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Abstract

The paper addresses the topic of an overall long-term productivity slowdown in labor productivity for a panel of 25 developed countries. Besides studying individual long-term trends of single countries using filtering techniques we also test for multiple structural breakpoints in the long-term trends. Furthermore after determining the country specific long-term productivity trends using state-space approaches, we extract a common factor from these long-term trend series using factor analysis. The country specific differences are only of second order importance. Dominant is an overall long-term productivity slowdown. The beginning of this slowdown already started in the 1970s and has persisted without any significant structural breakpoint afterwards until now. The same analysis for GDP growth and hours worked data were performed. We found similar results for the GDP growth data compared to the productivity data but not for the hours worked data. Furthermore Granger causality tests reveal that the trend productivity slowdown is driven by the downward trending GDP growth and not vice versa. For the hours worked data no significant relation to productivity growth could be confirmed.

Key words: Productivity slowdown, labor productivity, GDP measurement, Granger causality, factor analysis, Kalman filter, structural break

JEL Classification: E01, O47, C22, C38

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1. Introduction

Productivity growth has always been a key indicator for long-term prosperity and growth opportunities of societies. Changing trends in labor productivity growth have been factors for stabilizing or destabilizing distributional conflicts between capital and labor: As long as capitalism produced higher incomes for the majority of working people around the globe as in the decades after WWII due to diminished distributional conflict and trickle-down effects the legitimacy of income and wealth inequality was a less pressing social question. For long periods, capitalism did deliver what it promised, i.e. to make everyone better off. However, if, on the contrary, labor productivity growth slowed down as in the 1970s and afterwards social tensions on income distribution were on the rise.[1]

Therefore to study overall labor productivity growth of different economies has always been an essential part of macroeconomic analysis and theories of economic growth. The general view of economists in the decades after WWII were quite optimistic: Those countries lagging behind were catching-up, the leading countries were forging ahead by using their innovative capacities to specialize more and more into markets of high-tech products with high R&D investments and high-skilled human capital.[2] The picture of the last decades, however, is not very rosy.

The topic of productivity slowdown after the end of WWII already came to the fore of the economic debate in the mid-1970s.[3] The explanation for this development however mainly took into account certain major disruptions like the two oil price shocks. The rapid increase of information and communication technologies (ICT) then led to a debate, if this overall trend of productivity slowdown could be reversed. Rapid technological progress in particular in ICTs however did not show up in rising productivity numbers. In this situation, Robert Solow made his famous statement, "I see computers everywhere, but not in the statistics", i.e. the Solow-Paradox.[4]

For a short time since the mid-1990s until the beginning of the new millennium many economists believed that by correcting the statistical measurement of productivity growth (i.e introducing hedonic price indices for ICT-capital) was sufficient to show that the overall productivity slowdown has been reversed. This hope however faltered since then, when the

[1] Nouriel Roubini (2016), Globalization's Political Fault Lines, in: *Project Syndicate*, July 4, 2016. Joseph E. Stiglitz (2016), From Brexit to the Future, in: *Project Syndicate*, July 6, 2016.

[2] Moses Abramovitz (1986), Catching Up, Forging Ahead, and Falling Behind, in: *The Journal of Economic History,* **46**(2), p. 385-406; Georg Erber (1993), Catching-Up or Falling Behind - Relative Differences in Productivity and Price Competitiveness between U.S. and German Industries, 1960-1985, Research Report financed by the German Marshall Fund of the United States, German Institute for Economic Research, Berlin, August 1993.

[3] Edward F. Denison (1974), *Accounting for United States Economic Growth, 1929 - 1969*, Brookings Institution, 1974.

[4] Robert Solow (1987), We'd better watch out, in: *New York Times Book Review*, 12. July 1987, p. 36. Erik Bryniolfsson (1993), The productivity paradox of information technology, in: *Communications of the ACM*, **36**(12), 66-77.

new economy bubble burst.[5,6] After the start of the millennium the productivity growth in several countries returned to the previous long-term productivity slowdown trend.[7]

Improving the statistical measurement within the *System of National Accounts* (SNA) in 2008, to include R&D-expenditures as investment instead of expenditures and by this raising the gross domestic product (GDP) accordingly in 2014 in the US and in 2015 in Europe did not help either to raise measured productivity growth to a significantly higher level.

Currently a revision of the 2008 revision of the SNA is undertaken to try again to overcome this problem[8] and there is an ongoing debate about measurement problems of GDP and total factor productivity. The current state of the debate, however, is that even by correcting for potential measurement errors the long-term productivity slowdown prevails.[9]

The global financial and economic crisis of 2008 made the situation even worse. At first the crisis was considered by many economists as a short-term event, a "black swan"[10], in the global financial system. Remedies like very loose monetary policy and expansionary fiscal policy however failed to bring the global economy back on pre-crisis track, i.e. raise economic growth and productivity growth towards a pre-crisis level.[11] Lawrence Summers concluded that we have entered a new era of secular stagnation.[12]

There are two explanatory factors for this development: One is that the overall innovation process seemingly has slowed down. As Robert Gordon[13] and other authors illustrated by empirical analysis the rate of technological progress, measured by total factor productivity growth (TFP), has quite steadily diminished over the past decades - in particular in the highly industrialized countries like the US, Western Europe and Japan. The second is that there is emerging a global lack of effective demand[14], not only the developed economies are facing slower economic growth but the emerging economies and in particular the BRICS[15] are

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[5] Alan Greenspan (1996), *Remarks by Chairman Alan Greenspan*, Annual Dinner and Francis Boyer Lecture, The American Enterprise Institute for Public Policy Research, Washington D.C., 5. December 1996. Robert J. Shiller (2000), *Irrational Exhuberance*, Princeton University Press, Princeton, 2000.

[6] Dale W. Jorgenson, Mun S. Ho, Kevin J. Stiroh (2004), Will the U.S. Productivity Resurgence Continue?, in: *Current Issues in Economics and Finance*, **10**(13), 1-7.

[7] Daron Acemoglu, David Author, David Dorn, Gordon H. Hanson, Brendan Price (2014), *Return of the Solow Paradox? IT, Productivity, and Employment in U.S. Manufacturing*, , NBER WP 19837, Cambridge, Massachusetts, January 2014.

[8] Steven Landefeld, Dale J. Jorgenson, William D. Nordhaus (eds.) (2006), *A New Architecture for the U.S. National Accounts*, Chicago University Press, Chicago, 2006; Dale W. Jorgenson, Steven J. Landefeld, Paul Schreyer (2014), *Measuring Economic Sustainability and Progress*, Chicago University Press, Chicago, 2014.

