filters: the Hodrick-Prescott (HP) filter

Another common method is to filter productivity time series to separate the underlying trend from business cycle movements by a bandpass filter. The most used filter is the Hodrick-Prescott (HP) filter (see Bergeaud et al. (2015) and OECD (2016) for examples). Other bandpass filters are the Baxter-King filter (Baxter and King (1999)) and the Christiano-Fitzgerald bandpass filter (Christiano and Fitzgerald

(2003)). An example of this approach applied to productivity is Fernald and Wang (2016).

The HP-filter basically fits a smooth non-linear trend to the observed series.[5], which is why it is also called the smoothing parameter. The choice of the appropriate value of the smoothing parameter (λ, which sets the length of the cycle) is an important issue. For small values of λ, the trend will more closely follow the observed series, while for large values the trend will become smoother. For annual data, a standard value is $\lambda = 100$ but applied values vary from 6.25 (Ravn and Uhlig (2002)), 54 (OECD (2016)) to 500 (Bergeaud et al. (2015)).

Another issue with bandpass filters is the beginning and end point problem. That is, the filter methodology is particularly sensitive to outliers in the first and last observations in a time series. For instance, if the last observation is low, the bandpass filter trend for the last data point will also be low. At the end of a time series, information from the future does not exist and the HP filter becomes highly sensitive to changes in the observed variable. As a consequence, when (cyclical) productivity growth falls at the end of the sample, the HP-filter is biased towards concluding that there has been a (structural) slowdown. This is a well known problem that is common to many filtering techniques (see Orphanides and van Norden (2002).

3.4 Structural break tests

In addition to filtering cyclical and trend components of productivity growth, we also perform formal structural break tests. We do this by applying tests to check for multiple endogenous structural breaks at unknown dates, based on Bai and Perron (1998) and Bai and Perron (2003)). This approach has been widely applied to the productivity slowdown. Examples of this approach include Wegmuller (2015) and Bergeaud et al. (2015).

Three different types of tests are considered: the sequential test, the global test and the global information criteria (IC) test. The sequential test checks if there are $l+1$ versus l breaks. The global test has a null hypothesis of no structural breaks and the alternative is l global breaks. The IC test uses an information criteria (like the Schwarz IC) to select the number of breaks.

The Bai-Perron-type tests are well suited to identifying abrupt changes in productivity growth. However, they have low power when productivity is slowly

[5] The HP-filter minimises:

$$\min_{\bar{y}_t} \left(\sum_{t=1}^{T} (y_t - \bar{y}_t)^2 + \lambda \sum_{t=2}^{T-1} [(\bar{y}_{t+1} - \bar{y}_t) - [(\bar{y}_t - \bar{y}_{t-1})]^2 \right)$$

where y denotes the log of the observed series and $\bar{y}$ the trend value. The first term aims to limit the deviations between the observed and the trend values. The second term penalises variations in the trend growth rates. The weight of the second term is given by the parameter λ

changing (see Benati (2007)). Also, the sequential test lacks power when there are two breaks: one in one direction followed by another in the opposite direction. This test starts by comparing the null hypothesis of zero breaks with the alternative of one break, then comparing one against two, if zero is rejected. The first stage of testing (one break against zero) lacks power whenever the second segment is not significantly different from the first segment. This is highly relevant, since the increase in US productivity growth at the end of the 1990s has been followed by a fall.

3.5 State Space Model (SSM)

Using an HP filter has the drawback that it cannot completely account for the effects of a banking crisis. As with many other countries, the Netherlands suffered a banking crisis at the start of the Great Recession in 2008. A banking crisis is believed to permanently reduce the level of output and productivity, see Cerra and Saxena (2008) and more recently Candelon et al. (2015). The filters we have introduced above do not take this into account. Not accounting for the presumed permanent effects of the 2008 banking crisis will exacerbate the end-point problems (see Orphanides and van Norden (2002)). Hence, by also using an SSM, we can control for this undesirable feature of the filtering techniques.

We develop a State Space model (SSM) to account for the effects of banking crises on the potential or underlying growth rate of productivity following the work of Luginbuhl and Elbourne (2016). Our approach has two additional advantages over the HP filter. Firstly, a model based approach allows us to produce model consistent forecasts of the underlying growth of productivity, including forecast error bounds. Secondly, and more importantly, the optimal values of the filtering parameters implied by our model are empirically estimated by maximum likelihood estimation, or MLE. This is in stark contrast with the HP filter parameter where the smoothing is generally set using standard values that are selected on the basis of the frequency of the observed data. There is, however, no general agreement over these "standard" values, and as a result any decision about which HP filter parameter value to use is inevitably somewhat arbitrary.

Our decision to use an SSM to obtain estimates of the underlying growth rate of productivity is motivated by the intuitive nature of SSMs. Unobserved processes such as the business cycle or the recent banking crisis, tend to shock the level of measured productivity. However, the underlying (structural) level of productivity growth only changes gradually and smoothly. As a result, it is difficult to determine what the underlying long run growth potential of productivity is.

By modelling the unobservable components (such as banking crises and the business cycle) explicitly in an SSM, we can arrive at a better estimate of trend productivity growth. Modelling the unobservable components is done using the standard Kalman Filter and associated smoothing algorithms given the estimated model parameters (in our case here obtained by MLE[6]). See for example Harvey (1991) and Durbin and Koopman (2001) for more details.

We can then use this model to estimate the underlying growth potential of productivity. We generalise the cyclical model in Luginbuhl and Elbourne (2016) to include a random walk specification for the growth rates of output, to capture the secular declines in the growth rates of developed countries over the past 40 years.[7] In Appendix B we provide a more detailed description of our SSM.

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[6] In future work we would like to explore the use of Bayesian methods of estimation, which could help us to identify the unobserved components in the SSM.

[7] Based on the AIC model selection criteria and model interpretation, we propose the use of the random walk specification with rank reduction. An alternative for random walk is including a time trends. We impose rank reduction in the covariance matrices of the model shocks to obtain more parsimonious models.

4 Data

Key message: There are several datasets with labour productivity growth data. We use the KLEMS and OECD databases for the analysis of sectors and the panel regressions. For the SSM we use the Total Economy Database (TED). The data on Dutch productivity is obtained by Statistics Netherlands. We combined several datasets to generate a complete datasets (in terms of available variables, countries, sectors and year). Despite this, none matches our requirements for testing likely explanations of the productivity slowdown. The datasets are not complete (in terms of available variables, countries, sectors or years) and/or are not compatible.

There are five datasets that contain labour productivity growth data.[8]

1. The KLEMS database, linked to the World Input Output Database (WIOD). It is developed by the Groningen Growth and Development Centre and goes back to 1970. The KLEMS data was recently updated by the Conference Board, but cannot yet be used for analysis. The latest release only covers ten European countries from 1995 onwards. [9]

2. The OECD sectoral level database provides values from 1995 to 2015. The OECD database lacks data on hours worked in the US and Japan and does not provide additional sector-level explanatory variables (for example, on capital intensity). We use the OECD database to extract annual GDP and value added in constant prices, as well as hours worked by all persons employed (i.e. employees and self-employed). We conduct the analysis on the growth rate of GDP over hours worked. The OECD database includes data for Austria, Denmark, Finland, France, Germany, Greece, Italy, the Netherlands, Spain, Sweden and UK. Sector coverage equals 17 industries that greatly overlap, but do not always exactly correspond with KLEMS sectors.

3. The Total Economy Database (TED) provided by the Conference Board. We use its data on 'output, labour and labour productivity', which contains time series data (1950-2016) on Gross Domestic Product (GDP), population, employment, total hours worked, per capita income and labour productivity (measured as GDP per person employed and GDP per hour worked). Data is available for 123 countries.

4. The historical series provided by Bergeaud et al. (2015). They compute Dutch productivity back to as early as 1890. For our purposes, we use post-war data.

5. Statistics Netherlands (or CBS) provides national data on labour productivity. This series begins in 1970. We have used the latest release.

We use the OECD data to explore the trend (using the HP filter) for several countries. We use the KLEMS dataset, the TED dataset, the Bergeaud historical series and the database compiled by Statistics Netherlands to also estimate the trend and check our results obtained by using the OECD data. For the SSM, we extract from the

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[8] In addition, we also checked the STAN database provided by the OECD and Eurostat. However, the data covers only a limited number of countries for a limited number of years

[9] We use previous release of KLEMS that ends around 2007-2009. We use the new release only for correcting the Dutch aggregate data.

TED dataset annual productivity of GPD per hours worked for 30 developed countries[10] with a sample period covering the period from 1970 until 2015, which includes the Great Recession.

For the panel regression, both the KLEMS and OECD data are used because they include sectoral data. We combine both datasets in order to cover the period 1995 - 2015. From the KLEMS database we extract productivity data for twelve sectors. These are agriculture, electricity and utilities (for space purposes further labelled electricity); post and telecommunications, wholesale, retail trade, transport, hotels and restaurant services (labelled horeca), business services and other service activities such as art and recreation, etc. Manufacturing is split into ICT producing, ICT intensive manufacturing and ICT non-intensive manufacturing. The details are reported in table 7. We have complete data for sixteen countries: the Netherlands, Germany, France, Spain, UK, US, Japan, Portugal, Italy, Denmark, Finland, Ireland, Austria, Belgium, Sweden and Greece.

From the OECD database we extract productivity data for the sectors electricity, telecommunications, publishing, transport, wholesale, retail, arts and recreation, agriculture, horeca, water, administrative services, professional services, IT services and other services. We also include manufacturing split into IT producers, IT intensive and non-IT intensive manufacturing. Details of the sectoral decomposition are given in table 8.[11]

Not all sectors were included. The public sector, the education sector and the financial sector suffer several measurement problems. The sectors 'mining and quarrying' and 'real estate' show highly fluctuating product prices, hampering comparisons over time. Finally, the construction sector poses problems in measurement of both outputs and hours worked. We therefore exclude all these sectors.

The included sectors make up 56% of value added. We use the sectoral data mainly for panel regression analysis that explores the differences between countries and sectors, as well as specific explanatory variables derived from literature.

[10] The following countries were included: USA, Korea, Germany, Japan, Brazil, Turkey, Sweden, Argentina, Spain, Mexico, The Netherlands, Chile, UK, Iceland, Greece, Denmark, Belgium, Austria, Finland, Ireland, Switzerland, Norway, Portugal, Australia, Canada, France, Italy, Singapore, Taiwan, and New Zealand.

[11] We decided not to employ quarterly Eurostat data due to a number of reasons. First, the coverage consists of eleven sectors, but only six after necessary exclusions. Second, the data is available for twelve EU economies only. Third, we cannot distinguish between ICT producing, ICT intensive and non-intensive manufacturing. Finally, and most importantly, the estimated trends are flat and do not exhibit large variation.

