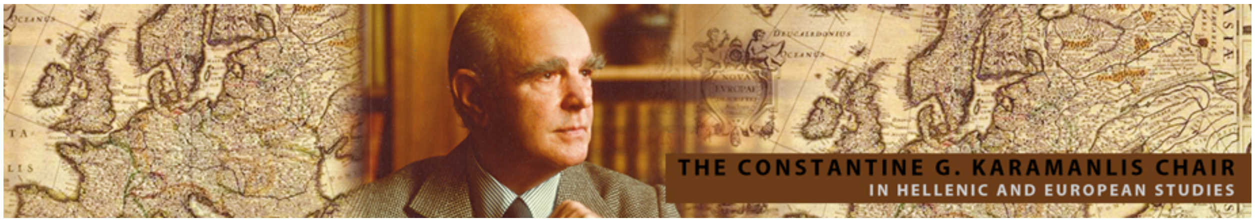

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Greek Economic Growth: Past and Future

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Greek Economic Growth: Past and Future

by

Nikolaos Leounakis[1] and Plutarchos Sakellaris[2]*

(June 2019)

Abstract

We decompose Greek economic performance over the last sixty years into the contributions of productivity, capital accumulation, and labor growth. Recent Greek economic history is a succession of long periods of boom with long periods of stagnation or depression. The decisive factor in either booms or slumps has been total factor productivity (TFP) growth. In particular, bad performance of TFP is the main culprit for the fourteen-year recession from 1980 to 1993 as well as for the current depression. This suggests that action on reversing the shortfall in productivity should be the most important focus for policy makers now. We argue that the crisis has led to permanent loss of output. In projections, we show that the economy needs to grow at average rates of about 3.5% over the next five years to be able to recover in 2026 the standard of living enjoyed in 2007, its peak historical level.

JEL classification: E32, N10, O40

Keywords: Greek economic growth; Growth accounting; Financial crisis; Total Factor Productivity

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1. Introduction

Economic performance in Greece since 2008 has been dismal. This period is unique when compared to anything that happened in the Greek economy all the way back to 1960. However, as Figure 1 aptly shows, it may be considered a dramatic episode of economic depression in a 50- year history of very volatile growth. This history is a succession of long periods of boom with long periods of stagnation or depression. This highly volatile macroeconomic environment has been generated by unsustainable policies that led to two boom-bust cycles since 1960.

Figure 1

Figure 2

In this paper, we aim at five goals. First, we provide consistent annual data on Greek economic growth and its decomposition into the contributions of capital, labor and Total Factor Productivity (TFP) for the years 1960 to 2017. We employ the standard growth accounting framework using capital stocks and total hours worked as the capital and labor factors respectively. Second, we augment our analysis using capital and labor services as productive inputs. This framework is theoretically more appropriate. However, data limitations confine the analysis to the years 1997 to 2017. Third, we contrast the two methodologies to uncover any differences in the implied decomposition of growth. Fourth, we include capacity utilization in our analysis in order to account for any procyclical effects that a variable utilization rate might have on our TFP estimates. Fifth, we classify different periods of economic growth using the "eyeball metric" (as in Figure 1) and statistical techniques.

Starting with the fifth goal, our statistical tests indicate two structural breaks in the time series for GDP per Capita: 1974 and 2008. Visual inspection of the time series, however, indicates that 1994 may be considered a third break point. Given the (relatively) short time series and the power of the statistical test, we argue for considering four separate episodes in Greek economic growth since 1960: 1) the *Great Expansion* (1960 – 1973), 2) the *Long Stagnation* (1974 – 1993), 3) the *Recovery* (1994 – 2007), and 4) the *Great Depression* (2008-2017). Regarding the "*Long Stagnation*" period, one might subdivide it further into a) the *Moderate Expansion* (1974 – 1979) and b) the *Great Recession* (1980 – 1993)[3].

How does this economic performance decompose into the contributions of TFP, capital stock and total hours worked? We find that the stunning average GDP growth rate of 8.87% over the period 1960-1973 was due to TFP and capital input contributing by 7.38% and 2.32%

[3] Gogos et al (2014) also provide evidence of a slowdown after 1974 and a great recession until 1994, followed by a recovery. They do not test statistically for breaks. They rely on a dynamic general equilibrium model and find that TFP is crucial in accounting for growth patterns.

respectively. The "*Great Expansion*" was mostly a phenomenon of rapid catch-up in economic efficiency and secondarily of unusually high capital accumulation. Of course, the latter was to a large extent driven by the former[4].

From 1974 to 1979 GDP growth slowed down to 3.28%, a good performance compared to later periods but markedly worse than the preceding fourteen years and a prelude to the future. This was a result of TFP growing at the lower pace of 0.44%, 6.94 percentage points lower than in the "*Great Expansion*" period. Despite the dramatic drop in TFP growth, capital accumulation continued surprisingly strong. In both of these periods, labor input's influence was practically minimal (-0.71% and 0.36%). Over the period 1980-1993 the Greek economy sank into a fourteen-year-long recession, as the GDP rate of change plunged to 0.75%. Capital accumulation slowed down dramatically, now contributing 0.84% to GDP growth while TFP subtracted from growth (-0.58%). The situation was partially offset by an improvement in labor input (0.50%).

During the period 1994-2007 the economy recovered partially. The growth rate of output averaged 3.62% as all three inputs improved (0.71%, 1.21% and 1.71% for labor, capital and TFP respectively). Beginning in 2008, the combined effect of financial and sovereign crises took its toll on the Greek economy. During the "*Great Depression*" of 2008-2017, GDP dropped at an annual rate of 2.82% on average. This was due to labor input decreases (-1.26% per annum) and TFP decreases (-1.56% per annum), while net capital formation dropped to the lowest average level of all periods since 1960 (+0.00% per annum).

Our results indicate that the decisive factor of influence on economic growth during the last fifty-seven years has been TFP. Its contribution to growth in output varies from 18% to 83% over the periods 1961-1973, 1974-1979 and 1994-2007. Furthermore, the performance of TFP proves to have been the main culprit for the fourteen-year recession from 1980 to1993 as well as for the current depression. Contrary to widespread belief that the credit boom in the eurozone periphery was used to finance unproductive sectors and investments, we show that TFP growth was very healthy before the crisis that started in 2008. During 1997 to 2007, annual TFP growth averaged 1.80% (standard methodology) or 1.71% (alternative methodology mentioned in the following paragraph). Annual results are contained in Appendix A.

We repeated the growth accounting exercise using capital and labor services as productive inputs instead. This methodology is theoretically superior to the one using stocks. As a result of accounting for changes in the quality of labor and capital, TFP growth is now measured to be slower. The empirical results point to some differences but not large ones. Depending on the period, TFP growth differs by 7%-16% when quality changes are accounted for. The qualitative conclusions do not change.

As a final attempt to refine our results further, we repeated the growth accounting decomposition including variable capacity utilization as a growth factor. As expected, capacity utilization displays a pattern of procyclical variability, so that its inclusion makes TFP slightly less procyclical than before but without materially affecting our conclusions.

[4] For an insightful analysis of the political and economic forces behind the periods of "Great Expansion" and "Long Stagnation" in Greece, see Alogoskoufis (1995).

In section 3, we focus on the period of the Greek Depression from 2008 to 2017. The financial crisis has had lasting effects on output. We ask the question: which parts of the productive process have been impaired the most? Knowing the answer is important for designing and implementing policies for eventual recovery. Using Solow's growth accounting methodology, as did Hall (2014), we find that output in 2017 is almost 50% below its counterfactual trend. This counterfactual trend in output and its components of total factor productivity, capital, capacity utilization and labor is calculated by projecting forward the historical growth experience of 1974 to 2007. The shortfall in productivity growth is the biggest culprit, accounting for 32% of the observed deficit. The next two most influential components are employment and the contribution of capital accounting respectively for 23% and 19% of the observed shortfall. Attempting to answer the question in the beginning of this paragraph, it seems necessary to implement policies to boost productivity growth in the medium term and, in parallel, to promote employment and investment.

In section 4, we turn to a discussion about future economic growth and the potential for growth of the Greek economy. First, we establish that the loss in output due to the crisis is permanent. We follow the literature that tests for the existence of unit root in historical output time series (Nelson and Plosser, 1982; Campbell and Mankiw, 1987; Cerra and Saxena, 2005a, 2005b and 2008). Indeed, we find evidence for the existence of unit root in the (log) level of Greek output. This implies that output lost should be forgotten. The policy effort now should be to grow as fast as possible from a new, and lower, base level. The best case scenario is for the Greek economy to reach average growth rates of Average Labor Productivity (ALP) equal to those it attained during the 1974 to 2007 period. This period includes both a boom and a slump in economic activity and excludes the "growth miracle" of the 1960s and the "Great Depression" of the last 10 years, both extreme economic episodes. During the thirty three year period of 1973 to 2007, ALP grew on average at 1.38% per annum (p.a.). We deem that this growth rate may be attainable in the future under a program of ambitious and focused economic reform.[5] The task is not easy. To give an indication, income per capita would have to grow to an average annual rate of 3.5 % from 2019 to 2024 in order for standards of living to recuperate in 2026 the peak that they had attained in 2007. Such growth rates currently look unlikely unless there is a drastic and effective shift in the mix of policy towards growth.

The present paper contains several appendices. In Appendix A, we elaborate on the methodology and present annual results. In Appendix B, we provide some sensitivity tests and in Appendix C, we list the data sources.

[5] The specification of such a program is beyond the scope of this paper and the subject of other papers in this volume.

2. The sources of growth: 1960 to 2017

Figure 2 depicts the evolution of GDP per capita since 1960. One can discern four distinct periods of growth. A period of explosive growth spans the years 1960-1973, during which GDP per capita grew at an average rate of 8.42%. We call this the "Long Expansion". Then came the period of the "Long Stagnation," when GDP per capita grew at 0.70%. This period lasted from 1974 to 1993. Beginning in 1994 the economy recovered, and until 2007 per capita GDP grew at 3.22% annually. This was a "Recovery" period. Finally, in 2008, Greece entered a "Great Depression" period during which per capita GDP declined at a dramatic rate of -2.56%.

We use Solow's growth accounting framework to decompose the rate of change of output into the respective contributions of TFP and the other inputs. The results are shown in Table 1.

Table 1

During the 1960s and until 1973 GDP growth averaged 8.87% annually thanks to strong TFP growth and capital accumulation. A period of tapered growth started after the first oil shock and lasted for 6 years, during which growth slowed down to 3.28%.The main culprit was the drastic reduction in TFP growth (averaging 0.44% annually). In 1980, Greece entered a prolonged slump that lasted for fourteen years. Capital accumulation rates fell dramatically to 0.84% on average, and TFP was substantially lower at the end of the period than in the beginning. The situation was partially offset by an improvement in labor input, whose growth has a positive, though small, contribution of 0.49% to GDP growth. During the period 1994-2007 the economy recovered as GDP grew at 3.62% per year. All three inputs contributed to this recovery and TFP grew annually at a rate of 1.71%, the highest rate since 1973. Finally, in 2008, after 14 consecutive years of growth, the Greek economy went into a long downward slide as a result of the global financial crisis and its own sovereign debt and banking crisis. GDP fell by an average of 2.82% annually until 2017. Unemployment rose and total employment and TFP fell dramatically. Appendix A.2 contains the growth decomposition analysis using capital and labor services; the two methodologies give substantially similar results.