[9] OECD (2015), *The Future of Productivity*, Organisation for Economic Cooperation and Development, Paris, 2015. IIE (2015), *Making Sense of the Productivity Slowdown*, Conference at the Peterson Institute for International Economics, Washington D.C., 16. November 2015.

[10] Nassim Nicholas Taleb (2007), *The Black Swan: The Impact of the Highly Improbable*, Random House, New York.

[11] Richard C. Koo (2015), *The Escape from Balance Sheet Recession and the QE Trap*, Wiley, New York, 2015.

[12] Lawrence H. Summers (2014), U.S. Economic Prospects: Secular Stagnation, Hysteresis, and the Zero Lower Bounds, in: *Business Economics*, Vol. 49(2), pp. 65-73.

[13] Robert J. Gordon (2012), *Is U.S. Economic Growth Over? Faltering Innovation Confronts The Six Headwinds*, National Bureau of Economic Research, NBER WP 18315, Cambridge, Massachusetts, August 2012.

[14] Loukas Karabarbounis, Brent Neimann (2013), *The Global Decline of the Labour Share*, National Bureau of Economic Research, NBER WP 19136, Cambridge, Massachusetts, June 2013.

[15] BRICS - Brasil, India, China, Russia, South Africa. Michael J. Boskin (2015), Can the BRICS escape the middle-income trap?, World Economic Forum, June 18 2015.

slowing down as well. The latter face the problem of ending up in the middle income trap.[16] Economic growth in most countries has furthermore become more and more debt-driven.[17] To close the demand gap, increasing long-term public and private debt is created. This however is unsustainable in the long-run since the accumulated debt cannot be serviced even if repayment is stretched out over very long time spans as long as productivity growth does not jump to significantly higher levels.[18] Debt restructurings and "hair cuts" are becoming at some point a necessity. This however causes major global economic disruptions since defaulting debtors lose access to credit markets or have to pay at least very high mark-ups of interest rates.

Our current paper addresses this topic of an overall long-term productivity slowdown in labor productivity for a panel of 25 countries. Besides studying individual long-term trends of single countries using filtering techniques we also test for multiple structural breakpoints in the long-term trends in labor productivity growth. Furthermore after determining the individual long-term productivity trends for single countries using state-space approaches, we extract a common factor from these long-term trend series by means of factor analysis. This sheds some insight on the specific differences between single countries and a common long-term trend. After removing differences in business cycles using respective filtering techniques, the results confirm that all countries experience a strong correlation towards a common global long-term productivity slowdown trend. Therefore the impact of individual differences between countries on the overall productivity slowdown can only be considered of second order importance. Dominant is a general long-term productivity slowdown for the majority of countries. The beginning of this overall slowdown already started in the 1970s and has prevailed without any significant structural breakpoint until now.

To identify the origins of this development we apply the same techniques on the two separate panel data sets of real GDP and labor input measured in hours worked. Again we can identify a couple of breakpoints in both data sets. The GDP data show a larger number of break points than the labor input data. Germany and Japan have three, the highest number of significant breakpoints in the country sample. Looking at the long-term development of selected major countries we find that all breakpoints indicate lower productivity growth rates after the break as before. This is consistent with a common pattern of a slowdown in GDP growth for all countries. Contrary the break-tests for labor inputs show a quite different pattern. There is not a general persistent downward trend observable in labor inputs and the co-movement between countries is less significant. Extracting again a common factor from the real GDP and the labor input data and comparing these with the common trend of labor productivity growth, we observe that the global labor productivity and real GDP growth are highly correlated but the one for the labor input data is not. Differences between countries in labor productivity are resting much more significantly on the labor input changes and increasing the variation between countries than from real GDP growth. This points into the direction of significant differences in in the labor market regimes of different countries.

[16] Barry Eichengreen, Dinghyun Park, Kwanho Shin (2013), *Growth Slowdowns Redux, New Evidence on the Middle-Income Trap,* National Bureau of Economic Research, NBER WP. 18673, Cambridge, Massachusetts, January 2013. Dani Rodrik (2015), *Premature Deindustrialization*, National Bureau of Economic Research, NBER WP 20935, Cambridge, Massachusetts, February 2015.

[17] Carmen M. Reinhart, Kenneth S. Rogoff (2010), *This Time is Different - Eight Centuries of Financial Folly*, Princeton University Press, Princeton; IMF (2016), Fiscal Monitor, International Monetary Fund, Washington D.C., April 2016; Engelbert Stockhammer, Rafael Wildauer (2015), Debt-driven growth? Wealth, distribution and demand in OECD countries, in: *Cambridge Journal of Economics*, November 2015.

[18] Greece is currently the most prominent example.

Granger causality tests reveal that the causality runs from the GDP growth trend to the productivity trend but not vice versa.

In the final section some reflections about the economic reasons behind these findings are suggested which might inspire future research.

2. Empirical analysis

Throughout this paper we use a single data set, which is based on The Conference Board Total Economy Database™. Annual level series are running from 1950 through to 2015, growth rates start in 1951. Productivity is measured as labor productivity using hours worked while real GDP is measured as millions of 2014 US$ (converted to 2014 price level with updated 2011 PPPs). Our dataset contains 25, mostly developed, mature or industrialized countries[19]. The baseline model used throughout this section is based on a model introduced by Robert Gordon[20] and takes on the following form:

$$(1)\ p_t = \beta_0 + \beta_1 y_t + \beta_2 y_{t+1} + \epsilon_t,$$

where p_t is the growth rate of labor productivity, β_0 is a constant, β_1 and β_2 are the slope coefficients of the present (y_t) and the one period ahead (y_{t+1}) output-gap. The present and future output-gaps are used to control for variations in the growth rate of productivity over the business cycle by assuming that productivity fluctuations are typically ahead of the cycle. The output-gaps are calculated using the asymmetric version of the Christiano-Fitzgerald[21] Band-Pass filter on logs of real GDP.