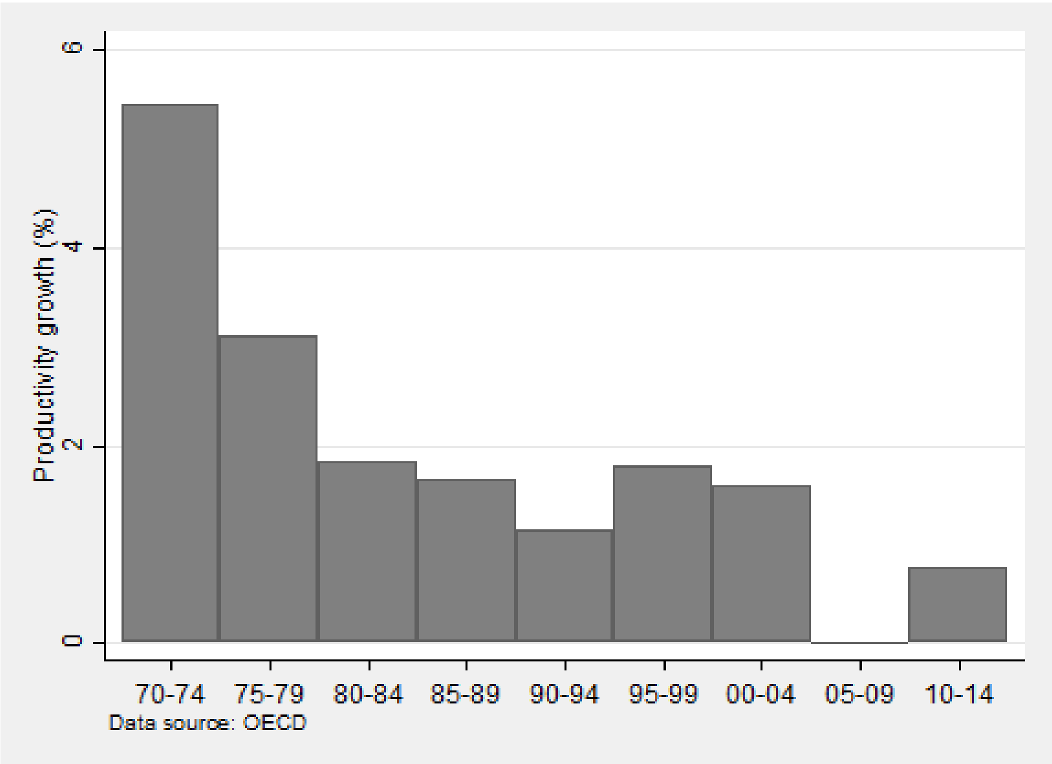
5 Productivity growth trend

Key message: Overall, we observe that the productivity slowdown is widespread. There is some variation in the timing of the slowdown, but all the observed countries seem to experience relatively low productivity trends in recent years.

5.1 Averages

Figure 2 shows the five year averages of productivity growth for the Netherlands, from 1970 to 2014. The average productivity growth fell from well over 5% in the period 1970-74 to just above 1% in the period 1990-94. A modest boost can be seen during 1995-1999, after which productivity growth slows down again. In the period 2005-09, which includes the Great Recession, productivity growth was very low.

Figure 2: Five year averages for productivity growth (GDP per hour worked) in the Netherlands (1970-2014)



5.2 HP filter

OECD (2016) presents evidence based on the HP filter of a widespread productivity slowdown in their sample of countries. The OECD shows that the trend in the productivity growth rate slowed down in Germany and the UK well before the Great Recession. Moreover, there is no strong case for slowdown in the US, except for the dismal performance after the Great Recession. From 1995 to 2002 US experienced a short-lived productivity growth boom that is traced back to ICT revolution. However, the study does not report results for the Netherlands.

Figure 3 reproduces the study for the Netherlands. The only exception is that the OECD (2016) uses λ of 54.12 and we opt for λ of 100. Later on, we will show that our results are robust to this choice. The reason for choice of λ of 100 is that it's fairly standard in the literature, while the value of 54.12 is rather arbitrary. We use the same OECD annual productivity data as is used in OECD (2016). The time span equals 46 years, from 1970 to 2015. We observe that the productivity trend was higher in the 1970s, when European economies were still in the catch-up process with the United States. From the 1980s to 2008, productivity trend remains roughly equal. It is lower in the most recent part of the sample.

The development of Dutch productivity is in line with the findings for other advanced economies. Figure 4 shows the productivity trend for the Netherlands and two large EU economies (Germany and France). The general pattern is the same in all three countries. They all experienced high growth rates in the 1970s, which fell rapidly afterwards. The slowdown in Germany began with the unification in 1990. Slowdown in the Netherlands and France dates around 2000.

Compared to the small open economies of Belgium and Denmark, the Netherlands experienced lower trend growth in the 1980s and the 1990s (Figure 5). The productivity slowdown in Belgium and Denmark began in the mid 1990s, compared to around 2000 in the Netherlands. The underlying trend in the recent years seems to be more positive for the Netherlands, but one should be careful to draw such a conclusion given the end-point problems of the filter.

Finally, we compare trend productivity growth in the Netherlands to the UK and the US (Figure 6). The US had a relatively stable rate of productivity growth over the sample. Around 2000, the US experienced a short-lived acceleration, followed by a deep slowdown from which it has yet to recover. The United Kingdom experienced less of the catching up effect in the 1970s and enjoyed strong productivity growth up to 2000.

Figure 3: Trend productivity growth (GDP per hour worked), the Netherlands (λ =100)

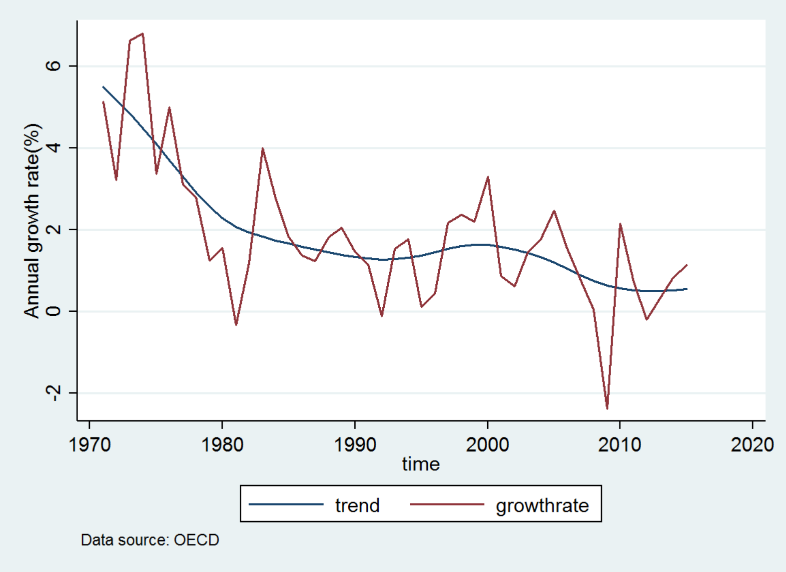


Figure 4: Trend productivity growth (GDP per hour worked) for the Netherlands, Germany and France

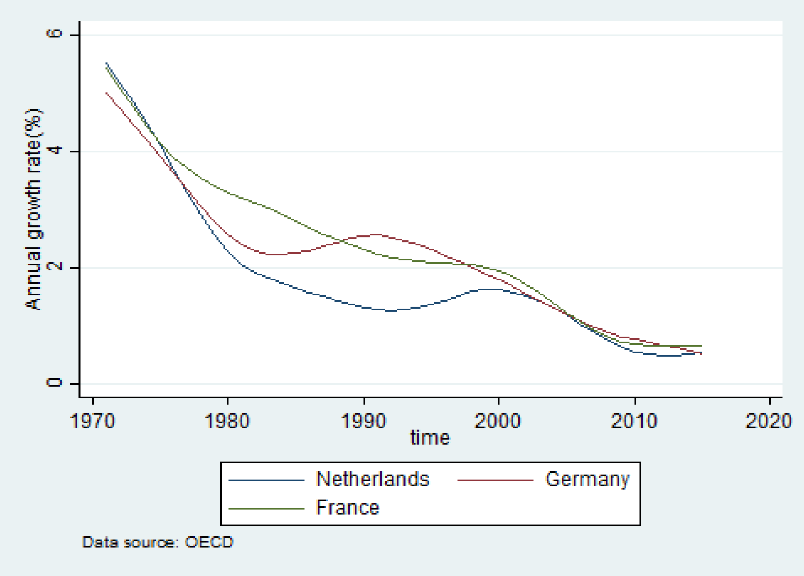


Figure 5: Trend productivity growth (GDP per hour worked) for the Netherlands, Belgium and Denmark

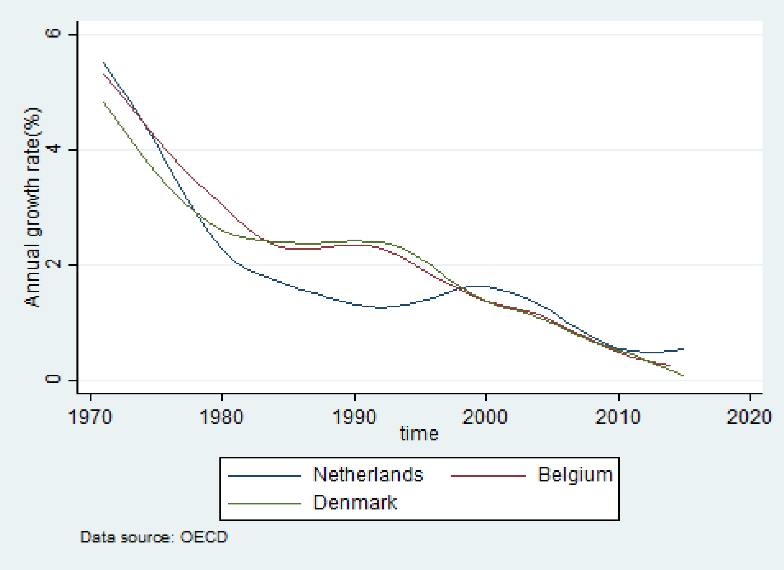
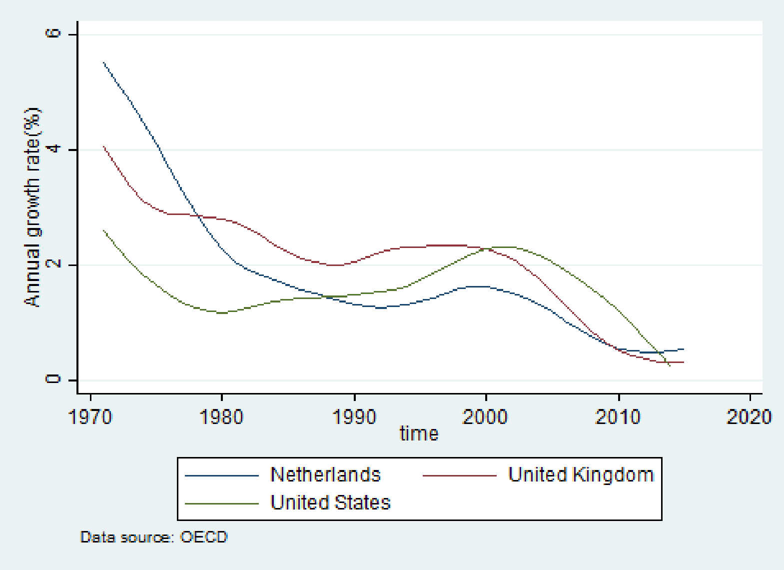


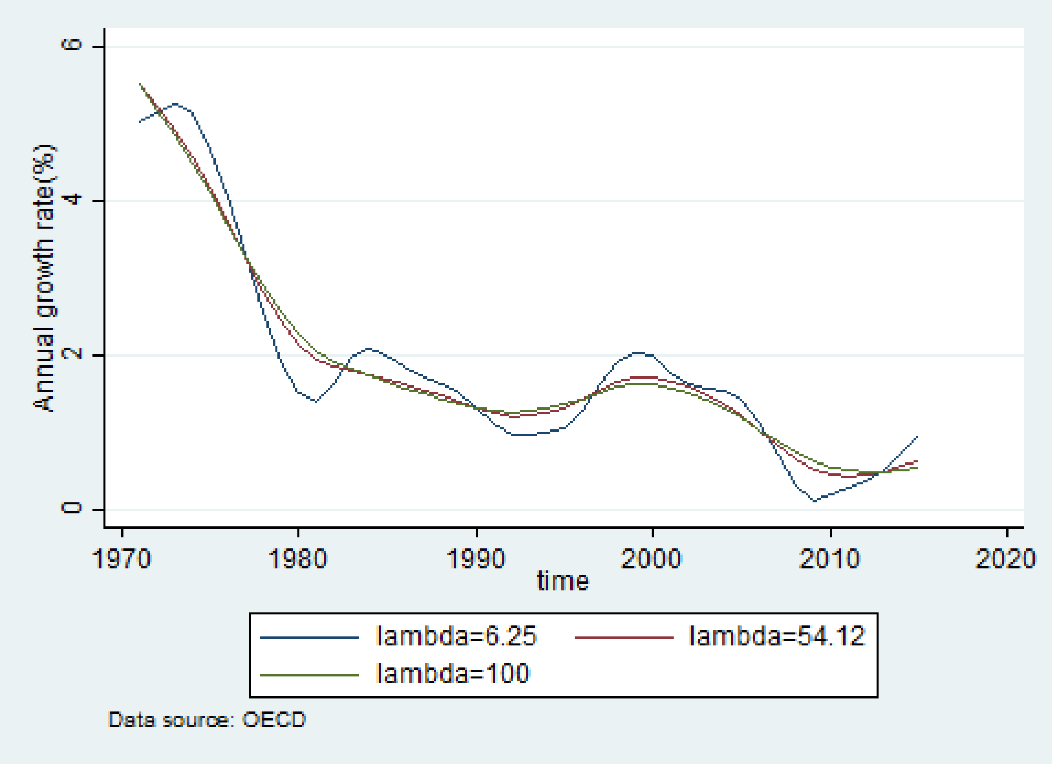
Figure 6: Trend productivity growth (GDP per hour worked) for the Netherlands, UK and US



Overall, we observe that the productivity slowdown is widespread. There is some variation in the timing of the fall, because it seems to occur earlier in US and the Netherlands, compared to the other countries. Nonetheless, all the economies seem to experience historically low productivity trends in recent years.