Figure 3 tells the same story from a different perspective. It contains the decomposition of labor productivity into the contributions of capital deepening[6] and TFP, the results of which are included in Table 2. It is clear that TFP growth in 1961-1973 is what sustained the rapid growth of labor productivity at 9.79%, while on the other hand, the slowdown that followed during 1974-1979 can be ascribed to a dramatic slowdown of TFP growth, as it dropped from 7.26% to 0.44%.

The 14-year slump that ensued saw labor productivity decline at 0.13% on average per year as a result of TFP and capital deepening contributing by -0.58% and 0.45% respectively. During the

[6] Labor productivity is computed as the ratio of total product to total hours worked. Capital deepening is the ratio of capital stock to total hours worked.

recovery period that started in 1994, labor productivity rose at 2.38% as capital deepening and TFP improved (0.67% and 1.71% respectively). Finally, from 2008 to 2017 labor productivity declined at a rate of -0.77% and TFP plunged at the rate of -1.56%. Capital, however, deepened as a result of total hours worked decreasing.

Figure 3

Table 2

Our breakdown of the data into separate growth periods was motivated by casual inspection of the figures and results presented before. Using a formal statistical test of break points in the time series of growth rates of GDP per capita, we arrive at a similar classification. We use procedures developed by Bai and Perron in a series of papers (1998, 2000, 2003) to determine the number and dates of possible structural breaks. Their methodology has the advantage of allowing multiple break points to be determined endogenously. The Bai-Perron test determined two breakpoints for the growth rate of GDP per capita: in 1974 and 2008. Table 3 contains the results of the same test for the growth rates of labor productivity and TFP. We first investigated the stationarity of these series using the Augmented Dickey Fuller (ADF) test and unit root tests that allow for the possibility of a structural break (Perron, 1997). For more details on these tests, see Appendix B.

Table 3

We note that the Bai-Perron tests identify breaks in 1974 and 2008 for GDP per capita; in 1974 and 2008 for Labor Productivity; and slightly earlier in 1972 for TFP. Based on these results, figures 3, 4 and 5 depict labor productivity (levels and growth rates) and TFP growth rates, each with the structural breaks and corresponding trend lines.

We repeated the growth accounting exercise using capital and labor services as productive inputs instead. This methodology is theoretically superior to the one using stocks. As a result of accounting for changes in the quality of labor and capital, TFP growth is now measured to be slower. The empirical results point to some differences but not large ones. Depending on the period, TFP growth differs by 7%-16% when quality changes are accounted for. The qualitative conclusions do not change.

It is sensible to claim that an important part of the variability in TFP is a measurement error due to lack of correction for capacity utilization. We therefore extend our model following King and Rebelo (1999) to account for the effects of variable utilization in the capital input. The results in

Table 4 indicate that utilization helped output growth with a small, positive contribution during 1961-1973 and 1994-2007, while it also added to the slowdown during the other periods with similarly small but negative rates of change. Accordingly, the procyclicality of TFP, and thus its effect on growth, is now slightly dampened; however, TFP remains the main explanatory factor of changes in output growth under all periods. Table 5, which is Table 2 including the effect of utilization, leads to the same conclusions. The analysis in the rest of the paper will be based on the results of the decomposition with capital stocks and total hours worked, also taking into account the correction for capacity utilization.

Table 4

Table 5

We have seen in this section that the decisive factor of influence on economic growth during the last fifty-seven years has been TFP. Most importantly, high output growth was accompanied by high TFP growth and similarly for periods of low growth. In particular, the performance of TFP proves to have been the main culprit for the fourteen-year recession from 1980 to1993 as well as for the current depression. Contrary to widespread belief that the credit boom in the eurozone periphery was used to finance unproductive sectors and investments, we show that TFP growth was very healthy before the crisis that started in 2008; during 1997 to 2007, annual TFP growth averaged 1.49% (standard methodology) or 1.71% (alternative methodology using capital and labor services). Annual results are contained in Appendix A.

Figure 4

Figure 5

Figure 6

3. The Greek Depression: Shortfall of Output

In this section, we focus on the period of the Greek Depression, running from 2008 to 2017. We investigate the lasting effects of the financial crisis on a number of macroeconomic variables. We ask the question: which parts of the productive process have been impaired the most? Knowing the answer is important for designing and implementing policies for eventual recovery.

We follow Hall (2014) and decompose output growth into the contributions of TFP, capital and labor input and capacity utilization using Solow's growth accounting formula. Labor input (H), measured as total hours annually worked, is further decomposed into the effects of population (P) growth, labor force (LF) participation, employment (E) rate and average hours worked:

$$\boldsymbol{H = P * \frac{LF}{P} * \frac{E}{LF} * \frac{H}{E}}$$

Working with growth rates, we calculate actual contributions to GDP growth and then counterfactual contributions by assuming that the variables grow under two scenarios. In the first scenario, the trend growth rate for each variable is maintained at their 1974-2007 average rate, whereas in the second scenario it is maintained at their 1994-2007 average rate. We subtract actual from counterfactual values to obtain the shortfall in growth for the output as well as for each productive factor. The following two tables contain the results of the analysis.

Table 6

Figure 7

Table 7

Figure 8

For each year, the Tables provide the <u>incremental</u> shortfall of output and each of its components relative to the respective counterfactual trend. The last three lines show the <u>cumulative</u> shortfall for output and each of its components over two, five and ten years into the Greek Depression. The 1994-2007 period saw higher growth rates for most of the variables, so that the shortfall in Table 7 is higher than that in Table 6 over the same periods. Both Tables show that in the first three years (2007 to 2010), the shortfall in output (16.4% below the 1974-2007 trend or 19.5% below the 1994-2007 trend), was mostly driven by bad performance of productivity. The second most important factor was capacity utilization and the third was the employment rate (mirroring the increase in the unemployment rate). The shortfall in capital accumulation, labor force participation rate, and average hours worked was marginal.

In the following three years, the shortfall in output grew much worse, to 42.3% or 48.4% when cumulated from 2007 to 2013. This period contains the two worst years of the Greek Depression in terms of growth: 2011 and 2012. Productivity continued to be the most important element of the shortfall (11% and 15.7%). The dramatic increase in the unemployment rate between 2010 and 2013 raised the contribution of the employment rate in the shortfall (to 14.3% and 14.7%). During these three years capacity utilization continued to worsen, while capital stock accumulation fell substantially leading to a rising, though still small, contribution of capital in the shortfall.

When the next four years (2014 to 2017) are taken into account, output shortfall grows only by a smaller amount (to 49.2% and 59.4%). This was because GDP growth showed signs of improvement in 2014 and again in 2017. Note that these two years productivity growth also improved. In addition, the employment rate grew higher than its historical trend, so its contribution to the shortfall decreased (to 9.2% and 10%). The contribution of capacity utilization to the shortfall also decreased as, starting in 2014, it grew at a small but positive rate. Labor quality too had a small role in reducing the shortfall. Capital stock continued to deteriorate, being 11.1% lower than its historical trends, while population also decreased thus adding to the widening gap.

Overall, for the 10-year period of the Greek Depression, we can say that productivity was the biggest driver of the poor output performance, accounting for more than one third of the total shortfall. It was followed by the capital stock, employment rate and capacity utilization, all of which performed badly. With the exception of labor quality, all other factors played a small, negative role. Attempting to give an answer to the question we posed at the beginning of this section, it is clear that policy action on improving productivity should be the most important focus for policy makers now.

4. The Future

In this section, we consider possible permanent effects of the financial crisis on Greek standards of living. A number of authors (e.g. Nelson and Plosser, 1982; Campbell and Mankiw, 1987) have provided evidence for the USA that deviations from trend output growth are permanent. This means that a demand or other shock causing a decline in output does not tend to be followed by a rebound during the recovery phase that brings output back on its initial, long-term track. Technically, there is a unit root in the time series of output, so that the latter is not mean-reverting, pointing to the importance of real stochastic innovations in understanding long-term movements in output. More recent work by Cerra and Saxena (2005a, 2005b and 2008) has shown how financial and political crises in different countries have led to permanent losses of output.

To test the unit-root hypothesis for the case of Greece, we performed a series of Augmented Dickey-Fuller (ADF) and Phillips-Perron unit root tests on the log of quarterly, seasonally adjusted, real GDP series beginning in 1960. Furthermore, to account for the possibility of having a false unit root on account of a structural break, we test for non-stationarity while taking into account the possibility of a break in the series. All of the tests indicate that the null hypothesis of a unit root in the log levels of real output cannot be rejected at the 5% significance level. Figure 9 shows the long oscillations of (log) output around a linear trend.

Figure 9

Having established that the loss in output due to the crisis is permanent. we turn to a discussion about future economic growth and the potential for growth of the Greek economy. We project forward the path of GDP per capita for two scenarios: a *Great Recovery* and a *No Crisis* scenario. For our calculations, we use the formula:

$$\frac{Y}{N} = \frac{Y}{H} * \frac{H}{E} * \frac{E}{L} * \frac{L}{WAP} * \frac{WAP}{N}$$

Where, $\frac{Y}{N}$ is GDP per capita, $\frac{Y}{H}$ is labor productivity, $\frac{H}{E}$ are average hours worked, $\frac{E}{L}$ is the employment rate, $\frac{L}{WAP}$ is the labor force participation rate and $\frac{WAP}{N}$ is the proportion of working age to total population. We employ OECD's forecasts of population and working age population (15-74 years) to 2030. We assume that average hours worked and labor force participation rate remain constant.

The *No Crisis* scenario is a counterfactual that indicates what the level of standards of living in Greece might have been had there been no crisis. The key driving variable here is average labor productivity, which is assumed to grow at 1.38% p.a. (its average rate between 1974 and 2007). These assumptions are applied from 2008 forward. In the *No Crisis* scenario, starting from 2007, the unemployment rate is held constant to its 2007 level of 8%.

Alas, the performance of the Greek economy in the ten years after 2007 has not been as in the *No* Crisis scenario. We move on to the task of projecting forward from the standpoint of where the economy stood in 2017. The best case scenario is for the Greek economy to reach average growth rates of Average Labor Productivity (ALP) equal to those it attained during the 1974 to 2007 period. This period includes both a boom and a slump in economic activity and excludes the "growth miracle" of the 1960s and the "Great Depression" of the last 10 years, both extreme economic episodes. During the thirty three year period of 1973 to 2007, ALP grew on average at 1.38% per annum (p.a.). We deem that this growth rate may be attainable in the future under a program of ambitious and focused economic reform. In the *Great Recovery* scenario, the unemployment rate is assumed to go down to 8% (its 2007 level) from its current level by 2027 starting in 2019. After that, it remains constant. We use OECD's forecast for 2018 Real GDP and unemployment rate (€ 190,610 million and 0.20 respectively).

As may be seen in Figure 10, the task of growth for the Greek economy ahead is not easy. To give an indication, income per capita would have to grow at an average annual rate of 3.5 % between 2019 and 2024 in order for standards of living to recuperate in 2026 the peak that they had attained in 2007. Such growth rates currently look unlikely unless there is a drastic and effective shift in the mix of policy towards growth.