2.1 Structural break tests

To determine the degree of time variation in trend productivity growth, structural break tests are conducted. As the inclusion of present and future output-gaps capture variations in the growth rate of productivity due to the business cycle, all other variation is included in the innovation ϵ_t. Whenever there is a significant change in the level of those non-cyclical components, usual tests should point towards structural breaks in the constant β_0. For a first look at the data, tests for unknown breakpoints seem to be most suitable as we have, so far, gathered no information on the timing of potential breaks. The Andrews-Quandt-test[22], for instance, tests on unknown breakpoints via Chow-tests for every single period in a specified trimmed sample. On a 5% significance level, the Andrews-Quandt-test points towards a structural break in any country except for South Korea. As the test cuts the sample at the beginning and the end, test results for pre-1960 and post-2005 are not available. However,

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[19] Those countries are: Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, Canada, United States¸ Japan and South Korea

[20] Robert J. Gordon (2003), *Exploding productivity growth: context, causes, and implications*, Brookings Papers on Economic Activity 2003.2: 207-298.

[21] Lawrence J. Christiano, Terry J. Fitzgerald (2003), *The band pass filter*, International Economic Review 44.2: 435-465.

[22] Donald W.K. Andrews (1993), *Tests for parameter instability and structural change with unknown change point*, Econometrica: Journal of the Econometric Society: 821-856.

the histogram in Figure 1 (left panel) shows that the structural breaks detected by the test are not uniformly distributed across decades. Instead, there is not a single significant breakpoint found in the 1960s, only two in the 1990s and a moderate number of 4 in the 1980s. In the 1970s, on the other hand, 13 breakpoints are measured and 5 in the 2000s.

Insert figure 1 about here

In the framework of the Andrews-Quandt-test we did not allow for a total number of structural breaks larger than one for any country. The sequential Bai-Perron-test[23] is explicitly designed to test the presence of multiple structural breaks. In a given full sample, it tests for an unknown breakpoint and, in case that a breakpoint was found, splits the sample and performs tests on the new samples and so forth (otherwise concludes that there are no structural breaks). Bai-Perron testing sequences suggest that indeed many countries do not just display a single structural break in the constant but often come up with 2 or more breaks across the sample (in the cases of Germany and Japan 3 breaks are found, South Korea does, again, not give reason to conclude that there is any break (figure 1, bottom panel)). Allowing for multiple breakpoints slightly changes the figure (figure 1, right panel), adding four points to the 1960s, but the 1970s still stand out. As the end of the sample in general is not easily testable for structural breaks, the detection of such a high number in the 2000s is remarkable and is likely to be associated with the 2008/2009 financial crisis.

The so far determined breaks in the constant term can be summarized in another figure. Figure 2 presents the implied time-shifting constant together with the original time series of productivity growth. The direction of the structural shifts in the constant (downwards) impressively confirms the prejudice of downward trending productivity growth rates in the cases of Germany, France and the UK, less so in the US. Italy and Spain also show downward shifts in the intercept, which in those cases occurred earlier (late 1970s/1980s) than in the other European countries.

Insert figure 2 about here

However, whenever a structural break occurred since the 1980s the direction of the shift is downwards. The structural break analysis is a first hint for a downward trend in productivity growth rates.

2.2 Filtering

As an alternative way to determine a potential trending behavior in the "structural" productivity growth rate, time series filter methods can be applied. Similar to Gordon (2003), we re-estimate equation (1) but now under the explicit assumption of a time-varying constant. Therefore we reformulate the model in its state space form allowing the constant to evolve as a random walk:

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[23] Jushan Bai, Pierre Perron (2003), *Computation and analysis of multiple structural change models,* Journal of applied econometrics 18.1: 1-22.

(2) $p_t = \beta_t + \beta_1 y_t + \beta_2 y_{t+1} + \epsilon_t$,

(3) $\beta_{t+1} = \beta_t + u_{t+1}$,

where equation (2) is the measurement equation and (3) the state equation. Estimation of the time-varying constant can be done using the Kalman-filter or smoother. Error bands are calculated using the estimated variance for ϵ_t and u_{t+1}.

Insert figure 3 about here

In Figure 3 the Kalman-smoothed productivity trend-series are shown for the same countries as above. The US are the only country that saw a recovery of the productivity trend between the 1980s and today. However, this "productivity miracle" has to be considered as unsustainable after the sharp revision of the trend in the last decade. In all other countries, figure 3 shows a more or less steady downward trend in productivity growth rates with Spain being the only exception in recent years. In Spain, productivity increased by more than two percent in the post-crisis years, largely due to the sharp increase in unemployment and shedding of the labor force[24].

Figure 3 and the state-space analysis seem to confirm the conclusions drawn from the structural break analysis: in any country sampled in this case, the productivity growth rate is trending downwards at least since the 1970s. Even though the downward trend seems to be drastic in all cases, Italy and the United Kingdom are even more tragic than Germany and France. Italy's productivity growth trend turned negative several times in the last decade while the UK only stays slightly above zero very recently.

2.3 Factor analysis

As many time series in the sample showed a similar trending behavior, it appears reasonable to explore the (joint) multivariate dimension of those series. For this sake, a factor analysis is conducted. The factor model has the following form:

(4) $p_{it} = \lambda_i' F_t + e_{it}$,

where p_{it} is now the vector of productivity growth rates for every country i at every given point in time t. λ_i' is the vector of loadings, F_t is the matrix of factors, the common component of the multivariate time series, and e_{it} is the idiosyncratic component of every country series.

It turns out that a single factor does indeed explain significant shares of the variance of some of the productivity growth series, but very small shares of others. For instance, nearly 75% of Germany's productivity growth rate is explained by such a common component, but not even 10% of the United States' series follows the common path. It should be noted,

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[24] Thierry Tressel, et al. (2014), *Adjustment in Euro area deficit countries: progress, challenges, and policies*, IMF Discussion Note No. 14-17. International Monetary Fund

however, that significant amounts of the variance in the (non-filtered) productivity growth series is likely to be due to changes in the business cycle. The single common factor thus has to capture both co-movements in the trend and the cycle.

Table 1 thus summarizes the output of a factor analysis on the productivity growth trend.

Insert table 1 about here

Now the case that the share of the variation in trend productivity growth explained by the idiosyncratic component is larger than the share of the common component is a rare exception. In fact, only in Norway, Japan and Switzerland the idiosyncratic component explains a higher fraction of the variation than the common factor. Now, the common component also matches the variation in those countries that might have asymmetric business cycles, such as continental European countries on the one hand and the United States and Canada on the other. From this analysis, we can conclude that the bad performance of the one factor in the analysis on the productivity growth series is largely due to the fact that it doesn't match the heterogeneous business cycles and that there is indeed a significant proportion of variation in the trend explained by a common (downward) trend component. However, the common component (Figure 4) does not capture the sharp downturn observed in many country series after the financial crisis with values of productivity growth close to or even below zero, which might be due to the fact that we only use a single mean[25] to infer the level of the common component series from the standardized series.