These results are robust to the choice of the smoothing parameter. Figure 7 presents the Dutch productivity trend with three values of λ: 100 as in our baseline, 54.12 as applied by OECD (2016) and 6.25 which is suggested by Ravn and Uhlig (2002). The resulting trend lines for the first two values are very similar, implying that the analysis is comparable to OECD (2016)). The value of 6.25 provides a trend line that displays some cyclical pattern. We do not believe that the underlying productivity trend follows such a volatile pattern. Nonetheless, it provides a similar picture and leads to similar conclusions.

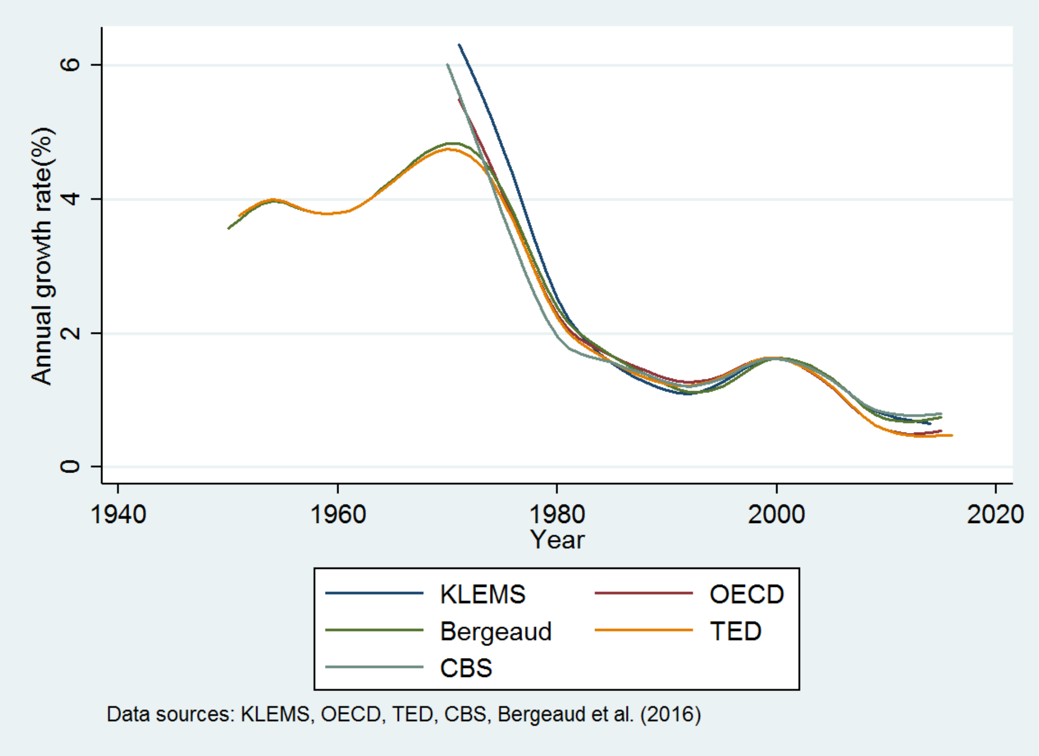
Figure 7: Trend productivity growth for the Netherlands with different values of λ



The conclusions remain similar regardless of the dataset we use. We estimate the trend based on the data provided by four additional databanks: The Total Economy Database (TED), the historical series provided by Bergeaud et al. (2015), the KLEMS database and the national data provided by the latest release by Statistics Netherlands (CBS).

Estimated trends look remarkably similar (see Figure 8). When plotted, results based on the OECD, TED, the historical series and CBS are indistinguishable from each other. Most discrepancies are observed at the end points, which is a well known drawback of the HP filter. The same problems arise at the beginning of the series. This means the first three and last three annual estimates should be interpreted with caution. However, the slowdown that we find did not take place in the last three years. It begins earlier, around 2004, and is therefore less likely to be driven by the end-point problem.

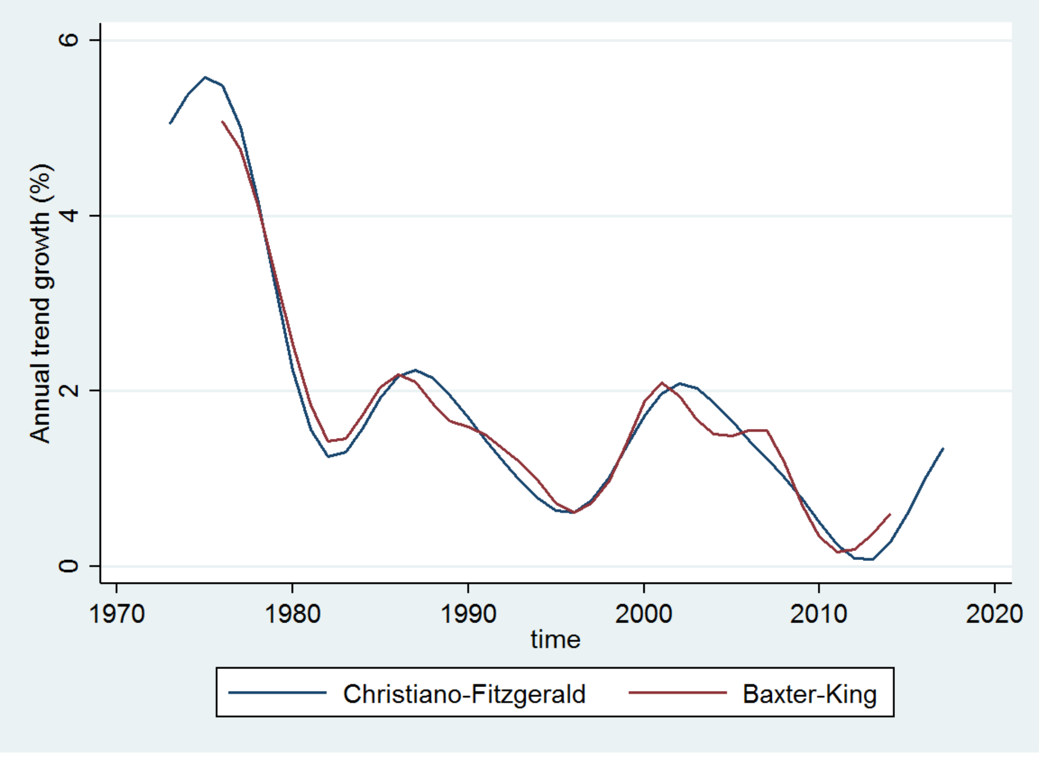
Figure 8: Trend productivity growth (GDP per hour worked) for the Netherlands (λ =100)



5.3 Other bandpass filters

For both Baxter-King and Christiano-Fitzgerald filters we choose standard parameters for business cycle duration. That is, fluctuations with a duration between two and eight years are considered business cycle fluctuations and we choose parameters accordingly. Longer period fluctuations are considered as an indication of the trend. The resulting trend estimates are presented in Figure 9. The estimated trend falls from more than 5% annual productivity growth in 1975 to 1-2% in the following decades. In the most recent cycle, the trough has the lowest observed value. In other words, the trend is lower than at any earlier point in our sample, indicating that there is a slowdown. However, as the estimated trend still exhibits some cyclical behaviour and large fluctuations, we cannot draw any definite conclusions from this result.

Figure 9: Trend productivity growth (GDP per hour worked) for the Netherlands (bandpass filters)



5.4 State Space Model (SSM)

The estimated trend component, as depicted on the Figure 10, exhibits a slowdown in the 1970s and downward dynamics in the estimated trend since about 2000. The estimated trend is both qualitatively and quantitatively similar to the estimates from the other filters. Since the regression technique allows for estimation of the confidence bands, we see that the estimated trend for the post 2010 period is about 0.9% growth per year. For most of the immediate pre-Great Recession period, that would have been very close to but inside the lower 95% confidence band. It would have been clearly outside the bands in 2000. That represents fairly strong evidence that the underlying trend productivity growth is lower today than it was in the period immediately before the Great Recession. It is too early to conclude that the Great Recession has had a structural effect on the productivity growth, but it is a finding that deserves close monitoring in the years to come. Especially because in the recent years, the value of the trend component is more uncertain, which can be seen by observing that the bands are wider at the end of the sample. Furthermore, we observe that the estimated trend component is quite similar to the estimates obtained by employing bandpass filters.

Figure 10: Trend productivity growth (GDP per hour worked) for the Netherlands (SSM and its 68% and 95% confidence intervals)

5.5 Filtering techniques compared

A comparison between different filtering techniques (see Figure 11) suggests that the trend estimation of Dutch productivity growth is robust to the filtering technique used. The HP filter, bandpass filters and SSM lead to very similar conclusions. The correlation coefficients between these series are presented in Table 1. There is strong positive correlation between the estimated trend growths. We observe that these results are most similar to the HP filter with smoothing parameter equal to 6.25.

Figure 11: Trend productivity growth (GDP per hour worked) for the Netherlands: comparison of different filtering techniques

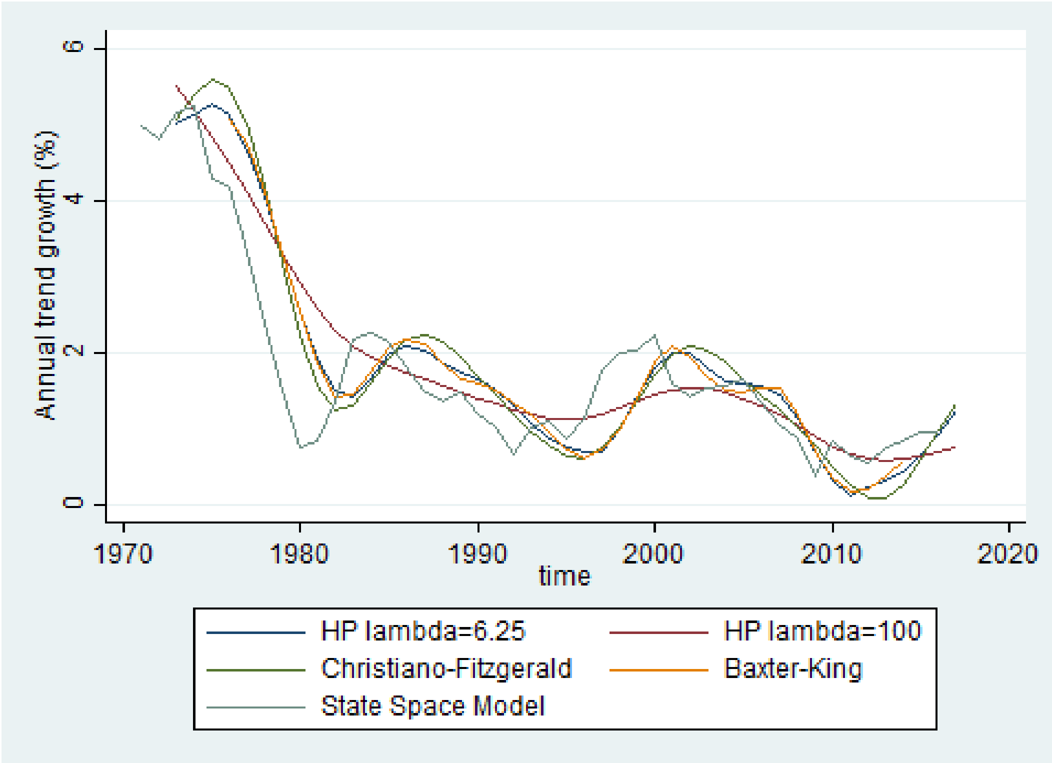


Table 1: Correlation between trends from different filters

	HP λ =6.25	*HP λ =100*	*C-F*	*B-K*	*SSM*
Hodrick-Prescot λ =6.25	1				
Hodrick-Prescot λ =100	0.963	1			
Christiano-Fitzgerald	0.994	0.945	1		
Baxter-King	0.998	0.941	0.987	1	
State Space Model	0.868	0.873	0.876	0.768	1

5.6 Structural break tests

We conduct three versions of the Bai-Perron break test (see appendix D for results). As explained in Section 3, they differ by their alternative hypotheses. Nonetheless, all three tests lead to the same conclusion. They detect one break in the growth rate of productivity in 1978. This is line with Wegmuller (2015), but this study also finds a break in 2008. According to our estimates, the most likely time for a break was in 2007, although it is not statistically significant. Apparently, the test is only able to detect the abrupt change in the growth rate in the 1970s and fails to detect significant breaks in the latter periods.