Figure 10

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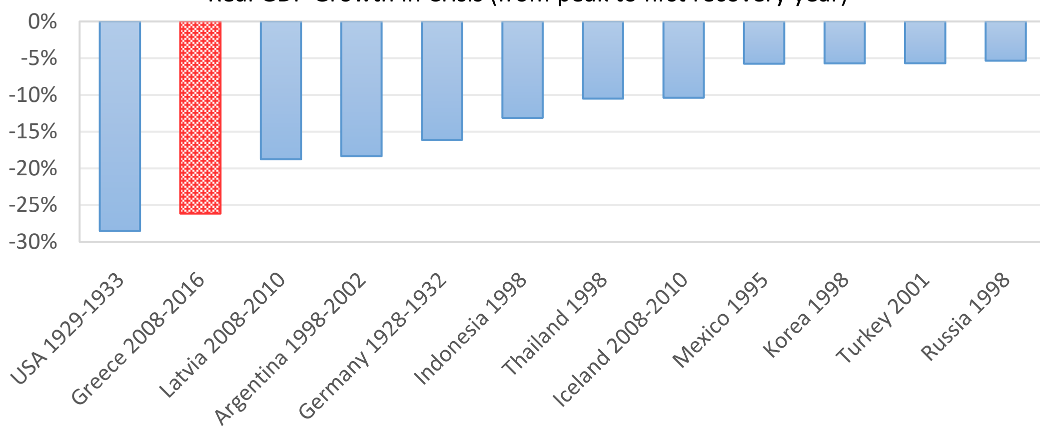
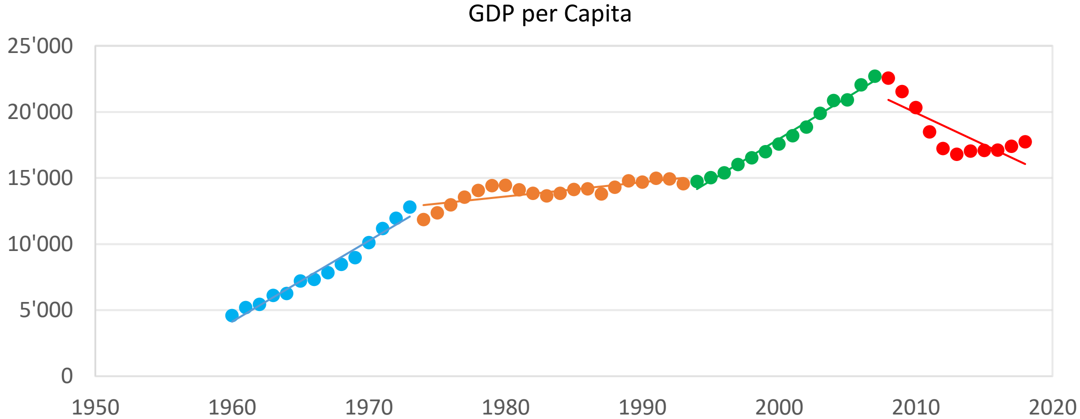
Figures and Tables

Figure 1
Real GDP Growth in Crisis (from peak to first recovery year)



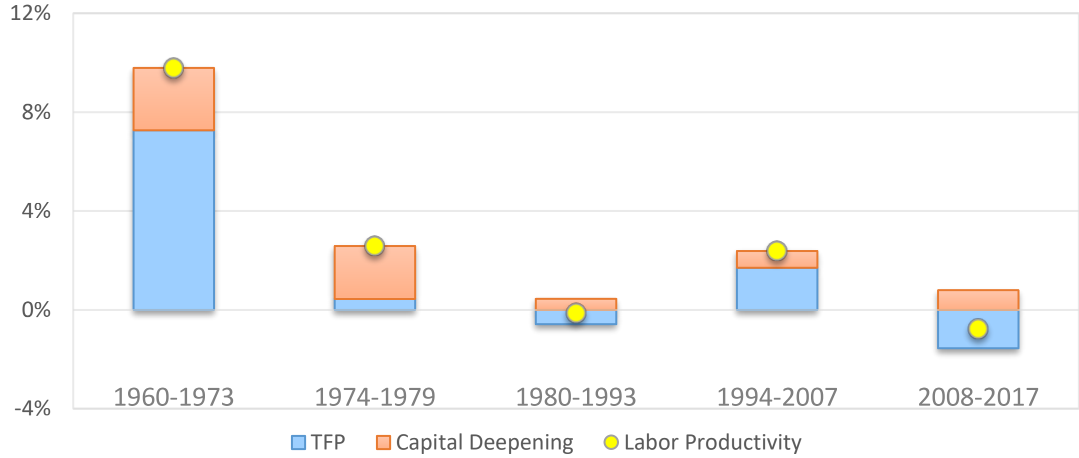
Source: IMF, Angus Maddison Historical Statistics of the World Economy, Authors' calculations
The figure compares the contraction in Greek GDP during the crisis with contractions experienced historically in other major crises.

Figure 2
GDP per Capita



Source: Authors' calculations
Great Expansion (1960 – 1973), Long Stagnation (1974 – 1993), Recovery (1994 – 2007) and Great Depression (2008-2017)

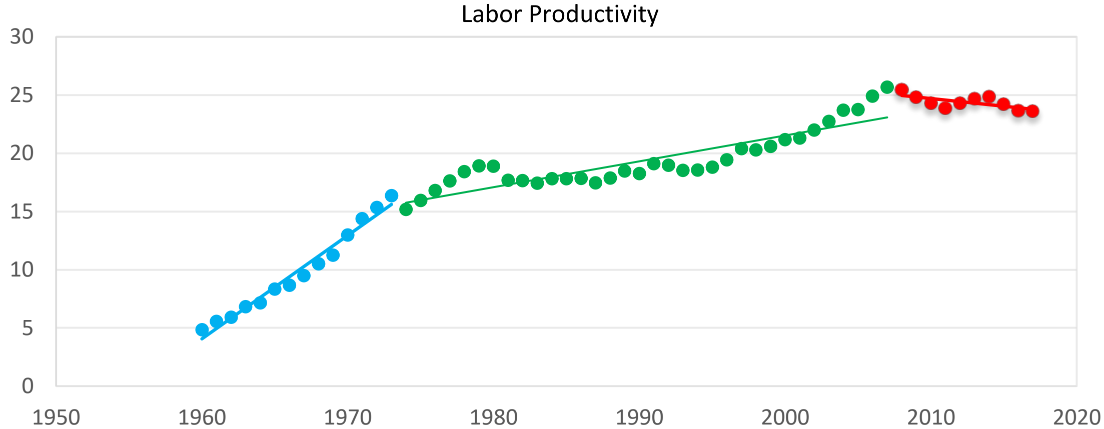
Figure 3
Contributions to Labor Productivity Growth



Source: Authors' calculations

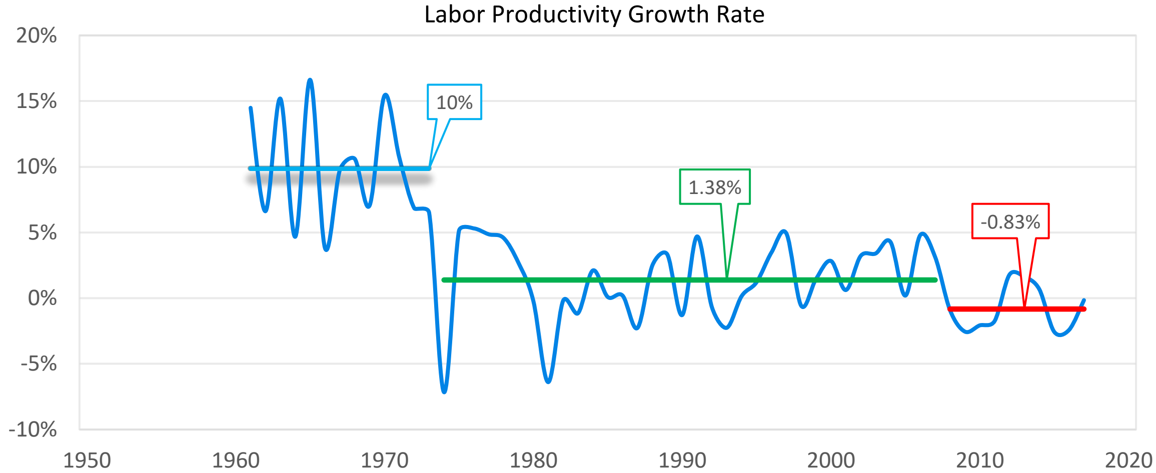
The calculations are based on the formula: $\mathbf{\Delta Ln\frac{Y_t}{L_t} = g_t + S_{K,t} * \Delta Ln\frac{K_t}{L_t}}$, according to which the growth in labor productivity equals the contributions TFP and capital deepening.

Figure 4
Labor Productivity



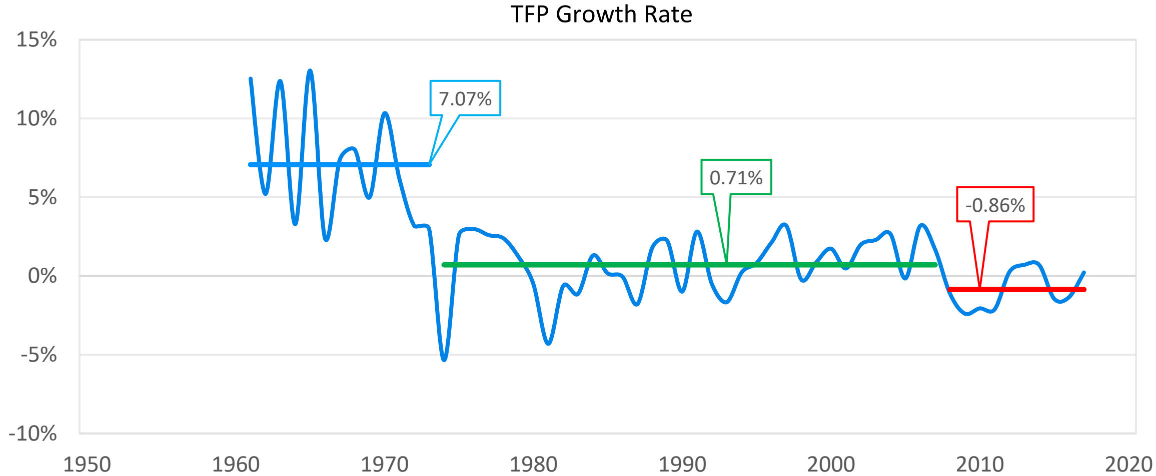
Source: Authors' calculations

Figure 5
Labor Productivity Growth Rate



Source: Authors' calculations

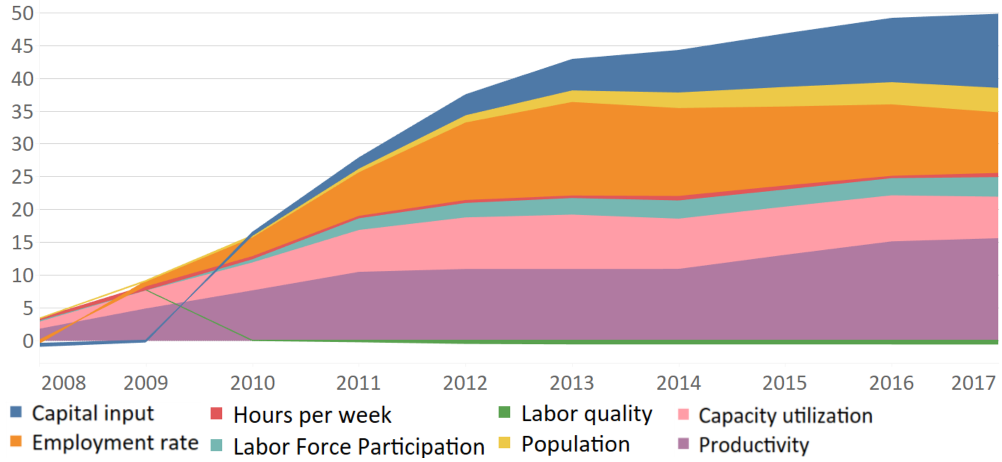
Figure 6
TFP Growth Rate



Source: Authors' calculations

Figure 7

Components of Shortfall (1974-2007 trend)