Insert figure 4 about here

2.4 Decomposition into trend GDP and hours worked growth

In this section, we apply the same structural break-tests and filtering methods to the underlying decomposed GDP growth and hours worked growth series as above. We find that, first, the number of structural breaks in the GDP series is much higher than in the hours series and that, second, the patterns of timing and direction of the breaks in GDP growth and productivity growth are by far more in line than productivity and hours growth. Furthermore, the smoothed trend productivity growth and GDP growth series take on a very similar path which is comparable across countries. The hours growth trend series, however, differ a lot across countries. Some European countries share some common patterns, but in general size and direction are not comparable[26].

2.4.1 Factor analysis

In order to shed some more light on the possible roots of the general downturn of productivity growth rates we now investigate the multivariate dimension of the decomposed series in the same way as above. Following equation (4), table 4 displays the results of a factor analysis for the Kalman-smoothed trend growth rate of the input variable hours.

[25] The mean is calculated using cross-section means derived from the loadings of the factor analysis.
[26] More detailed results are available from the authors upon request.

Again, the number of factors is fixed at one and the same 25 countries are included as above. It turns out that the factor solution performs much “worse” than on the productivity series. 13 of the 25 countries show a communality of less than 0.5; that is the factor doesn’t even explain half of the variation in the trend series in more than half of the sample. For comparison: in the case of the factor analysis on the productivity growth series, only 4 countries displayed uniqueness larger than communality. [27] However, there are groups of countries that obey the factor to a large positive or negative extent. Continental European and Scandinavian Countries (Austria, Belgium, Luxembourg, Norway, Sweden and France) have a high loading and low uniqueness. Their hours growth might follow a very similar trend. Same is, in part, true for non-continental European countries: Japan, South Korea and the UK (the US to a lesser extent) have negative loadings and indeed high communality with the factor.

Insert table 2 about here

Again, the picture changes when it comes to the GDP growth trend, where the results are indeed very similar to those of the “combined” productivity growth series. In this case, only 3 countries (Ireland, Malta and Luxembourg) have uniqueness shares larger than their respective communality shares - those three can be interpreted as outliers. Apart from those three, the only countries now with a loading smaller than 0.9 are South Korea and Switzerland.

Insert table 3 about here

Figure 5 now compares the loadings of all countries across the three variables (hours, GDP and productivity) in a boxplot. The boxplots show that the loadings of the common GDP and productivity component seem to share a common structure with low variance, only few outliers and skewness towards 1. Furthermore, their median values are both between 0.9 and 1 and their means are larger than 0.8. The loadings of the hours growth series do not share this structure and display very high variance. With a value close to 0, the median loading is far away from 0.9 displaying the overall weakness of the factor in explaining larger parts of the time series. When running a regression without a constant of the loadings of the GDP and hours series on productivity, it turns out that the GDP-loadings for every country are indeed significant in explaining the productivity loading for the same country while the loadings of hours are insignificant.

Insert figure 5 about here

Figure 6 displays the same common productivity trend component series as Figure 4, but now the analogous series are added for hours and GDP. The common component of hours

[27] The share explained by the common component, i.e. the time series which arises as a result of the factor analysis, is called “communality”, while the share unexplained by the common component is called “uniqueness” throughout this text.

has a positive trend while the other two series have a, indeed very similar, downward trend. It is also true that, being derived from the factor analysis transformations, those common component growth rates do not add up (not even approximately), while the basic series for any country is consistent.

Insert figure 6 about here

The conclusion of this factor analysis is that hours growth seems to be unsystematic in the sense that it is firstly uncorrelated with any of the series and secondly the factor analysis yields results that are inconsistent with the non-decomposed productivity series, while the common downward trend of productivity and GDP-growth are indeed consistent.

Thus, while the single common factor for GDP seems to be just as good an approximation as productivity itself, the common factor of hours growth is not helpful in providing any information about the reason for the downward trend in the common component of productivity. Hence, our first prejudice that GDP is more likely to be the main driver of the downward path of productivity is confirmed by the factor analysis.

2.4.2 Causality analysis

In the above sections we approached the productivity series mainly using descriptive techniques. The conclusion of the last section was that we can essentially exclude hours to be a key driver of the common component of productivity growth (as the factor analysis yielded inconsistent and thus meaningless results) and that the relationship between common GDP and common productivity seems to be somehow stable. This section thus focuses on the relationship between the production and the productivity series and the aim is to shed some light on potentially causal relationships.

Even though the literature on causality is huge and still growing, VAR-based Granger-Causality analysis is still a prominent choice in the time series context. We thus base our analysis on the bivariate VAR including the common component of GDP growth and the common component of productivity growth:

$$(5)\ y_t = c + A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_p y_{t-p} + \epsilon_t,$$

where y_t and its lags are the 2x1 row-vectors consisting of the common component series of contemporaneous productivity and GDP and their lags. Also, we include a linear trend in the estimation where needed.

To allow for non-stationarity in assessing the causality question, we will make use of the more general framework of Toda and Yamamoto[28]. The approach implies several steps: first determine the potential order of integration (m), second determine the lag-order p of a VAR for the variables under investigation and then run Granger-causality tests up to order p in a VAR of order p+m using the Chi-square test-statistic. The additional lags in the specified VAR do not imply that the lag-length selected in the first step was wrong – as information criteria

[28] Hiro Y. Toda, Taku Yamamoto (1995), *Statistical inference in vector autoregressions with possibly integrated processes,* Journal of Econometrics 66.1: 225-250.

are still valid in the case of non-stationarity – but to make sure that the inference using Chi-square tests for linear restrictions are still valid. We now estimate the VARs as described above and test for Granger causality in all the bivariate models for every single country. Figure 7 displays a histogram, which summarizes the results. The blue bars display the number of P-Values of the test with the hypothesis “GDP does not cause Productivity” and the red bars those for the hypothesis “Productivity does not cause GDP”. Low P-Values point towards a rejection of this hypothesis and thus that there actually is causality in the tested direction. The results, in this case, are not unambiguous: the number of test statistics in the range from 0 to 0.1 is higher for GDP causing productivity than the other way around and the number of countries showing a P-value very close to 0 is higher for GDP causing productivity as well. However, as we tested 24 countries, in both cases the majority of the test results points towards causality implying that both time series are causal for each other in the majority of the cases.