This may be due to the lack of break or low power of the test. Benati (2007) finds that structural break tests produce, overall, surprisingly little evidence of time-variation in trend productivity growth. He concludes that historical changes in equilibrium productivity growth have most likely been too gradual to be detectable via such a powerful, but ultimately quite crude methodology.

6 Productivity trends in sectors

Key message: the sectors show a variety of trend productivity growth patterns.

Trend productivity growth across different sectors shows large heterogeneity. Not only do they show different patterns, but also different growth rates (see Figure 12; note that the vertical axes are not the same).

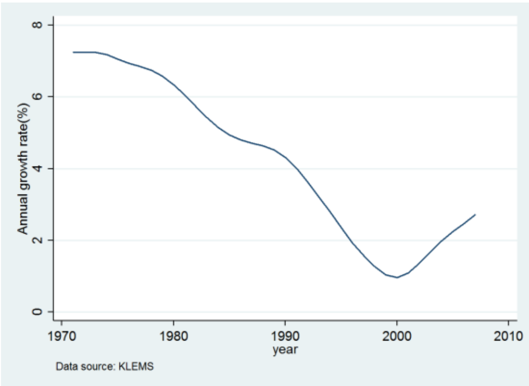
Four sectors experienced a slowdown from around 2000 onwards: post and telecommunications, business services, electricity and water, as well as accommodation and food services. In contrast, the trend in productivity growth of transport, agriculture, wholesale, retail, ICT production and ICT intensive manufacturing increased in the same period. Finally, for non-ICT intensive manufacturing and for other services, the trend remained relatively flat.

The vastly different growth patterns beg the question what explains these. The patterns seem to indicate that the ICT revolution played a role in productivity growth in different sectors. The ICT production sector shows a rather large increase before 2000, coinciding with the ICT revolution. However, the role of ICT in explaining productivity growth is not clearcut (see Inklaar et al. (2005)). First, the ICT intensity in sectors may vary. For instance, agriculture in general uses little ICT. Second, the timing of ICT investment matters. Van Ark and Inklaar (2005) explain that early normal returns on ICT are usually the result of the direct productivity effects of ICT production and ICT investment (which they call the 'hard savings'). But after this, there is a period of 'negative spillovers' in which investments are made in human capital and knowledge capital as well as organizational innovations which do not immediately result into an acceleration of productivity growth. It takes time before the combination of ICT investment and intangible investments and innovations (which they call 'soft savings'), have an effect on productivity.

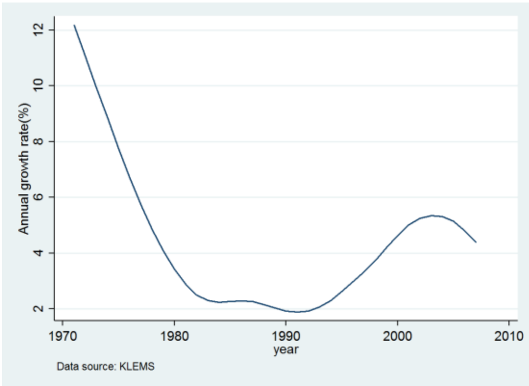
Productivity growth in one sector may spur productivity growth in another. Van Ark and Inklaar (2005) provide the example of the retail sector, where introduction of the barcode allowed for more efficient check-out systems. But introducing the barcode also triggered a reorganization of the supply chain, the introduction of new shopping concepts which required investment complementary technologies such as transportation technology and organizational change, such as adjustments in the logistic supply chain. Thus, the transportation sector is then also affected. In the panel regression the sectors will be analysed in more detail, but a thorough investigation requires more in-depth research into the sectors, using firm-level data.

Figure 12: Productivity growth trend for Dutch sectors (value added per hour worked; HP filter with λ =100)

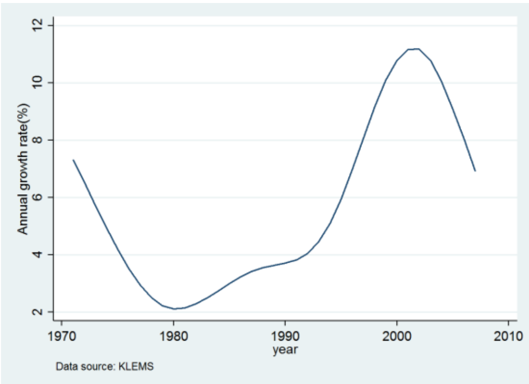
agriculture



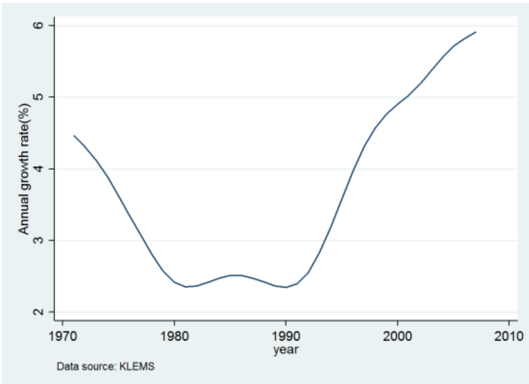
electricity and water



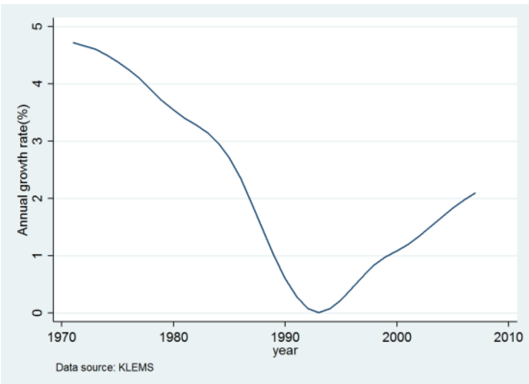
post and telecommunications



wholesale



retail



transport

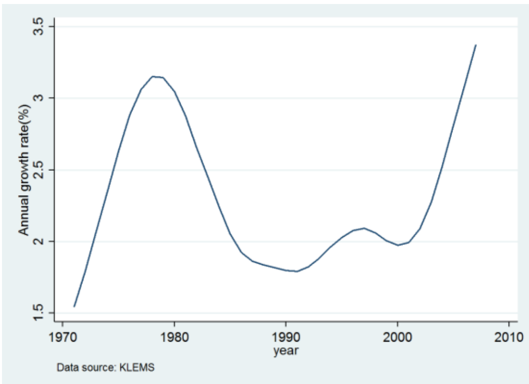
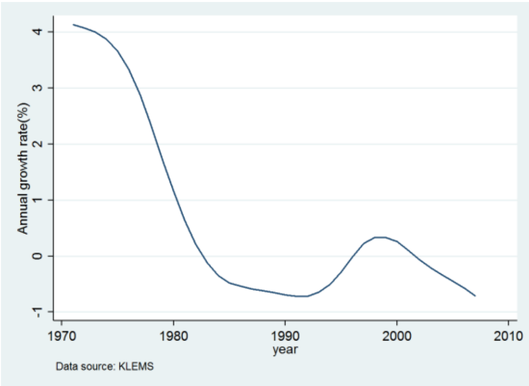
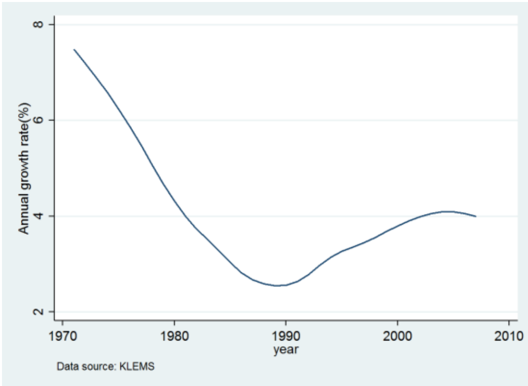


Figure 12: Continued

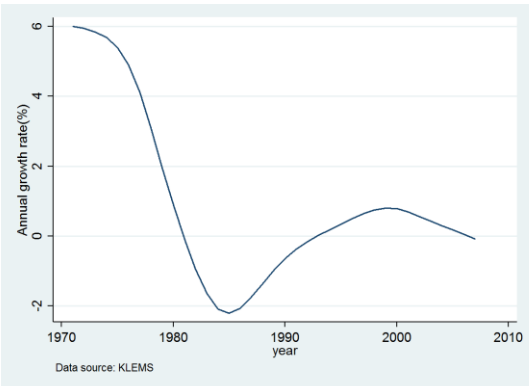
accommodation and food services



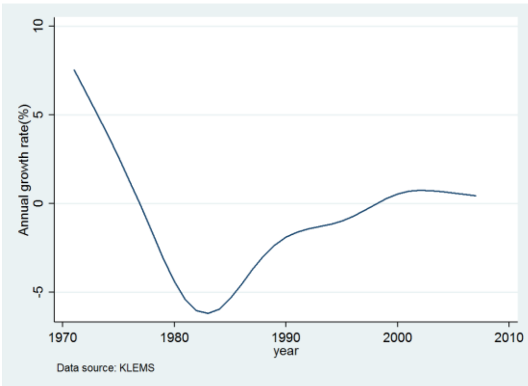
non-ICT intensive manufacturing



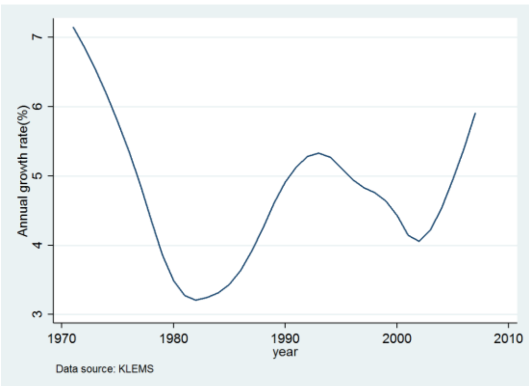
business services



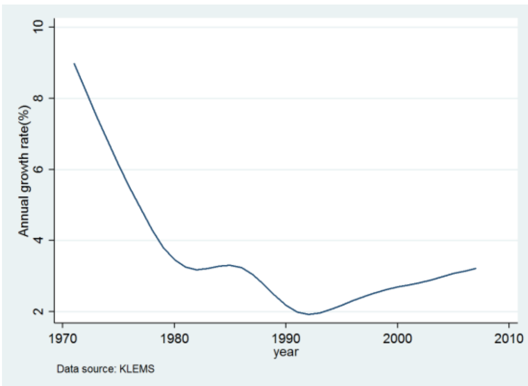
other services



ICT production (manufacturing)



ICT-intensive manufacturing



7 Results of panel regressions

Key message: The productivity growth slowdown in the Netherlands shows a similar pattern as the US (before the Great Recession) and the UK (including the Great Recession). Before the Great Recession, the sectors 'ICT users' and 'ICT producers' contributed significantly more to productivity growth than other sectors, followed by 'other services' and 'business' that also contributed significantly more, albeit to a lesser degree. These four sectors are highly ICT intensive. When we extend the period to include the Great Recession, this significant effect disappears and none of the sectors contribute significantly more to productivity growth than the benchmark sector. Almost none of the explanatory variables are significant, except share of women in the workforce, education, ITK and non-ITK intensity.