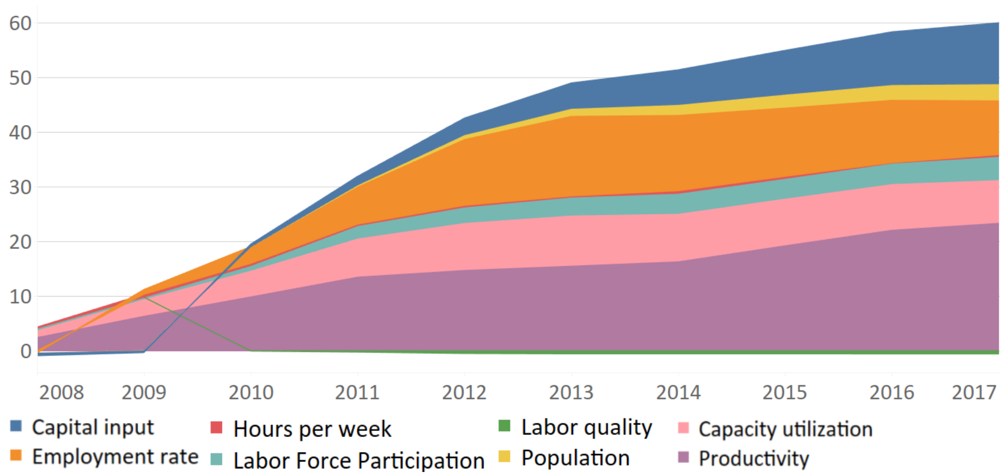


Source: Authors' calculations

The shortfall for each factor is first calculated yearly as the counterfactual % change based on the 1974-2007 trend minus the actual % change. For the chart, we aggregate the previous results up to a given year in order to obtain the cumulative shortfall for that year. For example, 2011 figures show the cumulative shortfall over 2008, 2009, 2010, and 2011.

Figure 8

Components of Shortfall (1994-2007 trend)

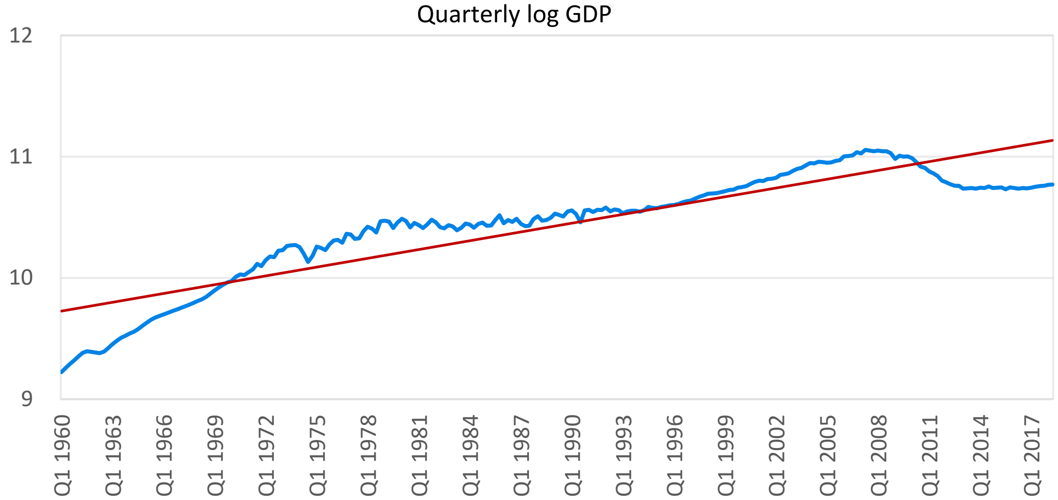


Source: Authors' calculations

The shortfall for each factor is first calculated yearly as the counterfactual % change based on the 1994-2007 trend minus the actual % change. For the chart, we aggregate the previous results up to a given year in order to obtain the cumulative shortfall for that year. For example, 2011 figures show the cumulative shortfall over 2008, 2009, 2010, and 2011.

Figure 9

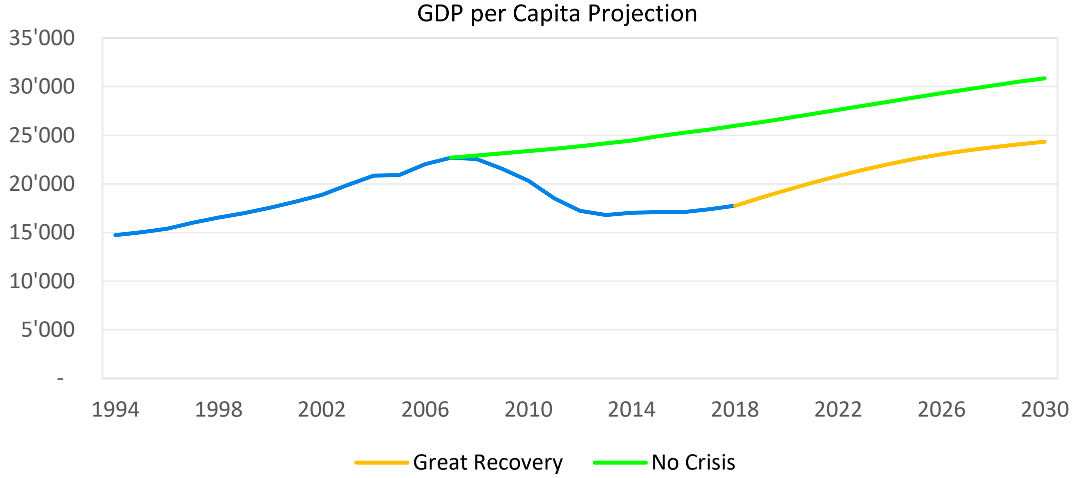
Quarterly log GDP



Source: Authors' calculations
Quarterly, seasonally adjusted, real GDP data are obtained from the OECD. The figure shows long oscillations around a linear trend

Figure 10

GDP per Capita Projection



Source: OECD, own calculations
For both scenarios, ALP growth assumed at 1.38% (its 1974 to 2007 average). **Great Recovery**: Reduction of unemployment rate to 8% from current level by 2027 starting in 2019. **No Crisis**: unemployment rate is held constant to 2007 level of 8%. We use OECD's forecast for 2018 Real GDP and unemployment rate (€ 190,610 million and 0.20 respectively).

Table 1
Growth Decomposition with Capital Stocks and Total Hours Worked

	GDP	Labour Input	Labour Input breaks into: Total Employment	Average Hours Worked	Net Capital Stock	TFP
1961-1973	8.87%	-0.71%	-0.38%	-0.33%	2.32%	7.38%
1974-1979	3.28%	0.36%	0.32%	0.03%	2.48%	0.44%
1980-1993	0.75%	0.50%	0.49%	0.00%	0.84%	-0.58%
1994-2007	3.62%	0.71%	0.78%	-0.07%	1.21%	1.71%
2008-2017	-2.82%	-1.26%	-1.18%	-0.08%	0.00%	-1.56%

Source: Authors' calculations

The calculations are based on Solow's growth accounting formula: $\frac{\dot{Y}}{Y} = \mathbf{g_t} + \mathbf{S_{K,t}} * \frac{\dot{K}}{K} + \mathbf{S_{L,t}} * \frac{\dot{L}}{L}$, according to which the growth in GDP is decomposed into the contributions of TFP, capital input and labor input respectively. See appendix A1

Table 2
Labor Productivity Decomposition

	1961-1973	1974-1979	1980-1993	1994-2007	2008-2017
Labor Productivity	9.79%	2.58%	-0.13%	2.38%	-0.77%
Capital Deepening	2.52%	2.13%	0.45%	0.67%	0.79%
TFP	7.26%	0.44%	-0.58%	1.71%	-1.56%

Source: Authors' calculations

Table 3
Breakpoint Tests

	ADF Test	Unit Root with Break	Bai-Perron		
			sequential	global	information criteria
GDP per Capita	Stationarity	stationarity with break in 1974	break in 1974 break in 2008	rejects the null of no breaks, global optimizers for two breaks: 1974, 2008	break in 1974 break in 2008
Labor Productivity	Stationarity	stationarity with break in 1973	break in 1974	rejects the null of no breaks, global optimizers for one break: 1974, 2008	break in 1974
TFP	Stationarity	stationarity with break in 1974	break in 1972	rejects the null of no breaks, global optimizers for one break: 1972	break in 1972

Source: Authors' calculations

Table 4
Growth Decomposition with Capital Stocks, Total Hours Worked, and Capacity Utilization

	GDP	Labour Input	Labour Input breaks into: Total Employment	Average Hours Worked	Net Capital Stock	Capacity Utilization	TFP
1961-1973	8.87%	-0.71%	-0.38%	-0.33%	2.32%	0.19%	7.07%
1974-1979	3.28%	0.36%	0.32%	0.03%	2.48%	-0.63%	1.07%
1980-1993	0.75%	0.50%	0.49%	0.00%	0.84%	-0.35%	-0.23%
1994-2007	3.62%	0.71%	0.78%	-0.07%	1.21%	0.22%	1.49%
2008-2017	-2.82%	-1.26%	-1.18%	-0.08%	0.00%	-0.70%	-0.86%

Source: Authors' calculations
The calculations are based on the decomposition equation of King and Rebelo:
$\frac{\dot{\boldsymbol{Y}}}{\boldsymbol{Y}} = \mathbf{g_t} + \mathbf{S_{K,t}} * \frac{\dot{\boldsymbol{K}}}{\boldsymbol{K}} + \mathbf{S_{L,t}} * \frac{\dot{\boldsymbol{L}}}{\boldsymbol{L}} + \frac{\mathbf{S_{K,t}}}{\mathbf{S_{L,t}}+\xi} * (\mathbf{g_t} - \mathbf{S_{L,t}} * \frac{\dot{\boldsymbol{K}}}{\boldsymbol{K}} + \mathbf{S_{L,t}} * \frac{\dot{\boldsymbol{L}}}{\boldsymbol{L}})$, where the last term expresses capacity utilization and ξ is the elasticity of the marginal depreciation rate of capital with respect to the level of utilization. See appendix A1 for