Insert figure 7 about here

Apart from testing all countries separately, we also applied the procedure to the derived common component series of GDP and productivity. In this case, leaving aside all country-level idiosyncrasies, our results imply that the smoothed GDP growth trend is indeed causal for its productivity counterpart but not the other way around (table 4).

Insert table 4 about here

Thus, we are left with a somewhat puzzling result regarding causality: on the country level both trend productivity growth and GDP growth seem to be causal for each other while the cross-country common components point towards causality running from GDP to productivity only. However, this result seems to be in line with the above analysis: labor input does not play any particular role on the cross-country level as the trends differ a lot across countries. If there is any relation between cross-country productivity movements it is due to a shared movement in GDP, while labor input still influences country specific productivity growth trends.

3. Conclusion

Summing-up the results of this empirical analysis the findings are that firstly, the previous results of a long-term productivity slowdown of recent OECD studies and a debate at the Peterson Institute for International Economics are confirmed.

Secondly, however, there is some heterogeneity in this process between the different economies in our sample of 25 countries. Break-points of the downward trend occur in different frequencies and different periods. This however does not change the general pattern of an overall productivity slowdown beginning around the mid-1970s, i.e. the first oil-price shock and the collapse of the Bretton Woods system.

The hopes of the early 2000s that there would occur a long-term turnaround in this trend in particular due to the ICT-revolution overcoming the Solow-Paradox have been futile. Neither the petering out of the oil-price shocks nor the technological revolutions since the mid-1970s were able to change significantly the downward trends and current expectations of a turnaround in the near future are quite unlikely. This supports the conjecture of Robert Gordon that current innovations do not pay off as much as previous one in higher productivity growth.

Small countries like Malta, Luxembourg, Cyprus and Ireland however show less close communality in their correlation with the common global trend of all developed countries. South Korea, Sweden, Switzerland and Germany are another group with somewhat weaker communality with the common trend with values between 0,612% and 0,877%. All other countries have communality values above 0,9%. This rules out that particular policies and institutional designs matter much to explain this development.

Backtracking the origins of the slowdown by separating the two factors of labor productivity growth, i.e. output growth and input growth measured by hours worked, shows that the common factor for the overall productivity slowdown is a general downward trend in GDP growth. Contrary labor input growth shows no strong correlation with labor productivity growth. This might be due to huge differences in the institutional setting of national labor markets, openness of the different countries to global competition and specialization patterns of the different national economies.

After finding empirical evidence of a strong co-movement between labor productivity growth and output growth the investigation of a Granger causal relation between the two variables show that there exists some Granger causality from overall GDP growth towards overall labor productivity growth but not vice versa, however, the significance is not very strong. There are some fundamental theoretical objections against this finding because one would in principle expect the opposite causal relation. New technologies or technological progress is in the standard neoclassical theory assumed to be exogenous and should drive the economy. However, labor productivity is not total factor productivity which is the standard measure for the rate of technological progress. Therefore there is some reason to expect that because of partial endogeneity this might lead to the opposite results using labor productivity.

An argument in favor of our finding is that faster economic growth is a key factor for the more rapid diffusion of new technologies because of the embodiment in the input factors like investment in equipment and human capital. The process of causation would therefore run from higher GDP growth leads to higher investment into human and equipment capital growth and by this to a more rapid diffusion of productivity increasing innovations. Slower GDP growth operates vice versa.

The key hypothesis would be that it is not primarily the generation of new productivity enhancing innovations per se, but the ability to incorporate these innovations via higher investments into the production capacity through an accelerated diffusion of new innovations. The new enhancing innovations are only an antecedent but not sufficient condition for an acceleration of productivity growth. This conjecture is a stimulus for further analysis in the future. What are the chains of causation? New innovations, diffusion of innovations via higher output growth and investments finally materialize in higher productivity growth or are there other factors still not explicitly mentioned in the analysis which hamper or contribute significantly to this process.

Currently a first policy conclusion would be that it seems that a better balance of innovation generation and diffusion of such innovations through higher growth and investment might be joint key factors to speed-up productivity growth. Without taking this chain of causation in an appropriate balanced equilibrium the benefits of innovation do not show-up in the productivity numbers leading again to a new productivity paradox. We see numerous innovations everywhere but they do not show up in the productivity numbers. It's the insufficient diffusion of new productivity enhancing innovations due to a lack of slower output growth and by this slower investments in human capital and equipment which became over the past decades a major roadblock leading to productivity slowdown in the developed countries.

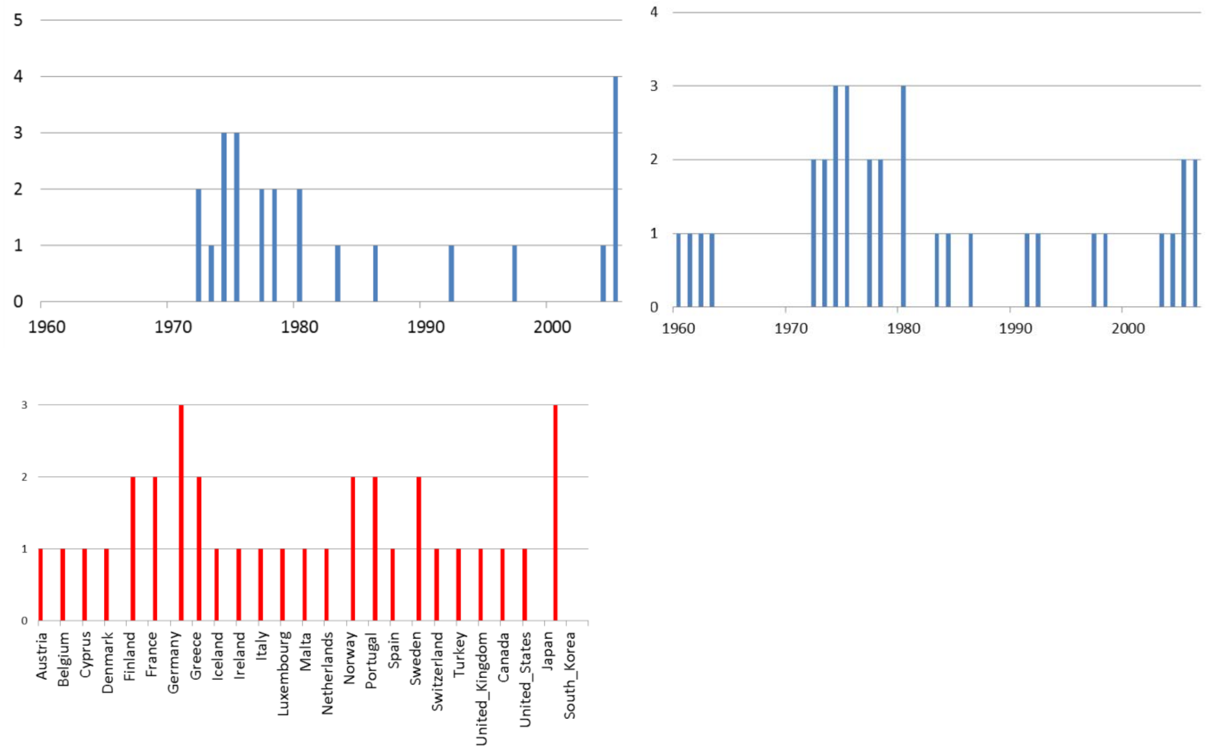
Another hypothesis of one global world economy for this outcome might be that the impact of globalization has led towards a more rapid diffusion of best practice technologies to developing countries. However, this led to significant capital outflows from the developed countries to the developing countries. Since the huge wage gaps between the developed world to the developing economies because of the location based factor price differences from an investors point of view, makes offshore locations more attractive to choose with less capital intensive technologies, a phenomenon known from capital theory as capital re-switching. This could have led to a slowdown in the diffusion of best practice technologies via foreign direct investments and offshore outsourcing towards developing countries with a low-wage labor force.