The pattern of productivity growth in The Netherlands shows a marked slowdown from 1970 onwards, a small bump around 2000, after which trend growth slows down again. This pattern resembles the patterns seen in the UK and the US, which both experienced a bump in 2000, while other European countries (such as Germany, Belgium and Denmark) did not. In the literature (see Fernald (2015) and section 2), this bump is attributed to the ICT revolution, which started after 1995, but once its benefits were reaped, productivity slowed down again, with a structural break found in the US for 2000. Although this structural break was not found for The Netherlands, we make use of this pattern, using five years' averages from 1995 to 2015. In addition to the 'ICT bump', there is a dip in 2009 caused by the Great Recession, which is mostly cyclical, but might also have structural effects.

We run several panel regressions, using KLEMS data that span 1996 to 2005 (pre-crisis) and OECD data that span 1997 to 2014 (including the Great Recession). We begin by exploring whether changes in trend productivity growth are mainly driven by country-specific and/or sector-specific features by only including country and sectoral fixed effects. We then extend the panel regression using KLEMS data with additional variables (see table 2) to test some of the possible explanatory factors for the different patterns mentioned in section 2.2.

7.1 Results for 1996-2005

The KLEMS panel consists of observations on 12 sectors in 16 countries. We use the trend growth rate that is calculated using the HP-filter (with $\lambda = 100$). The (unweighted) average rate is calculated for two periods of 5 years. In the base case, the first and second sub-period covers the years 1995-1999 and 2000-2004, respectively. The dependent variable is defined as the average trend in the second sub-period minus the average trend in the first sub-period. The constant term captures the fixed effect of the sector ‘retail’ and the fixed effect of the US. We perform sensitivity analysis for other sub-periods. A drawback of this specification is that productivity growth is split up into the same two sub-periods for all countries and sectors.

7.1.1 Fixed effects for sectors and countries

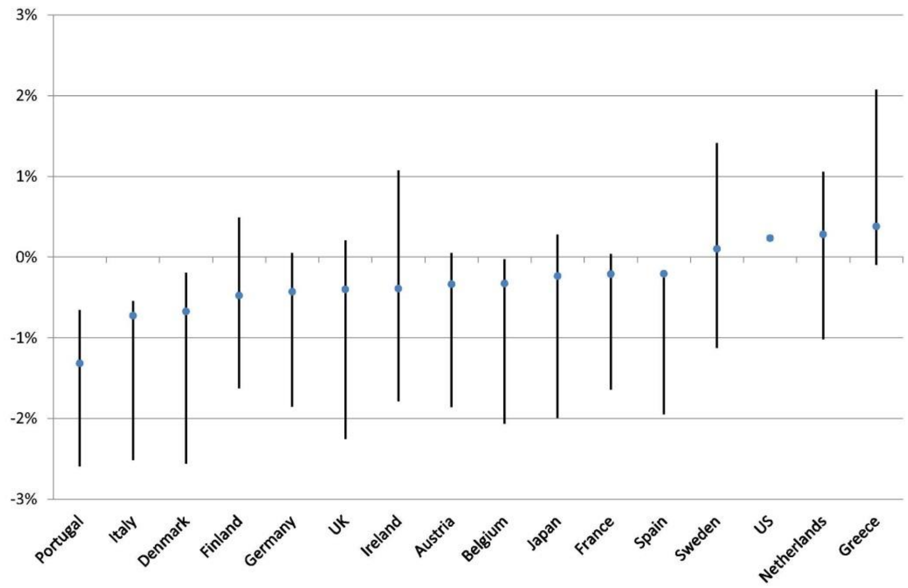
Productivity slowdown may be explained by a variable that is not included in the regression (i.e. an omitted variable). A common way to deal with omitted variable bias is to introduce dummy variables or ’fixed effects’ for space (i.e. countries) or time units (i.e. years). This greatly reduces, but not completely eliminates, the chance that a relationship is driven by an omitted variable. We include dummies for countries and sectors.

The estimated fixed effects are reported in the Appendix Table 5. We choose to drop the fixed effect of the retail trade sector and the fixed effect of the US since the absolute value of the dependent variable of this couple is closest to zero. Therefore, fixed effects should be interpreted relative to the constant term (which is not significantly different from zero).

The country fixed effects are illustrated in Figure 13. The vertical lines show the 95%-confidence intervals of the estimated country fixed effects; the coefficient can be found in the middle of the interval (not given). The dots (in blue) give the ‘observed’ change in the trend growth rate of GDP per working hour. Notice that the growth rate of GDP per hour is not equal to the average value in the sample since the selected sectors account for 56% of GDP. The countries are ranked according to the change in the growth rate of aggregate productivity.

Figure 13 illustrates two findings on the level and significance of the country fixed effects. First, we find a positive correlation between the ‘observed’ trend change and the estimated fixed effect. The larger the fall in trend productivity growth, the smaller is the fixed effect (relative to the US). Second, we find five countries with a fixed effect that is significantly negative: Portugal, Italy, Denmark, Belgium and Spain. Countries with a marginal significant effect are Germany (p-value=6.1%), Austria (6.4%) and France (6.3%). Two countries experienced a less pronounced slowdown in the productivity growth trend than the US: the Netherlands (but the fixed effect is not significantly different from zero) and Greece (marginally significant with p=7.3%). In sum, after controlling for sectoral effects, the significant country fixed effects suggest a role for country-specific developments.

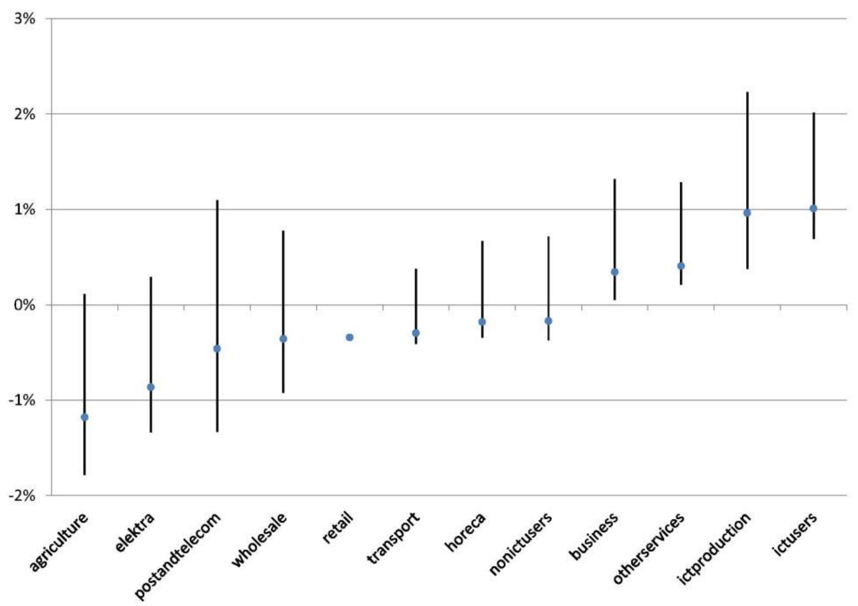
Figure 13: Country fixed effects 1996-2005: countries compared to benchmark US



Note: Vertical lines present the 95%-confidence interval of the fixed effects. The dots give the change in the trend growth rate of GDP per working hour.

The estimated sectoral fixed effects are similarly illustrated in Figure 14. The dots now depict the sample unweighted averages of the change in the trend productivity growth. Sectors are ranked according to this series. We again find a positive relationship between the 'observed' average change in the productivity growth and the sectoral fixed effects. Moreover, none of the sectoral effects are significantly different from the retail trade sector, except for the four sectors that experienced the highest increase in productivity growth: business, other services, ICT-producing and ICT-using manufacturing. In particular, the results for the three subsectors of manufacturing are noteworthy. The fixed effect of the non-ICT subsector is not significantly different from zero, whereas the effect of both the ICT-producing and ICT-using subsector is significantly positive (but not significantly different from each other). These outcomes suggest that sector-specific features, like ICT-intensity, might contribute to different growth in productivity.

Figure 14: Sectoral fixed effects 1996-2005: sectors compared to benchmark 'retail'



Note: Vertical lines present the 95%-confidence interval of the fixed effects. The dots give the sample average of the change in the trend growth rate of value added per working hour.

Finally, we perform a sensitivity analysis with respect to the choice of the (sub)periods; see Table 5. In general. the findings are robust to shifting the period one year forward or backward. When we consider later sub-periods 1996-2000 and 2001-2005, the set of significant sectoral fixed effects is unaffected, while the fixed effects for Belgium and Denmark become insignificant. When we instead experiment with earlier sub-periods 1994-1998 and 1999-2003, significance of the fixed effect shifts from the business sector to agriculture and the set of significant country fixed effects is extended with four countries.

7.1.2 Sectoral and country characteristics

Given the significant differences in developments between countries and sectors, we try to specify country- and sector-specific characteristics. Table 2 gives the definition and source of the variables that we have added one by one to the regression.[12] The first four variables and the last (export) are available for the country/sector combination, but not necessary for the complete panel. The other

[12] The two educational level shares are included together in the regressions. We tried to include openness of a sector, defined as the ratio of (imports + exports) and value added, but data on imports were missing for many sectors. Therefore, we used the export ratio. Data on exports in all countries are missing for the sectors 'horeca', 'post & communication', 'transport', 'retail' and 'wholesale trade'.

variables are only available at the country level and we assume this variable is the same for all sectors within a country. The level observed in 2000 of each variable is taken to describe a characteristic of a country and sector. We consider one exception to this choice. In addition to the level of ICT-intensity (in 2000), we add the difference in the average ICT-intensity in the two sub-periods.

Table 2: Definition and source of additional explanatory variables

Variabele	Definition	Database ,
ICT intensity	Share of ICT capital compensation in total capital compensation	country/sector KLEMS
Labour intensity	Share of labour compensation in total compensation	country/sector, KLEMS
ITK intensity	Contribution of ICT capital services to VA growth / Growth rate of Value Added	country/sector, KLEMS
Non-ITK intensity	Contribution of non-ICT capital services to VA growth / Growth rate of Value Added	country/sector, KLEMS
Share self-employment		country, OECD
Share of 50-plus in employment		country, OECD
Share of women in employment		country, OECD
Share of middle education	Upper secondary and post-secondary non-tertiary education	country, OECD
Share of higher education	Tertiary education	country, OECD
Ratio Exports/VA		country/sector, STAN
Employment Protection Legislation	1. regular contracts & collective dismissals 2. temporary contract	country, OECD
Product Market Regulation		country, OECD

Regression results are presented in Table 3. In column (1) the variable is included in addition to both country and sector fixed effects. This column seems most relevant when the variable has a country/sector dimension. In the second column only sector fixed effects are included as controls, which makes it interesting when the additional variable is a country-average. The last column serves as a basic benchmark without any fixed effect.

In general, we hardly find robust, significant effects of additional variables. In columns (2) and (3) we find a significant positive effect of both ITK intensity and non-ITK intensity (measured as contribution to value added growth). This shows that capital accumulation explains productivity growth but the difference between ICT-capital and non-ICT capital does not matter. This may be explained by the fact that ICT capital investment often requires complementary investments in knowledge-based capital, such as patents, design, firm-specific training etc. Investment in knowledge-based capital has been increasing over the past two decades, often at a faster pace than investment in traditional physical capital OECD (2016, p. 20).

Given the results of the sectoral fixed effects, it is surprising that both the level of ICT intensity (in 2000) and the change in the average level (measured as a % of the capital compensation) is not significant. Figure 15 illustrates that the correlation between the (unweighted) average of the ICT-intensity over the countries and the change in productivity growth is weak. For example, the sector with the highest ICT-intensity ('post and telecommunication') showed a fall in productivity growth. The share of women in employment has a positive effect (in the first two columns). This is correlated with the increasing education level.[13] As expected, a higher population share that finished tertiary education attributes to higher productivity growth (the coefficient in column (2) and (3) is significant with a p-value of 6.9% and 7.7%, respectively). Surprisingly, productivity growth is significantly lower in sectors that export a larger fraction of their production (the p-value is 5.5% and 2.5% in the first and second column, respectively). To understand why this is the case, more in-depth research into different firms within sectors is needed.