Table 5
Labor Productivity Decomposition

	1961-1973	1974-1979	1980-1993	1994-2007	2008-2017
Labor Productivity	9.79%	2.58%	-0.13%	2.38%	-0.77%
Capital Deepening	2.52%	2.13%	0.45%	0.67%	0.79%
Capacity Utilization	0.19%	-0.63%	-0.35%	0.22%	-0.70%
TFP	7.07%	1.07%	-0.23%	1.49%	-0.86%

Table 6

Components of the Shortfall of Output Two, Five and Ten Years into the Depression (1974-2007 trend)

Year(s)	*Output =*	*Productivity +*	*Capital input +*	*Capacity Utilization +*	*Population +*	*Labor-Force Participation +*	*Employment rate +*	*Hours per week +*	*Labor quality*
2008	2.4	1.8	-0.4	1.1	0.0	0.2	-0.5	0.2	0.0
2009	6.4	3.1	0.2	1.7	0.1	-0.2	1.2	0.4	0.0
2010	7.6	2.8	0.7	1.5	0.1	0.5	2.1	-0.1	0.0
2011	11.2	2.8	1.1	2.1	0.3	1.3	3.8	-0.1	-0.2
2012	9.4	0.4	1.5	1.5	0.6	0.4	5.2	0.1	-0.3
2013	5.3	0.0	1.6	0.4	0.7	0.3	2.4	-0.1	-0.1
2014	1.4	0.0	1.7	-0.6	0.6	0.2	-0.9	0.3	0.0
2015	2.5	2.2	1.7	-0.3	0.6	-0.2	-1.4	-0.1	0.0
2016	2.4	2.1	1.6	-0.3	0.4	0.0	-1.1	-0.3	0.0
2017	0.6	0.5	1.5	-0.7	0.3	0.4	-1.7	0.3	0.0
2007 through 2010	16.4	7.7	0.5	4.3	0.2	0.5	2.8	0.5	0.0
2007 through 2013	42.3	11.0	4.6	8.3	1.8	2.5	14.3	0.4	-0.6
2007 through 2017	49.2	15.7	11.1	6.3	3.7	3.0	9.2	0.6	-0.6

Source: Authors' calculations

Table 7

Components of the Shortfall of Output Two, Five and Ten Years into the Depression (1994-2007)

Year(s)	*Output =*	*Productivity +*	*Capital input +*	*Capacity Utilization +*	*Population +*	*Labor-Force Participation +*	*Employment rate +*	*Hours per week +*	*Labor quality*
2008	3.5	2.6	-0.4	1.2	0.0	0.3	-0.4	0.2	0.0
2009	7.4	3.9	0.2	1.8	0.0	0.0	1.3	0.4	0.0
2010	8.6	3.5	0.7	1.7	0.1	0.6	2.2	-0.1	0.0
2011	12.2	3.6	1.1	2.3	0.2	1.4	3.9	-0.1	-0.2
2012	10.4	1.2	1.5	1.6	0.5	0.6	5.3	0.0	-0.3
2013	6.4	0.8	1.6	0.6	0.6	0.5	2.5	-0.1	-0.1
2014	2.4	0.8	1.7	-0.5	0.5	0.4	-0.8	0.3	0.0
2015	3.6	2.9	1.7	-0.2	0.5	0.0	-1.3	-0.1	0.0
2016	3.4	2.8	1.6	-0.2	0.3	0.1	-1.1	-0.3	0.0
2017	1.6	1.3	1.5	-0.5	0.3	0.5	-1.6	0.2	0.0
2007 through 2010	19.5	10.0	0.4	4.7	0.0	0.9	3.1	0.4	0.0
2007 through 2013	48.4	15.7	4.6	9.2	1.3	3.3	14.7	0.2	-0.5
2007 through 2017	59.4	23.5	11.1	7.8	3.0	4.3	10.0	0.3	-0.6

Source: Authors' calculations

Appendix

A1. Methodology and Data

Growth accounting decomposes the growth of gross domestic product into components related to the accumulation of productive inputs and a residual term called Total Factor Productivity or Solow residual, in honor of Nobel laureate Robert Solow, who developed this idea (1957). Growth accounting decomposition does not explain but can help in understanding the forces that drive growth, such as institutions, the rule of law, and sound policies. The framework employs a standard neoclassical production function:

$$\boldsymbol{Y = F(A, K, L)} \tag{1}$$

where aggregate output *Y* is a function of capital input *K*, labor input *L* and total factor productivity, *A*. Differentiating with respect to time and then dividing by Y we get the growth rate of total output as:

$$\frac{\dot{Y}}{Y} = g + \frac{F_K * K}{Y} * \frac{\dot{K}}{K} + \frac{F_L * L}{Y} * \frac{\dot{L}}{L} \tag{2}$$

where F_K and F_L are the marginal products of capital and labor respectively and g = $\frac{F_A * A}{Y} * \frac{\dot{A}}{A}$ is the Solow residual. This is the part of economic growth that cannot be explained by the contributions of production inputs, and is interpreted as growth of total factor productivity. Assuming perfect competition in output and factor markets, the price of capital (U_K) is equal to the marginal product of capital and the wage (W) is equal to that of labor. It then follows that: $S_K = \frac{U_K * K}{Y}$ and $S_L = \frac{W * L}{Y}$ are the respective shares of each factor's remuneration in total product. The growth of output then equals the weighted sum of the growth rates of production inputs and that of the Solow residual:

$$\frac{\dot{Y}}{Y} = \mathbf{g_t} + \mathbf{S_{K,t}} * \frac{\dot{K}}{K} + \mathbf{S_{L,t}} * \frac{\dot{L}}{L} \tag{3}$$

The data we use was drawn mainly from the OECD and Eurostat. Detailed sources are provided at the end of this document in Appendix C. We note that 2010 was chosen as the base year and our calculations and results are in year-average prices.

Series on total investment were taken from the OECD and were available from 1960 onwards. Data on GDP were also available from 1960 and we extended it back to 1951 using data from the Penn World Table. Assuming that the flow of investment is equally distributed over the period, we calculate net capital stock and consumption of fixed capital in base-year average prices using the following equations:

Net Capital Stock (end of period): $Stock^t_{end} = Stock^t_{begin} + I_t - \delta * (Stock^t_{begin} + \frac{I_t}{2})$ **(4)**

Consumption of Fixed Capital: $\delta(Stock^t_{begin} + \frac{I_t}{2})$ **(5)**

In equation (4) we apply the perpetual inventory method, which denotes that at the end of the period, the net capital stock equals the stock at the beginning of that period plus investment minus the consumption of fixed capital. The aggregate depreciation rate (δ) was assumed to be constant and chosen to match the capital and labor services analysis[7].

The input of labor is measured by total hours worked, i.e. total employment times average hours actually worked in a year. As for the labor share we used the compensation of labor divided by gross value added, after accounting for the income of self-employed. The share of capital is computed as 1 minus that of labor.

A2. Decomposition Using Capital and Labor Services

From a theoretical point of view, capital and labor services are considered more appropriate for productivity analysis as they take into account compositional changes in employment and stock of capital. In this section we perform the growth accounting exercise using capital and labor services as inputs. Eurostat and the OECD provide us with enough data to perform such a task for the years 1997-2017[8]. This is, admittedly, a very limited time period. Still, comparing the results from the two methods during the years 1997-2017 is a good check of robustness.

Capital stock is not considered the best proxy to account for the contribution of the existing capital assets to aggregate production. There are three main problems with using the (net) capital stock as the capital input. The first problem is that, as a stock, it is inconsistent with other variables, such as total hours worked, that enter the production function as flows. Another problem when using capital stock is that it does not account for heterogeneity in capital assets. The third problem is that capital stock does not capture correctly the contribution of more productive assets which may have short asset lives and low price, since assets are weighted by their market value when computing the capital stock and therefore expensive assets with longer service lives are assumed to contribute more. One should keep in mind that the problem of heterogeneity of labor inputs arises also when measuring labor input by total hours. Specifically, using total hours worked as the labor input does not take into account important compositional changes, such as those in education level and the participation of women.

The modern approach is to consider the flow of productive services which originate from the stock of physical assets in a given time period. These are considered more appropriate to enter the production function as capital input. The same holds for labor services. The theory of measuring capital services was developed by Dale Jorgenson (1963, 1967, 1969 etc.) and other authors in the 1960s and since then, the literature has grown and detailed guidelines have been published. The methodology we follow and that we describe in detail in Appendix A is the one outlined by the OECD (2009).

Table 8 contains the results split in two separate periods: 1997-2007 (which is a subset of the "Recovery") and 2008-2017. Looking at this new data we can observe that, over both examined

[7] Details are provided in section 4.
[8] We concluded that no reliable data could be used to decompose growth before 1997.

periods, compositional changes in the amount of total hours worked have had a small, positive influence on growth (0.19% and 0.21%). Quality changes in the productive capital stock seem to have had a similarly small effect (0.07% and -0.20%). As a result, when we compare these findings with those in Table 1 (which, for convenience, are also given in Table 9 below, averaged over corresponding periods) we notice that, moving from capital and labor services to capital stocks and total hours worked overestimates the contribution of TFP by 24.14% in the first period and underestimates it by 8.24% in the second period. In other words, the two methodologies do not result in substantially different decompositions.

Table 8

Growth Decomposition With Capital and Labor Services

			Labour Input breaks into:				Capital Services break into:		
	GDP	Labour Input	Total Employment	Average Hours	Labour Composition	Capital Services	Net/Productive capital Stock	Quality Effect	TFP
1997-2007	3.99%	0.99%	0.89%	-0.09%	0.19%	1.54%	1.47%	0.07%	1.45%
2008-2017	-2.82%	-1.03%	-1.18%	-0.06%	0.21%	-0.08%	0.12%	-0.20%	-1.70%

Source: Authors' calculations

Table 9

Growth Decomposition with Capital Stocks and Total Hours Worked

			Labour Input breaks into:			
	GDP	Labour Input	Total Employment	Average Hours	Net Capital Stock	TFP
1997-2007	3.99%	0.80%	0.89%	-0.09%	1.38%	1.80%
2008-2017	-2.82%	-1.26%	-1.18%	-0.08%	0.00%	-1.56%

Source: Authors' calculations

A3. Estimation of Capital and Labor services

We present here the basic methodology followed for decomposing economic growth. First, we discuss the theory that underlies our calculations and then we provide annual results.

A3.1 Capital Stocks

Our estimation begins by computing the gross fixed capital stock. This is the accumulated stock of past investments corrected for retirement using an age-retirement pattern. It is called gross because consumption of fixed capital has not yet been deducted, thus ignoring asset decay. Once the gross fixed capital stock is computed, we can estimate the net fixed capital stock by applying an age-price profile that depicts an asset's loss in value over time. So the net capital stock is the stock of assets surviving from past periods that is corrected for depreciation, i.e. consumption of fixed capital. When a geometric age-price profile is used, i.e. a constant rate of depreciation is assumed, it can be shown that this can act as a good approximation to a combined age-price/retirement profile (OECD 2009). What this means is that we can derive the net capital stock without first having to estimate the gross capital stock.