However, our findings here are only a first step towards a more integrated view of the interdependencies between productivity slowdowns and the two outlined causation chains. Without a better understanding and isolation of key factors and their appropriate combination as drivers of higher productivity growth, policy designs of growth policies still rest on fragile empirical and theoretical foundations.

Appendix

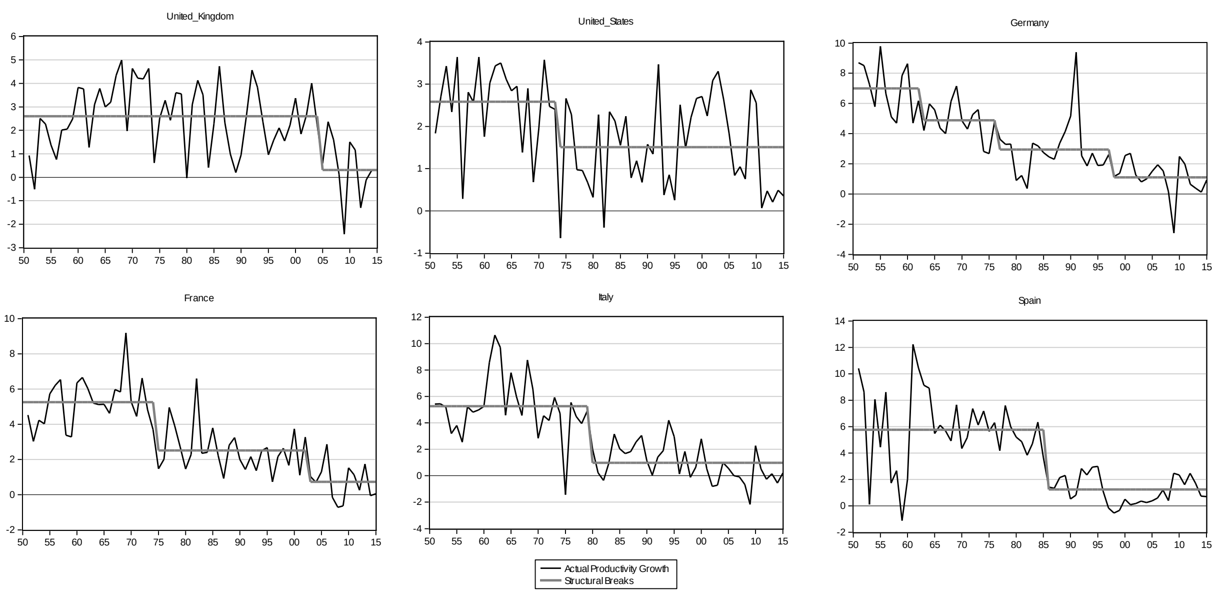
Figures

Figure 1: Distribution of structural breaks across time (left panel: unknown 1 break point, right panel: multiple breaks, bottom panel: breaks per country)



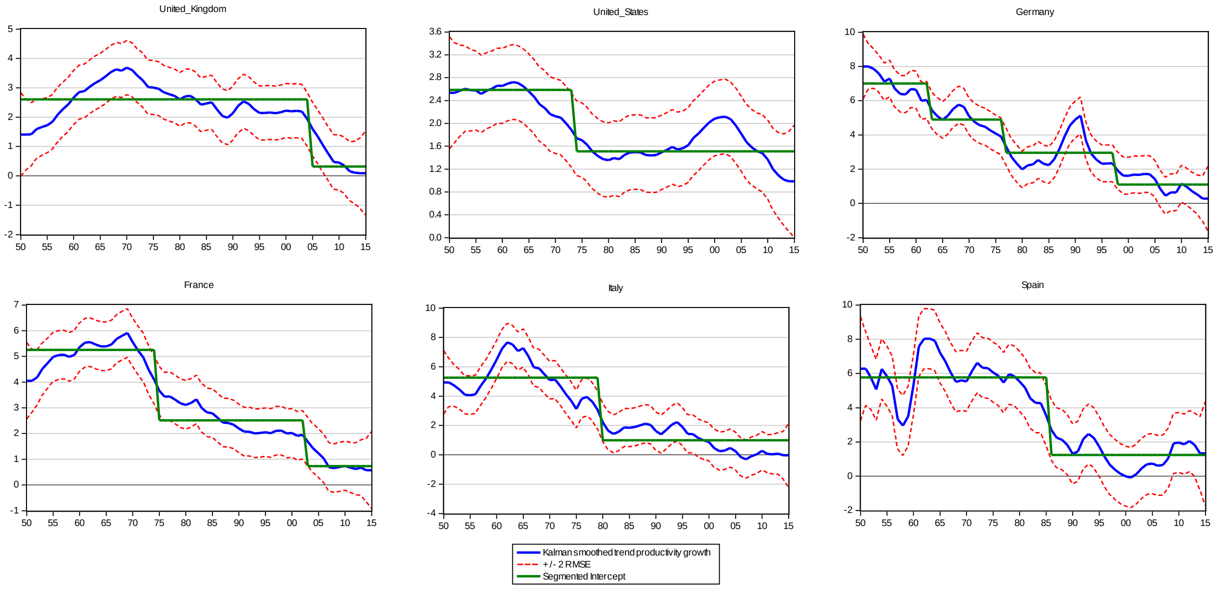
Left: results of Andrews-Quandt test on one unknown structural break, right: results of Bai-Perron test on multiple structural breaks. x-axis: time, y-axis: number of break points
Results of Bai-Perron test on multiple structural breaks for all countries in the sample. x-axis: countries tested, y-axis: number of break points for every country