Table 3: Results of panel regression with country and/or sectoral Fixed Effects (1996-2005)

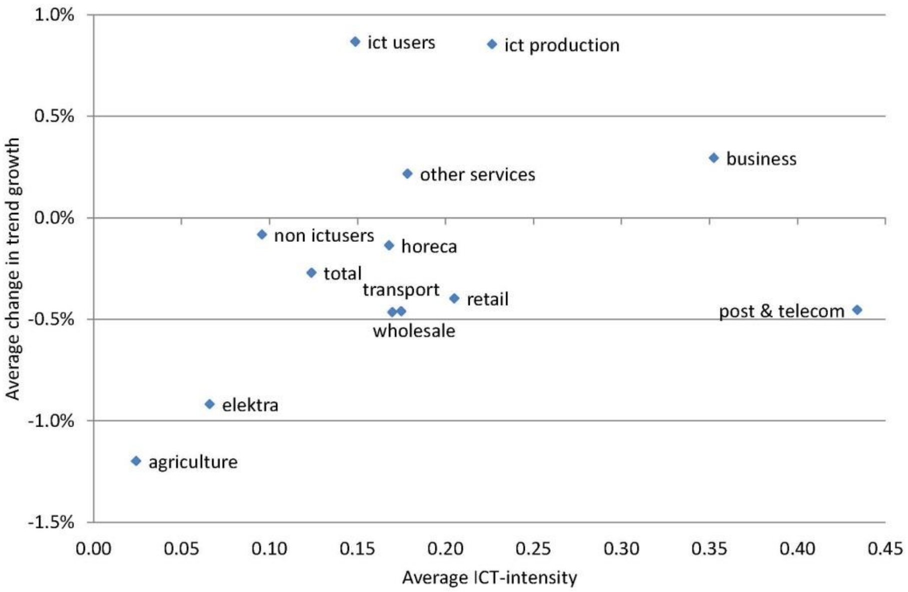
	(1)		**(2)**		**(3)**		**obs**
ICT intensity	-0.281		0.156		0.901		168
Δ ICT intensity	-1.647		-0.110		1.712		182
Labour intensity	0.446		0.279		0.741		192
ITK intensity	0.029		0.025	*	0.046	*	168
Non-ITK intensity	0.022		0.024	*	0.032	*	168
Share self-employment	0.029		0.013		0.013		192
Share 50-plus	-0.067		-0.067		0.010		192
Share female	0.057	*	0.057	*	0.011		192
Share middle education	-0.005		0.005		0.005		168
Share higher education	0.066	*	0.030		0.030		168
Export ratio	-0.002		-0.002	*	0.001		109

[13] Correlations are -0.60 for primary education, 0.50 for secondary and 0.61 for tertiary education level.

EPL regular contract	-0.555		-0.407	-0.407	168
EPL temporary contract	0.299		0.039	-0.039	168
Product market regulation	2.235	*	0.288	0.288	168
Country FE	YES		NO	NO	
Sector FE	YES		YES	NO	

The dependent variable equals the difference between the 5-year average growth trend rate of labour productivity in the second sub-period minus the average growth rate in the first sub-period. Robust standard errors in parentheses, * denotes significant at 5% level. The constant term represents the retail sector in the US.

Figure 15: Relationship between ICT-intensity and sectoral productivity growth



7.2 Results for 1997-2014

In the previous section we used (KLEMS) data up to 2005. Since slowdown continued in later years, we also consider a longer period 1997-2014, using sectoral data from the OECD. Unfortunately, data are only available for 11 European countries, thus not for the US and Japan. The number of included sectors is increased to 17.

The average growth rate of labour productivity is calculated for two sub-periodes of 9 years: 1997-2005 and 2006-2014. For these longer sub-periods, the average HP-trend growth rate is close to the average observed rate. The dependent variable is defined as the average growth rate in the second sub-period minus the average growth rate in the first sub-period. The constant term captures the fixed effect of the sector 'other services' and the fixed effect of France.

Country fixed effects are presented in Figure 16.[14] We notice the quite different ranking of the countries when compared to the analysis in the previous Section, reflecting the different pattern in productivity growth over a longer period. The country fixed effect for Greece is significantly negative (when compared to France), where the effects for Denmark[15] and Spain are significantly positive. The Netherlands now belong to the central group of countries with an insignificant effect.

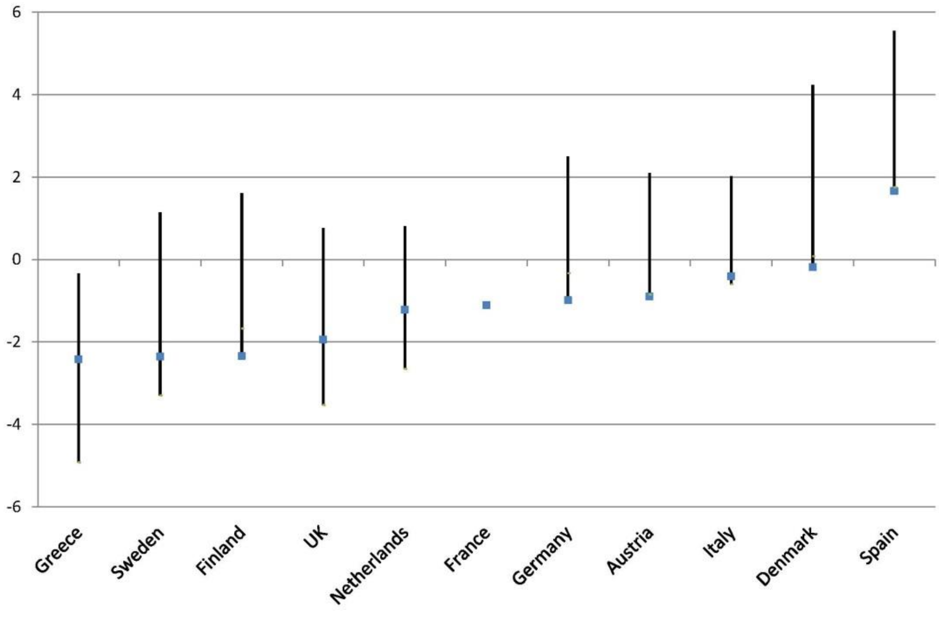
A different pattern also results for the sectoral fixed effects in Figure 17. In particular, the fixed effect for the 'ICT-producing manufacturing' shifts from the upper end in Figure 17 to the lower end in Figure 14, following a drop in the productivity growth. The sectors 'electra', 'it-producing manufacturing', 'publishing' and 'wholesale trade' have a significant effect, while it is insignificant for the other sectors.

We again find no strong evidence that the variables in table 4 explain the different patterns. In particular, the positive effect of the higher education share seems to shift to the middle education share in columns (2) and (3). In sum, the estimation results on the change in productivity growth are sensitive to the period under consideration. The ranking and significance of both the country and sectoral fixed effects are rather different when using the short period before the crisis (1996-2005) or the longer period including the crisis (1997-2014).

[14] The full estimation results can be found in the Appendix Table 6.

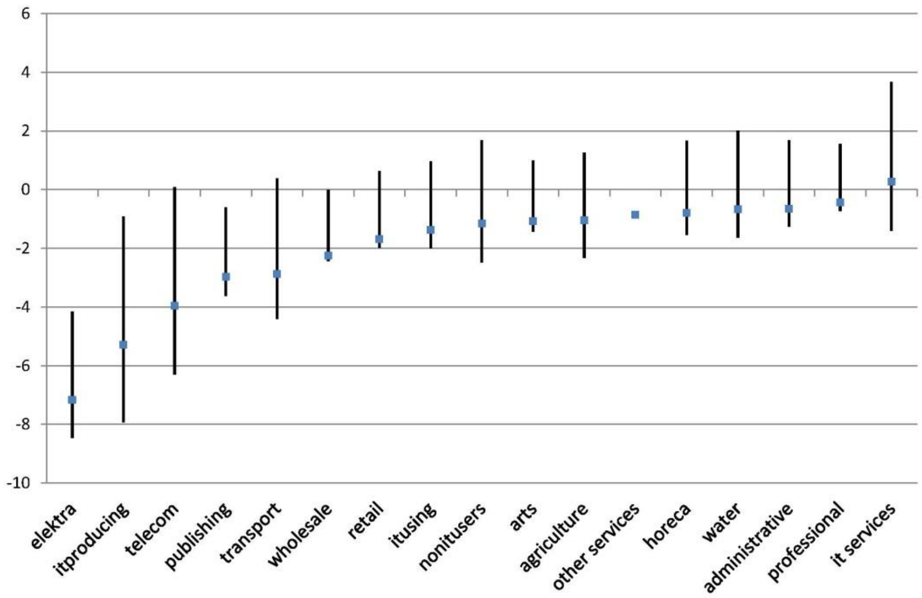
[15] The Figure is misleading for Denmark by showing a negative lower end of the confidence interval.

Figure 16: Country fixed effects 1997-2014: countries compared to benchmark France



Note: Vertical lines present the 95%-confidence interval of the fixed effects. The dots give the change in the trend growth rate of GDP per working hour.

Figure 17: Sectoral fixed effects 1997-2014: sectors compared to benchmark 'other services'



Note: Vertical lines present the 95%-confidence interval of the fixed effects. The dots give the sample average of the change in the trend growth rate of value added per working hour.

Table 4: Results of panel regression with country and/or sectoral Fixed Effects, (1997-2014)

	(1)		(2)		(3)		obs
Share self-employment	-0.080	*	-0.067	*	-0.066		162
Share 50-plus	-0.107		-0.070		-0.075		162
Share female	-0.052		0.017		0.015		162
Share middle education	-0.154	*	0.114	*	0.111	*	145
Share higher education	0.042		-0.067		-0.065		145
EPL regular contract	1.280		-0.071		-0.078		162
EPL temp. contract	0.409		-0.257		-0.250		162
Product market regulation	1.593		-0.931		-0.914		162
Country FE	YES		NO		NO		
Sector FE	YES		YES		NO		

The dependent variable equals the difference between the 9-year average growth rate of labour productivity in the second sub-period minus the average growth rate in the first sub-period. Robust standard errors in parentheses, * denotes significant at 5% level. The constant term represents 'other services' in France.

8 Discussion and conclusions

This paper reviews the evidence for the Netherlands of a productivity slowdown using various techniques and datasets (both at macro and sector level). The analysis is based on the trend of labour productivity (GDP per hour).

We find that productivity growth in The Netherlands has slowed down, with a bump around 2000. This slowdown is structural, which means it is corrected for business cycles. This finding corroborates the conclusion of the OECD (2016), which finds that productivity growth remains below pre-crisis rates in many countries. It voices the concern that this reflect a ’new low productivity growth paradigm, with consequential impacts on well-being and inequalities’ OECD (2016, p. 9). This pattern may also be seen as a return to normal growth rates, if we assume that a normal rate is the average productivity growth rate since the eighties, which shows ups (ICT boom) and downs (financial crisis).

By comparing countries and sectors, we try to pinpoint possible explanations for this slowdown. In addition, we regress several explanatory variables on the differences between average growth rates (i) before and after 2000 and (ii) before and after 2005, with fixed effects for countries and sectors. Because of the wide variety in patterns between countries as well as sectors, the results contain a lot of ’noise’ and no clear picture emerges. Combined with the problem of how to measure a slowdown when the pattern is one of increasing and subsequent decreasing growth (see section 3.1), it may not come as a surprise that we were not able to pinpoint any satisfactory explanations of why the productivity growth has slowed down.

That said, the analysis does produce some interesting findings pertaining to the role the ICT boom of the late 1990s played. The pattern of productivity growth in the Netherlands clearly shows a bump: after slowing down considerably after the late 1970s, the trend of productivity growth seems rather stable, except for a bump around 2000. Although recent years are somewhat unreliable due to measurement problems, productivity growth seems to be slightly below its long-term average.