We saw that equation (4) is the perpetual inventory identity which allows us to construct time series on net capital stock. However, in the absence of full time series of investment, we need to estimate the initial capital stock in year 1951. We do so by following a methodology similar to that of Kehoe and Prescott (2007). According to that, the initial value of the capital stock K_{1951} must satisfy that:

$$\frac{K_{1951}}{Y_{1951}} = \frac{1}{15} * \sum_{t=1952}^{1966} \frac{Kt}{Yt} \quad , \qquad (6)$$

where Yt is the value of real output in time t, so the ratio of capital stock to the initial product should equal the average of that ratio over the next fifteen years[9]. It is important to note that our investment series from the OECD go as back as 1960 only, so for the years 1951-1959 we assume that investment grew at the rate of real GDP.

Before moving on to calculating capital services, we make one final remark: the stock series generated by equation 4 is expressed in units of new assets. This means that the capital stock is measured in new asset prices that are observable in the market. This is important when calculating the rate of change of the stock of capital: with investment series by type of asset, it can be shown that the rate of change of total capital stock equals the sum of rates of change of all asset stocks, each weighted with relative market prices. This is different from the aggregation scheme that we use for the rate of change of capital services, in which relative rental prices are required instead. We will see that this also makes a difference for the shares of capital input in total product used in equation (3), when these are calculated in the case of capital stocks and in the case of capital services.

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[9] Various methods exist in the literature, like for example the steady-state approach. In general, each method comes with advantages and disadvantages, but choosing one over the other becomes less important when the initial year is chosen to be as far back in time as possible. It can then be shown that the resulting series from all methods over the examined period converge. This is the reason why we chose 1951 as our initial year, which is sufficiently long before the period we want to examine.

A3.2 Capital Services

We proceed by identifying 6 groups of assets. These are: dwellings, other buildings and structures, transport equipment, other machinery and equipment, intangible fixed assets and cultivated assets. The intermediate step towards calculating the flow of capital services from these assets is the estimation of the productive stock. This is derived similarly to the net capital stock, when one applies an age-efficiency profile in the place of the age-price profile described earlier. The age-efficiency profile depicts an asset's loss in productive efficiency over time and thus the productive stock is the stock of assets surviving from past periods that is corrected for its loss in productive efficiency. The flow of capital services for a group of assets is considered to be proportional to the productive stock of that group of assets. Again, in the case of geometric rates the age-efficiency profile can be used as an approximation to a combined age-efficiency/retirement profile. Using geometric rates also comes with the advantage that the age-efficiency and age-price profiles are identical and as a result the productive stock is the same as the net capital stock. We can therefore use equations 4, 5 and 6 to calculate the end-of-period, net capital stock for each asset group and this will also be equal to that asset's productive stock.

The depreciation rates for each type of asset are collected from the EUKLEMS (Timmer et al, 2007), which in turn bases its calculations to BEA depreciation rates by Fraumeni (1997). Across all industries, EUKLEMS uses a range of depreciation rates for each type of asset. We made sure that the rates we used did not exceed those ranges. The aggregate depreciation rate used in the case of capital stocks earlier was derived using the formula:

$$\boldsymbol{\delta} = \frac{\sum_t \boldsymbol{\delta}_t}{t} \quad \text{, where:} \quad \boldsymbol{\delta}_t = \frac{\sum_{i=1}^{6} \boldsymbol{\delta}_i * (\mathbf{Stock}_{i,begin}^{t} + \frac{I_i^t}{2})}{\sum_{i=1}^{6} \mathbf{Stock}_{i,begin}^{t}} \qquad \textbf{(7)}$$

As explained in footnote 5, we want the generated stock series to depend as little as possible on the initial capital stock and, consequently, on the method with which that was calculated. This is the reason why we did not take into account the first few observations generated by equation 4. However, skipping years like that is not possible in the present case due to limited data. We therefore decided to choose the depreciation rates so that the total initial capital stock in 1995 is as close as possible to the 1995 capital stock calculated in section 2 where the aggregate depreciation rate was used. So, although capital stock series from 1997 onwards remain highly dependent on the value of the initial stock, we can be sure that the target value we set for the 1995 capital stock is "correct" given the depreciation rates and the analysis with capital stocks discussed above.

The next step is to calculate the price of capital services or rental price. This is done using information on the real rate of return to capital, the depreciation rate and the rate of revaluation. We opted for the endogenous, ex post approach with regard to the real rate of return. According to that, internal rates of return are computed by imposing the condition that the estimated value of capital services exactly corresponds to gross operating surplus plus the capital element of gross mixed income. The total user costs for a particular asset type are then computed as the productive stock of that asset times its rental price.

Assuming that the flow of capital services from capital asset i moves in proportion with the corresponding, mid-year productive stock, we can compute the rate of change of capital services ΔLnBt as a Törnqvist index:

$$\Delta \mathbf{LnB_t} = \sum_{i=1}^{6} \bar{s}_{i,t} * \mathbf{\Delta LnK_{i,t}} \quad , \tag{8}$$

where

$$\bar{s}_{i,t} = \frac{s_{i,t}+s_{i,t-1}}{2} \qquad \text{and} \qquad s_{i,t} = \frac{U_{i,t}*K_{i,t}}{\sum_{i=1}^{6} U_{i,t}*K_{i,t}}$$

We use Ui,t to denote the rental price of asset type i in time t and Ki,t is the corresponding productive stock, so that Ui,t * Ki,t are the user costs for that asset. Equation (8) tells us that the rate of change of capital services equals the weighted sum of rates of change of the productive stocks for each asset group, where the weights are the shares in user costs.

A3.3 Labor Services

Labor input should take into account changes in total employment and average hours actually worked as well as compositional changes, such as those in education level and participation of women. For the period 1997-2016, we divide total employment by gender and three levels of educational attainment: a) pre-primary, primary and lower secondary education (levels 0-2 according to ISCED), b) upper secondary and post-secondary non-tertiary education (levels 3 and 4) and c) first and second stage of tertiary education (levels 5 and 6). That gives us a total of 6 groups of workers and our input will be the total hours worked by each group. Aggregating across hours worked by each group to get a measure of labor input change is similar to aggregating across assets like we did in the previous section. Assigning weights, however, should be somewhat easier since the price of labor is observable in the market in the form of wages, unlike rental price of capital which we had to compute. Similarly as in equation (6), the rate of change labor input is given by:

$$\mathbf{\Delta LnL_t} = \sum_{j=1}^{6} \overline{s_{j,t}} * \mathbf{\Delta LnH_{j,t}} \tag{9}$$

where:

$$\bar{s}_{j,t} = \frac{s_{j,t}+s_{j,t-1}}{2} \qquad \text{and} \qquad s_{j,t} = \frac{\frac{w_{j,t}}{\bar{w}_t}*H_{j,t}}{\sum_{j=1}^{6}\frac{w_{j,t}}{\bar{w}_t}*H_{j,t}}$$

We express mean hourly earnings of workers' group j in time t relative to the average earnings for each gender in time t with $\frac{w_{j,t}}{\bar{w}_t}$ and total hours worked by the same group with $H_{j,t}$. Due to data limitations we use relative wages which are assumed constant over periods of time[10]. This

[10] This kind of assumption is not new. See Scarpetta et al. (2000) and Schreyer et al (2003) who also hold earnings relative-to-average constant and Timmer et al. (WIOD 2012) who hold earnings relative to those of medium-skill workers constant.

doesn't change that $w_{j,t} * H_{j,t}$ expresses the compensation of workers' group j in time t so that equation (7) denotes that the rate of change of total labor input is given by the weighted sum of the rates of change of total hours worked by each group, with shares in total labor compensation acting as weights.

Regarding the data needed to construct labor services, we resorted to Eurostat. However, no data of hours worked by educational attainment was available, so we had to cross-classify between data on full-time/part-time employment by educational attainment and sex and data on average number of weekly hours actually worked by full-time/part-time type of employment and sex. In essence, this type of "concordance" makes the simplifying assumption that, on average, all persons working part-time (full-time respectively) worked the same amount of hours regardless of their educational level. This enables us to acquire series of total weekly hours worked by men and women of different educational level (which in this exercise is a proxy for skill). Finally, EUROSTAT time series on average working hours begin in 1983, so for the years 1970-1982 we complement with data from the OECD database. The rate of change for the total, skill-adjusted amount of weekly hours worked that serves as our labor input is constructed through the weighting scheme of equation (9). The required data on earnings by sex and educational attainment is provided by Eurostat for the years 2006 and 2010.

A3.4 Input Shares

We saw in equation (3) that when perfect competition is assumed, then each factor is paid with its marginal product. So the marginal product of labor will be equal to the labor wage and the marginal product of capital will be equal to the rental price of capital. We can then calculate the respective shares of labor and capital in time t as:

$$\mathbf{s_{L,t}} = \frac{1}{2}\left(\frac{\mathbf{w_t * L_t}}{\mathbf{w_t * L_t + \sum_{i=1}^{6} U_{i,t} * K_{i,t}}} + \frac{\mathbf{w_{t-1} * L_{t-1}}}{\mathbf{w_{t-1} * L_{t-1} + \sum_{i=1}^{6} U_{i,t-1} * K_{i,t-1}}}\right) \qquad \mathbf{(10)}$$

$$\mathbf{s_{K,t}} = \frac{1}{2}\left(\frac{\mathbf{\sum_{i=1}^{6} U_{i,t} * K_{i,t}}}{\mathbf{w_t * L_t + \sum_{i=1}^{6} U_{i,t} * K_{i,t}}} + \frac{\mathbf{\sum_{i=1}^{6} U_{i,t-1} * K_{i,t-1}}}{\mathbf{w_{t-1} * L_{t-1} + \sum_{i=1}^{6} U_{i,t-1} * K_{i,t-1}}}\right) , \qquad \mathbf{(11)}$$

where $\mathrm{w_t * L_t}$ is the total remuneration of labor in time t, which includes the compensation of both employees and self-employed) and $\mathrm{w_{t-1} * L_{t-1}}$ are the total user costs of capital in time t. The sum of the remuneration of capital and labor should equal gross value added[11].

[11] The reader is reminded that the endogenous, ex-post rate of return for every period was computed by equating gross operating surplus plus capital related taxes on production to the total user costs of capital.