Figure 2: productivity growth time series with sequential intercept estimates



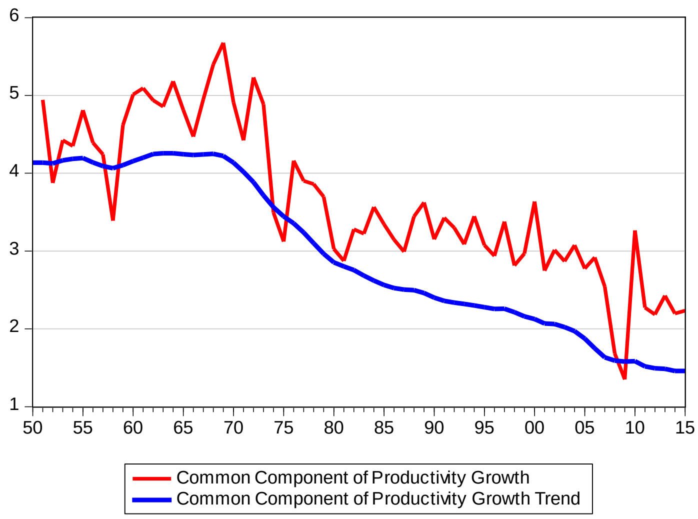
Original Labor productivity growth series (black line) Source: The Conference Board Total Economy Database™
Bai.Perron test implied segmented intercepts (green line).
x-axis: time (years), y-axis: yoy-change in %

Figure 3: Kalman-smoothed productivity growth in selected countries



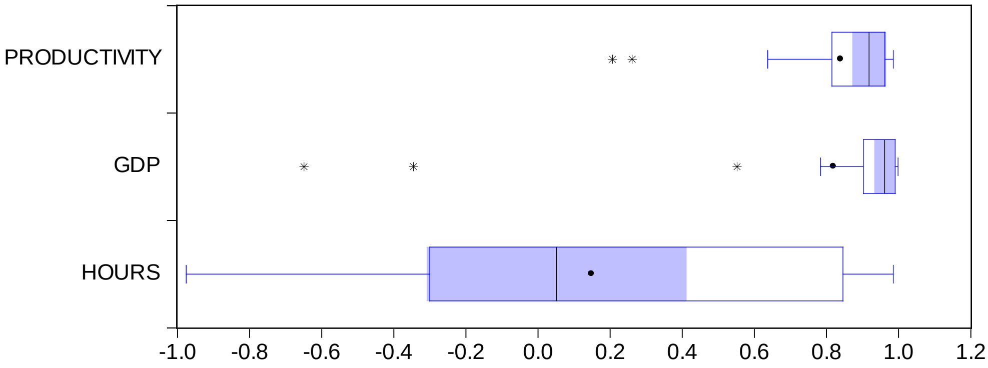
Kalman-smoothed labor productivity growth series (blue line) (red, dotted line: confidence interval) Bai.Perron test implied segmented intercepts (green line).
x-axis: time (years), y-axis: yoy-change in %

Figure 4: Common component of productivity growth and trend productivity growth



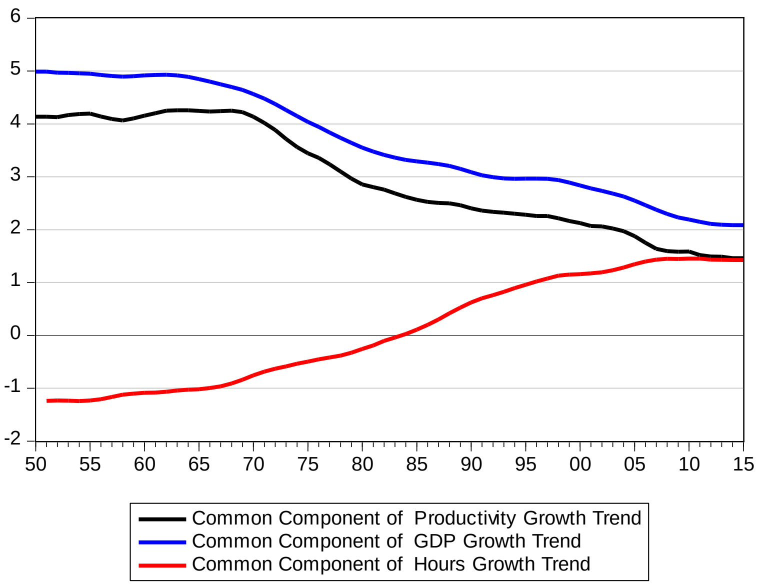
Common component of original productivity growth (factor scores of demeaned series + cross-section (loadings weighted), cross time mean of the sample (red line), Common component of trend productivity growth (factor scores of demeaned series + cross-section, cross time mean of the sample (red line) intercepts (blue line).
x-axis: time (years), y-axis: yoy-change in %

Figure 5: Loadings as a result of the factor analysis on the three variables: boxplots



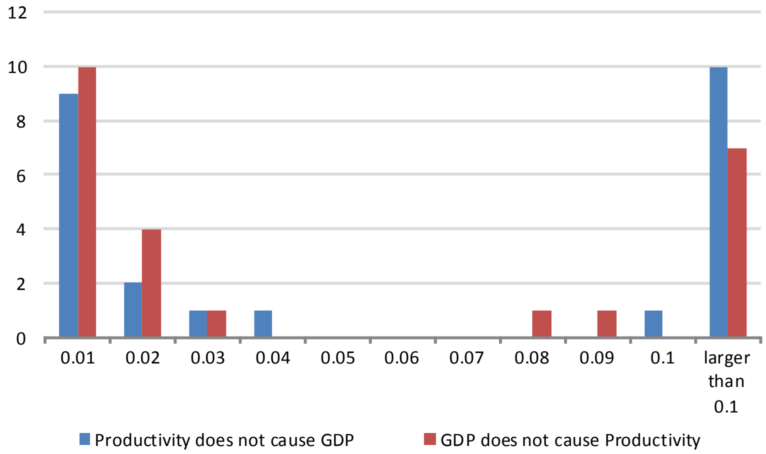
Boxplots of the country-specific loadings: the box limits the lower- and upper quartile of the distribution of loadings, the purple area is a confidence interval for the median, which is the line in its "middle", the black dot in every boxplot is the sample-mean, the tails of every box are the lower- and upper "whisker" of the box, asterisks are outliers.