This pattern of productivity growth in The Netherlands is not significantly different from that of the US (measured with data 1995-2005) or the UK (measured with data 1995-2015). Several studies on the productivity slowdown in the US have concluded that after the ICT boom (starting in the mid-90s and ending around 2000), productivity growth returned to normal. The pattern in the UK is a marked slowdown after the Global Recession.

We find that from 1995 to 2005, the sectors ’ICT producing’ and ’ICT using manufacturing’ contributed most to productivity growth, with sectors ’business’ and ’other services’ contributing less, but still significantly more to productivity growth than the retail sector (used as benchmark). When we extend the period to 2015, these sectors fade away and no longer contribute significantly more to productivity growth than other sectors.

Interestingly, we find no evidence that ICT intensity[16] (in all sectors for all countries) contributed significantly to productivity growth until 2005. A tentative explanation might be that the ICT boom period was triggered by a few sectors that became significantly more productive in this period (i.e. ICT producing, ICT using manufacturing, business and other services). However, it brings up more questions than answers of why this is the case and deserves further research into the role of ICT intensity.

Only a few other, non-ICT related factors turned out to be significant. As one might expect, the share of highly educated workers is significant (on average for all countries and all sectors) for the data until 2005. The share of middle educated workers shows a somewhat puzzling picture for the data until 2014 and therefore merits further investigation. The share of female workers is significant, but this may not necessarily imply a causal link. First, it is correlated with education level. Second, it could be a reflection of the fact that female labour participation has increased. If there is a causal link, the increase of the share of women in the labour market may be an indication of better use of capabilities, which possibly has a positive effect on productivity.

The significance of ITK in the regression analysis may point at capital misallocation. Capital misallocation means that some firms have too much capital and some have too little, in the sense that reallocating capital from firms with too much to firms with too little would lead to more output with the same amount of labour and capital inputs. Further research could explore the extent of capital misallocation in the Netherlands, and why, and how this may explain the productivity slowdown. It also highlights one of the conclusions made by Inklaar et al. (2005) that to explain the slowdown in the EU, non-ICT capital deepening is an important issue.

A rigorous testing of various explanations was hampered by the fact that we had no complete database with all the relevant variables until 2015 for all relevant countries. The KLEMS dataset only has data until 2005. The update (with data until 2015) is not complete for all variables and countries. The OECD database does include data up to 2015, but does not include the US or data on ICT intensity. In addition, the period after the Great Recession may as yet be too short to allow for a thorough analysis of its effect on productivity growth.

It is clear that the analysis of macro and aggregated data cannot answer all the questions on why productivity growth has slowed down. To achieve this, it is probably more fruitful to investigate productivity within sectors, and at firm level. This is in line with the conclusion of Drummond (2011) who, after several years of research on Canada's failing productivity growth, concluded: "the productivity research effort must shift. It must go more micro than macro. But the micro analyses must be aggregated in a fashion to explain the overall national trends." [17]

[16] measured as % of capital compensation

[17] This is especially poignant for Canada, which, despite adopting the recommendations made by OECD and IMF of stable macroeconomic policy and sound structural policy, experienced a considerable slowing down of productivity growth.

The large decrease in productivity during the Great Recession in the Netherlands also raises some questions that should be analysed with firm-level data. Recessions are often said to be cleansing in that the least efficient firms go bankrupt and exit the market to be replaced by new, more efficient entrants. But this raises the question why productivity growth has been so slow after the Great Recession? Could it be that the exit of inefficient firms and entrance of new firms stopped happening or slowed down?

Finally, our results on the different performance of sectors raise the question whether this can be explained by frontier firms. It may be that some sectors have more frontier firms than others. This may also corroborate the conclusion by the OECD (McGowan et al. (2015)) that the reason behind the productivity slowdown is a change in transmission mechanism: the productivity growth of the most productive firms has not slowed, but the transmission of the successful technologies employed by the frontier firms to the other firms in the economy has slowed. This has led to a divergence of the productivity performance of leading firms with strong productivity gains and the rest whose productivity growth has slowed.

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Appendix

Appendix A: Results Panel regressions

Table 5: Estimation results panel regressions 1996-2005

	1995-2004			**1996-2005**			**1994-2003**		
	coeff	std. error		coeff	std. error		coeff	std. error	
Fixed effects Sectors									
Agriculture	-0.0084	(0.0048)		-0.0079	(0.0055)		-0.0087	(0.0044)	
Business	0.0069	(0.0032)	*	0.0076	(0.0030)	*	0.0062	(0.0037)	
Electricity	-0.0052	(0.0041)		-0.0087	(0.0048)		-0.0024	(0.0041)	
Horeca	0.0016	(0.0026)		0.0018	(0.0029)		0.0019	(0.0024)	
Ict production	0.0130	(0.0047)	*	0.0109	(0.0048)	*	0.0150	(0.0050)	
Ict users	0.0135	(0.0033)	*	0.0161	(0.0041)	*	0.0114	(0.0030)	
Non ictusers	0.0017	(0.0028)		0.0013	(0.0035)		0.0022	(0.0023)	
Other services	0.0075	(0.0027)	*	0.0074	(0.0028)	*	0.0072	(0.0027)	
Post and telecom	-0.0012	(0.0062)		-0.0076	(0.007)		0.0046	(0.0053)	
Transport	-0.0002	(0.0020)		0.0022	(0.0025)		-0.0022	(0.0018)	
Wholesale	-0.0007	(0.0043)		-0.0014	(0.0047)		0.0000	(0.0039)	
Fixed effects Countries									
Austria	-0.0090	(0.0048)		-0.0083	(0.0061)		-0.0091	(0.0039)	*
Belgium	-0.0104	(0.0052)	*	-0.0100	(0.0062)		-0.0105	(0.0041)	*
Denmark	-0.0138	(0.0060)	*	-0.0130	(0.0074)		-0.0145	(0.0048)	*
Finland	-0.0057	(0.0054)		-0.0050	(0.0060)		-0.0058	(0.0048)	
France	-0.0080	(0.0042)		-0.0089	(0.0052)		-0.0065	(0.0034)	
Germany	-0.0090	(0.0048)		-0.0085	(0.0061)		-0.0090	(0.0036)	*
Greece	0.0099	(0.0055)		0.0050	(0.0060)		0.0143	(0.0052)	*
Ireland	-0.0036	(0.0072)		-0.0034	(0.0095)		-0.0028	(0.0061)	
Italy	-0.0153	(0.0050)	*	-0.0146	(0.0054)	*	-0.0152	(0.0047)	
Japan	-0.0086	(0.0057)		-0.0063	(0.0068)		-0.0106	(0.0048)	*
Netherlands	0.0002	(0.0053)		0.0000	(0.0059)		0.0007	(0.0048)	
Portugal	-0.0162	(0.0049)	*	-0.0156	(0.0059)	*	-0.0166	(0.0042)	*
Spain	-0.0120	(0.0038)	*	-0.0100	(0.0047)	*	-0.0133	(0.0032)	*
Sweden	0.0014	(0.0064)		-0.0002	(0.0068)		0.0031	(0.0062)	
UK	-0.0103	(0.0062)		-0.0104	(0.0072)		-0.0096	(0.0052)	
constant	0.0035	(0.0036)		0.0029	(0.0046)		0.0036	(0.0027)	
R^2	0.3324			0.2869			0.3877		

The dependent variable equals the difference between the 5-year average trend growth rate of labour productivity in the second sub-period minus the average growth rate in the first sub-period. Robust standard errors in parentheses, * denotes significant at 5% level. The constant term represents the retail sector in the US. Number of obs. = 192.

Table 6: Estimation results panel regressions 1997-2014 OECD

	coeff	std.error	
Fixed effects Countries			
Austria	0.6242	(0.7483)	
Denmark	2.1559	(1.0521)	*
Finland	-0.0327	(0.8289)	
Germany	1.0839	(0.7174)	
Greece	-2.6264	(1.1603)	*
Italy	0.7093	(0.6631)	
Netherlands	-0.9234	(0.8750)	
Spain	3.6528	(0.9612)	*
Sweden	-1.0813	(1.1228)	
UK	-1.3817	(1.0871)	
Fixed effects Sectors			
Administrative	0.2065	(0.7450)	
Agriculture	-0.5348	(0.9047)	
Arts	-0.2185	(0.6103)	
Electricity	-6.3047	(1.0881)	*
Horeca	0.0673	(0.8108)	
It services	1.1326	(1.2842)	
It producing	-4.4288	(1.7745)	*
It using	-0.5208	(0.7466)	
Non itusers	-0.3971	(1.0519)	
Professional	0.4190	(0.5771)	
Publishing	-2.1115	(0.7650)	*
Retail	-0.6711	(0.6592)	
Telecom	-3.1080	(1.6174)	
Transport	-2.0175	(1.2120)	
Water	0.1875	(0.9206)	
Wholesale	-1.2228	(0.6110)	*
constant	-0.7081	(0.7343)	

The dependent variable equals the difference between the 9-year average growth rate of labour productivity in the second sub-period minus the average growth rate in the first sub-period. Robust standard errors in parentheses, * denotes significant at 5% level. The constant term represents the sector 'other services' in France. R^2 = 0,445. Number of obs. = 162.

Appendix B: Space State Model

We adopt the notation for the log of the level of productivity for country i in the year t of $y_{i,t}$. This is our observed level of productivity we model with a state space model. As we have described above, in this model the observed data is assumed to be given by the sum of two unobserved processes: an underlying trend potential component denoted by $\mu_{i,t}$ and business cycle component denoted by $\psi_{i,t}$:

$$y_{i,t} = \mu_{i,t} + \psi_{i,t} \quad (1)$$

The business cycle component is assumed to shock the measured level of productivity in a temporary fashion: after one complete cycle the level of productivity returns to the trend level $\mu_{i,t}$.[18] This implies that the business cycle has no permanent effect on the level of productivity. The underlying trend level of productivity is itself assumed to follow a random walk plus the sum of a time varying growth rate $\beta_{i,t}$ and the effect of the banking crisis modeled using the dummy variables $D_{i,t-s}$. It is the estimated $\beta_{i,t}$ series that we want to estimate. This series represents the underlying growth potential of productivity. The trend therefore has the following specification.

$$\mu_{i,t} = \mu_{i,t-1} + \beta_{i,t} + \sum_{s=0}^{5} \delta_s D_{i,t-s} \quad (4)$$

[18] The business cycle component is modeled by a trigonometric cyclical component, which is specified as follows.

$$\begin{pmatrix} \psi_{i,t} \\ \psi^*_{i,t} \end{pmatrix} = \rho \begin{bmatrix} \cos\lambda & \sin\lambda \\ -\sin\lambda & \cos\lambda \end{bmatrix} \begin{pmatrix} \psi_{i,t-1} \\ \psi^*_{i,t-1} \end{pmatrix} + \begin{pmatrix} \zeta_{i,t} \\ \zeta^*_{i,t} \end{pmatrix}, \quad \text{(B.2)}$$

where ρ is an autoregressive dampening coefficient and λ is the angular frequency of the cycle. The period of the cycle is given by $2\pi/\lambda$. We calibrate the business cycle to be $2\pi/\lambda = 7$ years. We also calibrate the dampening coefficient $\rho = 0.7$. Calibrating these parameters allows for a reduction in the number of parameters estimated. For both parameters it is fairly straight forward to determine plausible values, and their exact values do not substantially effect the results. The vector of shocks ζ_t and ζ^*_t are assumed to be uncorrelated, and have the same covariance matrix:

$$\begin{pmatrix} \zeta_t \\ \zeta^*_t \end{pmatrix} \sim N\left(0, \begin{bmatrix} \Sigma_\zeta & 0 \\ 0 & \Sigma_\zeta \end{bmatrix}\right), \quad (\zeta_{1,t}, \ldots, \zeta_{n,t})' \equiv \zeta_t \quad \text{(B.3)}$$

We estimate this model using the restriction that there is no correlation between the cyclical innovations $\zeta_{i,t}$ and $\zeta_{j,t}$ for $i \neq j$ or between $\zeta^*_{i,t}$ and $\zeta^*_{j,t}$ for $i \neq j$. This assumption implies that the business cycle in each country is independent of the other countries' business cycles. This results in a much more parsimonious model than for one in which we allow for correlation between the business cycle from different countries. We note however that estimates we have obtained with models which do allow for this correlation indicate that there is no long run effect of banking crises on the level of productivity. In further research we hope to further investigate the robustness of our current results to various model specifications. This research is however beyond the scope of this current project.

$$\beta_{i,t} = \beta_{i,t-1} + \xi_{i,t}, \quad (\xi_{1,t}, \ldots, \xi_{N,t}) \equiv \xi_t : N(0, \Sigma_\xi). \quad (5)$$

In equation (4) a banking crisis in country i beginning in the year t is modeled by $D_{i,t} = 1$ and that the contribution of this dummy variable to the trend continues for five years following the beginning of the crisis. The effect on the level of the trend in each year following the crisis being given by the dummy coefficient δ_s, a level shift which is assumed to be the same over all countries in the panel. We assume that the growth rate, $\beta_{i,t}$ also follows a random walk.