A4 Capacity Utilization

We have seen how our estimated productivity is procyclical and can explain a large part of the observed variation in GDP over time. Basu and Kimbal (1997) have argued that such a procyclicality may also result from measurement error. In particular, they argue that if other procyclical inputs are systematically mismeasured or omitted, this will translate into a biased estimate for TFP. To account for variable capital utilization, we implement the decomposition of King and Rebelo (1999) and incorporate capital utilization in a Cobb-Douglas production function as follows:

$$\boldsymbol{Y = F(A,K,L) = A_t * F(z_t * K_t, L_t)\, L_t = A_t * F(z_t * K_t, L_t)\, L_t = A_t * (z_t * K_t)^{1-a} * L_t^{\,a}} \quad \textbf{(12)}$$

Where $\mathbf{z_t}$ denotes the rate of utilization. We also assume that a variable utilization of capital affects the formation of capital through the relation:

$$\boldsymbol{Stock_{end}^{t} = Stock_{begin}^{t} + I_t - \delta(z_t) * \left(Stock_{begin}^{t} + \frac{I_t}{2}\right)} \quad \textbf{(13)}$$

Where $\boldsymbol{\delta}$ is a convex, increasing function of the utilization rate. Profit maximization with optimal utilization rate implies that the representative firm equates the marginal benefit of higher utilization with the marginal cost. It can then be shown that:

$$\boldsymbol{\frac{\dot{Y}}{Y} = g_t + S_{K,t} * \frac{\dot{K}}{K} + S_{L,t} * \frac{\dot{L}}{L} + \frac{S_{K,t}}{S_{L,t}+\xi} * \left(g_t - S_{L,t} * \frac{\dot{K}}{K} + S_{L,t} * \frac{\dot{L}}{L}\right)} \quad \textbf{(14)}$$

Where the last term expresses capacity utilization and ξ is the elasticity of the marginal depreciation rate of capital with respect to the level of utilization:

$$\xi = \frac{z*\delta''(z)}{\delta'(z)} > \mathbf{0}$$

Most studies use a ξ between 0 and 2, mostly based on Basu and Kimball (1997) who found a 95% confidence interval between these values. With a higher value for ξ the effects of capital utilization diminish and TFP becomes more procyclical, as shown below. For our calculations, we use a value of 0.5 for ξ**.**

Table 10
TFP estimates for different values of ξ

	ξ=0.1	ξ=0.5	ξ=1	ξ=1.5	ξ=2	Without correction for utilization
1961-1973	7.00%	7.07%	7.12%	7.15%	7.17%	7.26%
1974-1979	1.30%	1.07%	0.91%	0.82%	0.76%	0.44%
1980-1993	-0.11%	-0.23%	-0.32%	-0.37%	-0.41%	-0.58%
1994-2007	1.41%	1.49%	1.54%	1.56%	1.60%	1.71%
2008-2017	-0.61%	-0.86%	-1.03%	-1.14%	-1.21%	-1.56%

A5 Annual Results

Table 11

Growth Decomposition with Capital Stocks, Hours Worked and Capacity Utilization

	GDP	Labour Input	Labour Input breaks into: Total Employment	Average Hours	Net Capital Stock	Capacity Utilization	TFP
1961	14.44%	-0.04%	0.33%	-0.37%	1.13%	0.81%	12.53%
1962	5.08%	-1.17%	-0.81%	-0.36%	1.22%	-0.18%	5.21%
1963	13.07%	-1.47%	-1.11%	-0.35%	1.16%	1.00%	12.38%
1964	2.86%	-1.34%	-1.00%	-0.34%	1.43%	-0.51%	3.29%
1965	15.29%	-0.86%	-0.53%	-0.34%	1.84%	1.27%	13.04%
1966	2.42%	-1.00%	-0.67%	-0.33%	1.86%	-0.83%	2.39%
1967	7.96%	-1.24%	-0.90%	-0.33%	1.48%	0.33%	7.39%
1968	8.79%	-1.25%	-0.91%	-0.34%	1.84%	0.18%	8.03%
1969	6.26%	-0.56%	-0.23%	-0.33%	2.31%	-0.48%	5.00%
1970	13.06%	-1.31%	-0.06%	-1.24%	2.63%	1.41%	10.34%
1971	11.05%	0.19%	0.16%	0.02%	3.80%	0.89%	6.17%
1972	7.45%	0.30%	0.26%	0.04%	4.79%	-0.82%	3.18%
1973	7.63%	0.53%	0.50%	0.03%	4.67%	-0.55%	2.98%
1974	-7.00%	0.08%	0.05%	0.03%	2.13%	-3.87%	-5.35%
1975	5.28%	0.08%	0.05%	0.03%	2.37%	0.23%	2.60%
1976	6.64%	0.63%	0.60%	0.03%	2.43%	0.60%	2.97%
1977	5.77%	0.45%	0.42%	0.03%	2.63%	0.10%	2.59%
1978	5.08%	0.26%	0.22%	0.04%	2.68%	-0.24%	2.39%
1979	3.89%	0.65%	0.61%	0.04%	2.60%	-0.58%	1.22%
1980	1.22%	0.78%	0.76%	0.02%	1.72%	-0.78%	-0.50%
1981	-1.52%	2.83%	2.83%	0.00%	1.26%	-1.30%	-4.31%
1982	-1.29%	-0.61%	-0.60%	-0.01%	1.03%	-1.06%	-0.64%
1983	-0.78%	0.21%	0.28%	-0.07%	1.10%	-0.95%	-1.14%
1984	1.85%	-0.14%	-0.13%	-0.01%	0.56%	0.14%	1.29%
1985	2.56%	1.43%	1.46%	-0.03%	0.75%	0.22%	0.16%
1986	0.55%	0.21%	0.20%	0.01%	0.72%	-0.32%	-0.05%
1987	-2.25%	0.01%	-0.05%	0.06%	0.56%	-1.04%	-1.78%
1988	4.06%	0.85%	0.93%	-0.07%	0.59%	0.81%	1.81%
1989	3.82%	0.27%	0.21%	0.06%	0.68%	0.64%	2.23%
1990	0.11%	0.84%	0.77%	0.06%	0.72%	-0.45%	-0.99%
1991	2.92%	-0.98%	-1.02%	0.03%	0.80%	0.29%	2.82%
1992	0.74%	0.81%	0.81%	0.00%	0.69%	-0.24%	-0.52%
1993	-1.48%	0.44%	0.46%	-0.02%	0.57%	-0.82%	-1.66%
1994	1.94%	0.98%	1.03%	-0.05%	0.46%	0.27%	0.22%
1995	2.15%	0.52%	0.50%	0.01%	0.52%	0.28%	0.83%
1996	2.82%	-0.36%	-0.32%	-0.03%	0.70%	0.35%	2.12%
1997	4.54%	-0.21%	-0.18%	-0.04%	0.74%	0.82%	3.19%
1998	3.79%	2.52%	2.54%	-0.03%	1.25%	0.25%	-0.22%
1999	3.16%	0.96%	0.26%	0.70%	1.37%	-0.02%	0.85%
2000	3.87%	0.58%	0.85%	-0.27%	1.36%	0.19%	1.73%
2001	4.11%	1.95%	1.74%	0.21%	1.46%	0.22%	0.48%
2002	4.03%	0.45%	0.76%	-0.31%	1.32%	0.27%	1.98%
2003	5.72%	1.31%	1.15%	0.16%	1.63%	0.50%	2.28%
2004	5.09%	0.45%	0.58%	-0.13%	1.63%	0.35%	2.66%
2005	0.60%	0.24%	0.47%	-0.23%	1.07%	-0.55%	-0.16%
2006	5.69%	0.53%	1.13%	-0.61%	1.47%	0.50%	3.18%
2007	3.24%	0.07%	0.48%	-0.41%	1.88%	-0.39%	1.68%
2008	-0.30%	0.37%	0.59%	-0.22%	1.60%	-1.15%	-1.12%
2009	-4.31%	-1.12%	-0.72%	-0.39%	0.92%	-1.72%	-2.39%
2010	-5.51%	-2.21%	-2.32%	0.10%	0.35%	-1.59%	-2.06%
2011	-9.13%	-4.77%	-4.85%	0.09%	-0.05%	-2.19%	-2.12%
2012	-7.30%	-5.63%	-5.54%	-0.09%	-0.40%	-1.54%	0.27%
2013	-3.24%	-2.95%	-3.00%	0.05%	-0.51%	-0.49%	0.71%
2014	0.74%	0.04%	0.35%	-0.31%	-0.56%	0.57%	0.69%
2015	-0.40%	1.33%	1.27%	0.06%	-0.54%	0.25%	-1.45%
2016	-0.23%	1.34%	1.09%	0.25%	-0.47%	0.26%	-1.35%
2017	1.51%	1.00%	1.29%	-0.29%	-0.35%	0.64%	0.22%

Table 12

Growth Decomposition with Capital and Labor Services

	GDP	Labour Input	Labour Input breaks into: Total Employment	Average Hours	Labour Composition	Capital Services	Capital Services break into: Net/Productive capital Stock	Quality Effect	TFP
1997	4.54%	-0.09%	-0.18%	-0.04%	0.12%	0.31%	0.93%	-0.62%	4.32%
1998	3.79%	2.86%	2.54%	-0.03%	0.35%	1.03%	1.23%	-0.20%	-0.10%
1999	3.16%	1.09%	0.26%	0.70%	0.13%	1.66%	1.56%	0.10%	0.41%
2000	3.87%	0.59%	0.85%	-0.27%	0.01%	1.70%	1.59%	0.11%	1.59%
2001	4.11%	2.04%	1.74%	0.21%	0.08%	1.75%	1.62%	0.13%	0.33%
2002	4.03%	0.69%	0.76%	-0.31%	0.24%	1.83%	1.54%	0.29%	1.51%
2003	5.72%	1.46%	1.15%	0.16%	0.14%	1.90%	1.58%	0.32%	2.37%
2004	5.09%	1.17%	0.58%	-0.13%	0.72%	1.89%	1.73%	0.15%	2.03%
2005	0.60%	0.21%	0.47%	-0.23%	-0.03%	1.32%	1.37%	-0.05%	-0.93%
2006	5.69%	0.70%	1.13%	-0.61%	0.18%	1.38%	1.32%	0.07%	3.61%
2007	3.24%	0.19%	0.48%	-0.41%	0.12%	2.23%	1.77%	0.46%	0.83%
2008	-0.30%	0.53%	0.59%	-0.22%	0.16%	2.13%	1.70%	0.43%	-2.96%
2009	-4.31%	-1.14%	-0.72%	-0.39%	-0.02%	1.24%	1.13%	0.11%	-4.41%
2010	-5.51%	-1.97%	-2.32%	0.10%	0.25%	0.45%	0.54%	-0.09%	-3.99%
2011	-9.13%	-4.43%	-4.85%	0.09%	0.34%	-0.22%	0.09%	-0.30%	-4.48%
2012	-7.30%	-5.33%	-5.52%	-0.09%	0.27%	-0.90%	-0.27%	-0.63%	-1.07%
2013	-3.24%	-2.46%	-2.99%	0.05%	0.48%	-1.12%	-0.45%	-0.66%	0.33%
2014	0.74%	0.01%	0.35%	-0.31%	-0.02%	-0.89%	-0.47%	-0.42%	1.61%
2015	-0.40%	1.42%	1.27%	0.06%	0.09%	-0.64%	-0.44%	-0.20%	-1.18%
2016	-0.23%	1.80%	1.09%	0.32%	0.38%	-0.52%	-0.37%	-0.16%	-1.50%
2017	1.51%	1.25%	1.29%	-0.23%	0.19%	-0.35%	-0.25%	-0.10%	0.61%

We note at this point that in Table 7 we decompose the rate of change of labor input into the rate of change of total hours and that of labor composition (ΔLnFt) using:

$$\mathbf{\Delta LnF_t = \Delta LnL_t - \Delta LnH_t} \quad \textbf{(15)}$$

Equation 15 tells us that the rate of change of labor composition equals the rate of change of labor input minus that of total hours worked. In the same way, we decompose the growth of capital services into the growth of productive stock (which in our case is the same as net capital stock) and that of quality of capital (Q):

$$\mathbf{\Delta LnQ_t = \Delta LnB_t - \Delta LnK_t} \quad \textbf{(16)}$$

B1. Unit Root Tests

The Augmented Dickey-Fuller test constructs a parametric correction for higher than first order lag correlation by assuming that the series follows an AR(*p*) process and adding lagged *p* difference terms of the dependent variable *y* to the right-hand side of the test regression:

$$\boldsymbol{\Delta_{y_t} = a * y_{t-1} + x'_t * \delta + \beta_1 * \Delta_{y_{t-1}} + \beta_2 * \Delta_{y_{t-2}} + \cdots + p * \Delta_{y_{t-p}} + \upsilon_t} \quad \textbf{(17)}$$

We tested three different versions of the above specification, namely an equation that includes a) a constant, b) a constant and a linear time trend, and c) one that has neither. The optimal number of lags was chosen based on the Schwarz Info criterion.