Figure 6: Time series of common components



Common component of trend hours growth (factor scores of demeaned series + cross-section, cross time mean of the sample) (red line), Common component of trend GDP growth (factor scores of demeaned series + cross-section, cross time mean of the sample) (blue line), common component of trend productivity growth (Factor scores of demeaned series + cross-section, cross time mean of the sample) (black line). x-axis: time (years), y-axis: yoy-change in %

Figure 7: Histogram of p-values for Toda-Yamamoto tests
Null hypothesis: No granger causality



y-axis: number of country-specific P-Values as a result of Granger-Causality test with the null hypothesis „x does not cause y", x-axis: ranges of P-values, the number below the range is the upper-limit of every range

Tables

Table 1: Factor analysis on trend productivity growth

Results: Factor Analysis, trend productivity growth

	Loadings	Communality	Uniqueness		Loadings	Communality	Uniqueness
Austria	0.975	0.951	0.049	Netherlands	0.927	0.858	0.142
Belgium	0.918	0.843	0.157	Norway	0.261	0.068	0.932
Cyprus	0.985	0.971	0.029	Portugal	0.973	0.947	0.053
Denmark	0.984	0.968	0.032	Spain	0.934	0.872	0.128
Finland	0.925	0.856	0.144	Sweden	0.909	0.826	0.174
France	0.907	0.823	0.177	Switzerland	0.206	0.043	0.957
Germany	0.980	0.960	0.040	Turkey	0.854	0.729	0.271
Greece	0.902	0.814	0.186	United_Kingdom	0.692	0.478	0.522
Iceland	0.821	0.674	0.326	Canada	0.951	0.904	0.096
Ireland	0.958	0.917	0.083	United_States	0.977	0.955	0.045
Italy	0.712	0.507	0.493	Japan	0.637	0.406	0.594
Luxembourg	0.950	0.902	0.098	South_Korea	0.797	0.636	0.364
Malta	0.847	0.717	0.283				

Results of a factor analysis (maximum likelihood) with a fixed number of factors (1), loadings, communality and uniqueness of the country-specific time series for trend (smoothed) productivity growth

Table 2: Factor analysis on hours trend growth

Results: Factor Analysis, hours trend growth

	Loadings	Communality	Uniqueness		Loadings	Communality	Uniqueness
Austria	0.938	0.880	0.120	Netherlands	0.437	0.191	0.809
Belgium	0.838	0.702	0.298	Norway	0.976	0.953	0.047
Cyprus	-0.019	0.000	1.000	Portugal	-0.243	0.059	0.941
Denmark	-0.185	0.034	0.966	Spain	0.525	0.276	0.724
Finland	-0.269	0.072	0.928	Sweden	0.866	0.750	0.250
France	0.796	0.634	0.366	Switzerland	-0.395	0.156	0.844
Germany	0.051	0.003	0.997	Turkey	0.961	0.923	0.077
Greece	-0.653	0.427	0.573	United_Kingdom	-0.976	0.952	0.048
Iceland	-0.141	0.020	0.980	Canada	0.515	0.266	0.734
Ireland	0.885	0.784	0.216	United_States	-0.531	0.282	0.718
Italy	-0.146	0.021	0.979	Japan	-0.950	0.902	0.098
Luxembourg	0.985	0.971	0.029	South_Korea	-0.972	0.944	0.056
Malta	0.426	0.181	0.819				

Results of a factor analysis (maximum likelihood) with a fixed number of factors (1), loadings, communality and uniqueness of the country-specific time series for trend (smoothed) hours growth

Table 3: Factor analysis on trend GDP growth

Results: Factor Analysis, trend GDP growth

	Loadings	Communality	Uniqueness		Loadings	Communality	Uniqueness
Austria	0.984	0.969	0.031	Netherlands	0.990	0.980	0.020
Belgium	0.989	0.978	0.022	Norway	0.951	0.904	0.096
Cyprus	0.808	0.654	0.346	Portugal	0.959	0.919	0.081
Denmark	0.984	0.968	0.032	Spain	0.990	0.981	0.019
Finland	0.990	0.980	0.020	Sweden	0.904	0.816	0.184
France	0.998	0.997	0.003	Switzerland	0.894	0.799	0.201
Germany	0.937	0.877	0.123	Turkey	0.966	0.934	0.066
Greece	0.995	0.989	0.011	United_Kingdom	0.905	0.820	0.180
Iceland	0.961	0.923	0.077	Canada	0.996	0.991	0.009
Ireland	-0.346	0.120	0.880	United_States	0.955	0.912	0.088
Italy	0.993	0.987	0.013	Japan	0.991	0.983	0.017
Luxembourg	-0.649	0.421	0.579	South_Korea	0.783	0.612	0.388
Malta	0.552	0.305	0.695				

Results of a factor analysis (maximum likelihood) with a fixed number of factors (1), loadings, communality and uniqueness of the country-specific time series for trend (smoothed) GDP growth

Table 4: Toda-Yamamoto's test on the extracted factor series
Null hypothesis: No granger causality

VAR:
Smooth Common Components

VAR Granger Causality/Block Exogeneity
Wald Tests
Date: 06/10/16 Time: 14:47
Sample: 1950 2015
Included observations: 61

Dependent variable: Common Component GDP
with (-4) and (-5) as non-tested exogenous variables (Toda-Yamaoto)

Excluded	Chi-sq	df	Prob.
Common Component Productivity	2.82	3	0.42
All	2.82	3	0.42

Dependent variable: Common Component: Productivity

Excluded	Chi-sq	df	Prob.
Common Component GDP	9.69	3	0.02
All	9.69	3	0.02

Results: Toda-Yamamoto (1995) approach to causality testing, upper panel: trend productivity causes trend GDP, lower panel: trend GDP causes trend productivity