[19] In this way the growth rate is free to evolve up and down over time to capture changes in the underlying growth rate potential in a country's output. [20]

We obtain our estimates from a program using the matrix language OX Doornik and Ooms (2001) and the Kalman Filter routines in SsfPack Koopman et al. (1999). This results in maximum likelihood estimates for the model's parameters. Given these parameter estimates we then obtain so-called smoothed estimates of the model's unobserved components: the business cycle component, the trend, and the growth rate. We discuss these estimates in the next section.

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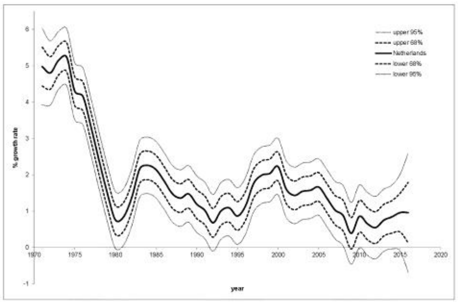
[19] Without the cyclical component, this model is commonly referred to as the local linear trend model, see Harvey (1991).

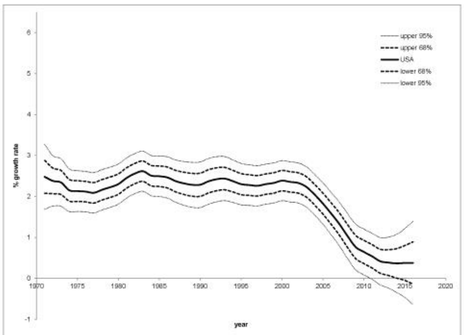
[20] A random walk specification for the growth rate has a number of advantages over a time trend. The forecast for a random walk which is given by a constant value equal to the estimated value in the final period of the sample. This reflects the most current information about the current growth potential, while still remaining neutral about the future movement either up or down in this growth rate. A random walk is also generally less restrictive than a time trend, because in each period a random walk is free to move either up or down. A time trend on the other hand imposes a fixed step movement in the same direction each period. An additional benefit of the random walk specification is that it is more parsimonious than the time trend.
The estimation via maximum likelihood is also much faster for the random walk specification than the AR growth specification used in Cerra and Saxena (2008). This is because the size of the state needed in the SSF for the CSM is much greater: an AR(4) specification requires 4N elements be included in the state, We also regard the constant long run growth rate implied by the AR specification to be unrealistic. The flexible and parsimonious specification of the random walk makes it well suited to capture the developments in the long run growth potential without imposing the direction of the change.

Figure 18: Productivity Growth in Netherlands, USA, Germany, Japabn, Belgium Italy (SSM)

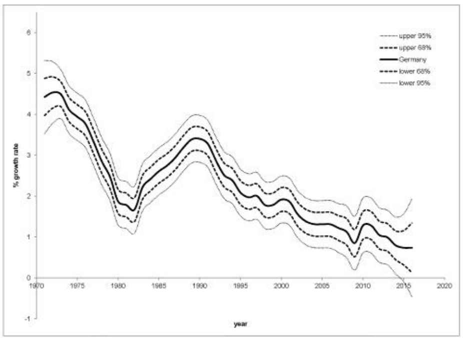
Netherlands



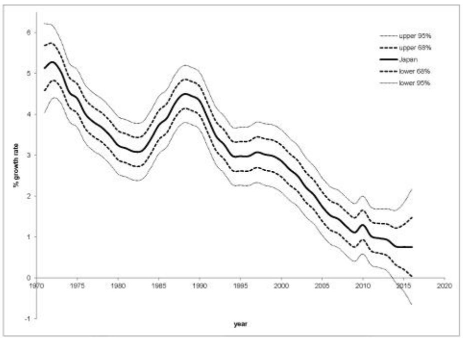
USA



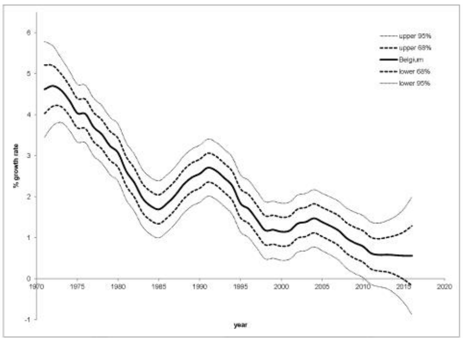
Germany



Japan



Belgium



Italy

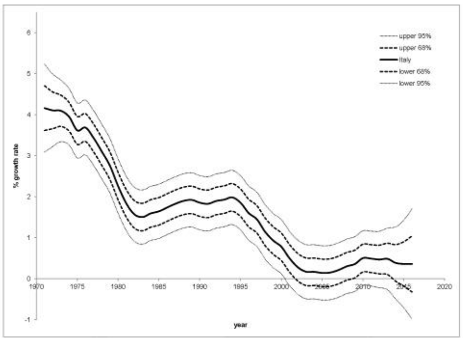
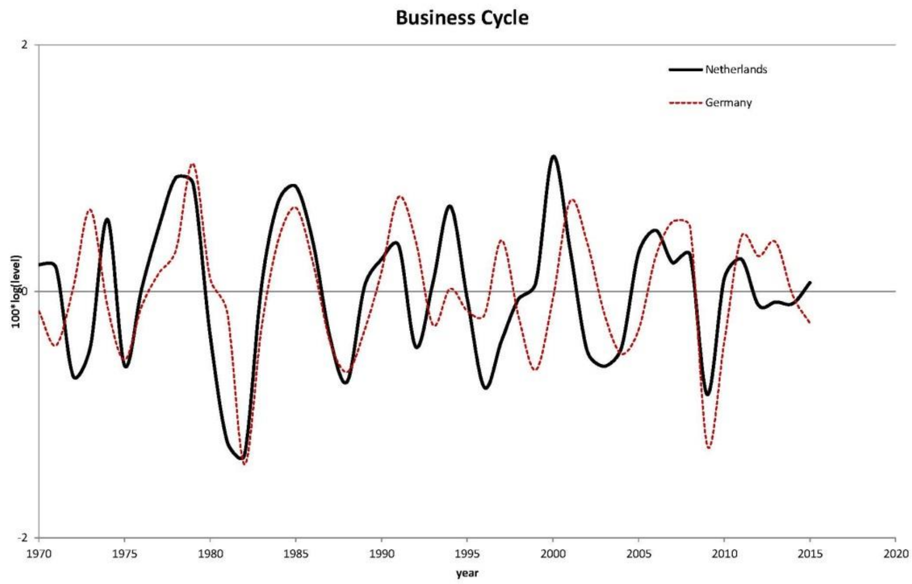


Figure 19: Business Cycle



Appendix C: Sectors in KLEMS and OECD databases

Table 7: KLEMS sectors

Sector	**KLEMS name**	**KLEMS code**
agriculture	agriculture, hunting, forestry and fishing	A+B
electricity	electricity, gas and water	E
post and telecom	post and telecommuncations	64
wholesale	wholesale trade and commission trade, except of motor vehicles and motorcycles	51
retail	retail trade, except of motor vehicles and motorcycles; repair of household goods	52
transport	transport and storage	60-63
horeca	hotels and restaurants	H
business services	(includes: renting of machinery and equipment, computer and related activities, R&D, other business activities)	71-74
other services	Other community, social and personal services (includes: sewage, recreation and culture, activities of membership organisations)	O
ICT-producing manuf.	electrical and optical equipment	30-33
ICT-intensive manuf.	pulp and paper, machinery, nec; manufacturing, nec and recycling	21-22 (29, 36-37
non-ICT intensive manuf.	manufacturing not listed above	

Table 8: OECD sectors

Sector	OECD name	OECD code
agriculture	agriculture, forestry and fishing	A
electricity	electricity, gas, steam and air conditioning supply	D
telecom	telecommunications	61
publishing	publishing, audiovisual and broadcasting activities	56-60
transport	transportation and storage	H
wholesale	wholesale trade, except of motor vehicles and motorcycles	46
retail	retail trade, except of motor vehicles and motorcycles	47
arts and others	arts, recreation and entertainment	R
horeca	accomodation and food services	I
water	water supply, sewage, waste management and remediation actitivities	E
administrative services	administrative and support services	N
professional services	professional, scientific and technical services	M
IT services	IT and other information services	62-63
other services	repair of computer and household goods, membership organisations and other services	S
ICT-producing manufacturing	computer, electronics and optical	26
ICT-intensive manufacturing	manufacture of electrical equipment; machinery and equipment, nec; and other manufacturing	27-28 + 31-32
non-ICT intensive manufacturing	all manufacturing except the above	

Appendix D: Results of the Bai Perron Structural break tests

Multiple breakpoint tests
Bai-Perron tests of L+1 vs. L sequentially determined breaks
Break test options: Trimming 0.05, Max. breaks 5, Sig. level 0.05

Sequential F-statistic determined breaks:	1

Break Test	F-statistic	Scaled F-statistic	Critical Value**
0 vs. 1 *	45.81183	45.81183	9.63
1 vs. 2	8.299655	8.299655	11.14

* Significant at the 0.05 level.
** Bai-Perron (Econometric Journal, 2003) critical values.

Break dates:

	Sequential	Repartition
1	1978	1978

Multiple breakpoint tests
Bai-Perron tests of 1 to M globally determined breaks
Break test options: Trimming 0.05, Max. breaks 5, Sig. level 0.05

Sequential F-statistic determined breaks:	5
Significant F-statistic largest breaks:	5
UDmax determined breaks:	1
WDmax determined breaks:	1

Breaks	F-statistic	Scaled F-statistic	Weighted F-statistic	Critical Value
1 *	45.81183	45.81183	45.81183	9.63
2 *	31.85192	31.85192	34.93553	8.78
3 *	24.91019	24.91019	30.55862	7.85
4 *	21.18850	21.18850	28.30031	7.21
5 *	20.41732	20.41732	29.38995	6.69

UDMax statistic*	45.81183	UDMax critical value**	10.17
WDMax statistic*	45.81183	WDMax critical value**	10.91

* Significant at the 0.05 level.
** Bai-Perron (Econometric Journal, 2003) critical values.

Estimated break dates:
1: 1978
2: 1977, 2007
3: 1977, 2008, 2010
4: 1973, 1975, 1979, 2007
5: 1973, 1975, 1979, 2008, 2010

Multiple breakpoint tests
Compare information criteria for 0 to M globally determined breaks
Break test options: Trimming 0.15, Max. breaks 5

Schwarz criterion selected breaks:	2
LWZ criterion selected breaks:	1

Breaks	# of Coefs.	Sum of Sq. Resids.	Log-L	Schwarz* Criterion	LWZ* Criterion
0	1	0.012725	119.9911	-8.086222	-8.038288
1	3	0.006161	136.3108	-8.642356	-8.496982
2	5	0.005056	140.7579	-8.670823	-8.425738
3	7	0.004896	141.4808	-8.533765	-8.186465
4	9	0.004540	143.1837	-8.440265	-7.987977
5	11	0.004457	143.5950	-8.289358	-7.728991

* Minimum information criterion values displayed with shading

Estimated break dates:
1: 1978
2: 1977, 2007
3: 1977, 1986, 2007
4: 1977, 1991, 1997, 2007
5: 1977, 1983, 1990, 1997, 2007

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