Phillips and Perron (1988) propose an alternative method of controlling for serial correlation when testing for a unit root. Their method estimates a non-augmented AR(1) Dickey-Fuller equation and modifies the *t*-statistic of the a coefficient so that serial correlation does not affect the asymptotic distribution of the test statistic. The Phillips-Perron test is based on the statistic:

$$z_a = t_a * \left(\frac{\gamma_0}{f_0}\right)^{1/2} - \frac{T*(f_0-\gamma_0)*(se(\hat{a}))}{2*f_0^{\frac{1}{2}}*s} \quad (18)$$

where $\hat{a}$ is the estimate, and t_a the *t*-statistic of a, $se(\hat{a})$ is the coefficient standard error, and s is the standard error of the test regression. In addition, γ_0 is a consistent estimate of the error variance in the simple Dickey-Fuller equation, and f_0 is an estimator of the residual spectrum at frequency zero.

Again, we test classifications that include a constant, a constant and a linear time trend, or neither.

B2. Unit Root Tests with a break

Structural change occurs in many time series for any number of reasons, including economic crises, changes in institutional arrangements, policy changes and regime shifts. Perron (1989) points out that conventional unit root tests are biased toward a false unit root null when the data are trend stationary with a structural break. Accordingly, we want to test for non-stationarity while taking into account the possibility of a break in the series. Two models exist in the literature which differ in their treatment of the break dynamics: the innovational outlier (IO) model assumes that the break occurs gradually, with the breaks following the same dynamic path as the innovations; and the additive outlier (AO) model assumes the breaks occur immediately. The tests based on these models evaluate the null hypothesis that the series follow a unit root process, possibly with a break, against a trend stationary with break alternative. For the IO model, we consider the following general null hypothesis:

$$y_t = y_{t-1} + \beta + \psi(L) * (\theta * D_t(T_b) + \gamma DU_t(T_b) + \varepsilon_t) \quad (19)$$

where: - $DU_t(T_b)$ is an intercept break variable that takes the value of 0 for all dates prior to the break, and 1 thereafter: $DU_t(T_b) = 1\ (t \geq T_b)$,

- $DT_t(T_b)$ is a one-time break dummy variable which takes the value of 1 only on the break date and 0 otherwise,

- ε_t are i.i.d. innovations,

- and $\psi(L)$ is a lag polynomial representing the dynamics of the stationary and invertible ARMA error process.

The break variables enter the model with the same dynamics as the innovations. For the AO model, $\psi(L)$ is excluded so that the full impact of the break variables occurs immediately. For our alternative hypothesis, we assume a trend stationary model with breaks in the intercept and trend:

$$\boldsymbol{y_t = y_{t-1} + \beta t + \psi(L) * (\theta * DU_t(T_b) + \gamma DT_t(T_b) + \varepsilon_t)} \qquad \textbf{(20)}$$

where: $DT_t(T_b)$ is a trend break variable that takes the value of 0 for all dates prior to the break, and is a break date re-based trend for all subsequent dates: $D_t(T_b) = 1\,(t \geq T_b) * (t - T_b + 1)$. The breaks again follow the innovation dynamics.

We consider different specifications that control for: a) an intercept break, b) an intercept and trend break, and c) only a change in trend. The break date is endogenously determined by minimizing the Dickey-Fuller t-statistic. The idea is to select the date providing the most evidence against the null hypothesis of a unit root and in favor of the breaking trend alternative hypothesis.

B3. Structural Break Tests

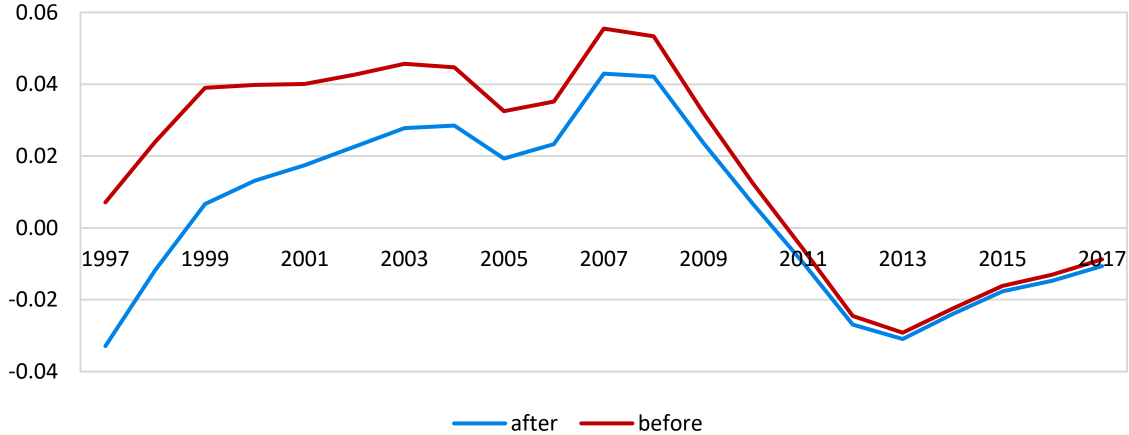
As our primary tool to detect breaks we use procedures developed by Bai and Perron. Their methodology has the advantage of allowing multiple break points to be determined endogenously, however it "precludes integrated variables (with an auto-regressive unit root)" (2000, p.10). Consequently, we look for a break in growth rates of variables that are found to be stationary. We carry out the following three procedures: i) a sequential test of L+1 breaks vs the alternative of L breaks, ii) a test of globally optimized breaks against the null of no breaks and iii) global information criteria to select the number of breaks.

C. Robustness checks for capital services

In this section we examine the robustness of our constructed measure of capital services by repeating the calculations based on some alternative assumptions.

We begin by examining the effect on the growth rates of capital services by an increase in initial capital stocks. We raise the initial stocks of all assets by 50% and the results are depicted in the following figure:

Figure 11
Capital services growth rates before and after a 50% increase in initial stocks

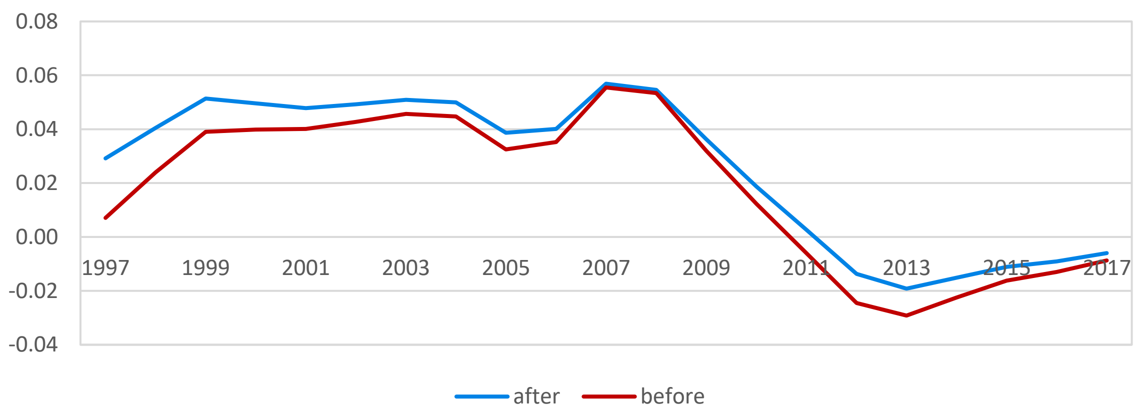


Source: Authors' calculations

Raising the capital stocks of all assets results in a decrease in capital services growth rates by 1.44% on average in comparison with our initial findings. The distance between the two curves is larger at the beginning and narrows towards the end of the period we examine.

Next, we consider the effects of a 25% decrease on the depreciation rates of all assets. The results are shown in the next figure:

Figure 12
Capital services rate of change before and after a 25% decrease in all depreciation rates

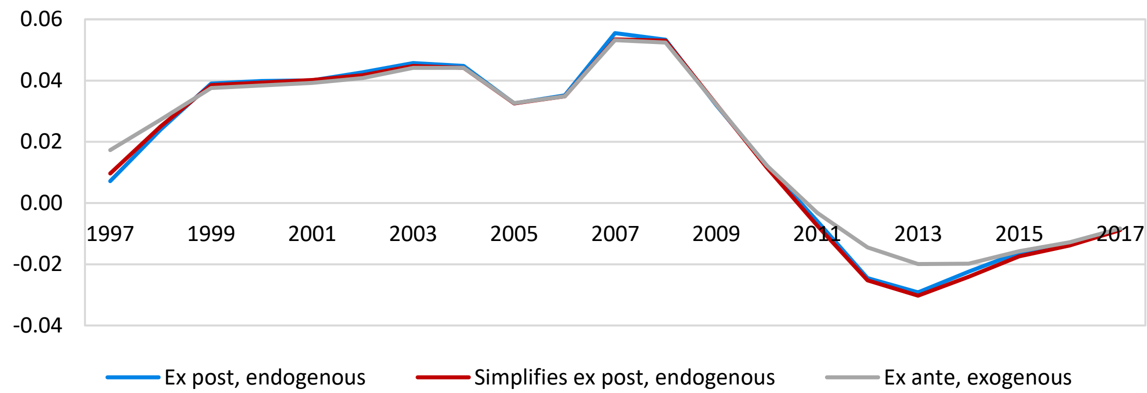


Source: Authors' calculations

The decreased depreciation rates cause our estimates to deviate by 0.77% on average.

We will now present the results of estimating capital services when different approaches in the estimation of rates of return to capital are used. In section 2.1 we explained the assumption of the endogenous, ex post approach that we followed. We now consider two more: the endogenous, simplified approach and the exogenous, ex ante approach. The endogenous, simplified approach rests on the assumption that real holding gains or losses are zero for each type of asset. Such an assumption will be reasonable if the asset price changes are not too far from general price changes. According to the exogenous, ex-ante approach the rate of return is chosen from financial market data so as best to express economic agents' expectations about the required return from investment. In this case equality between the value of capital services and gross operating surplus plus the capital element of gross mixed is not expected. Following the methodology of the Conference Board, the exogenous rate of return is computed as the maximum between the Central Bank's Discount Window, the Government Bond Yield and the Lending Rate. Series on the last two components are collected from the Bank of Greece Statistical Database, while for the Discount Window we resorted to the ECB. The results, shown below, indicate that our measures are robust to these considerations:

Figure 13
Tornqvist Indices



Source: Authors' calculations

D. Calculations of output shortfall in the Greek Depression

The calculations in Tables 6 and 7 and Figures 7 and 8 embody the basic identity:
Output growth = productivity growth + capital contribution + labor contribution.
In turn, *capital contribution = capital share × change in log per capita input*
and *labor contribution = labor share × change in log labor input.*
Finally,
Change in log labor input = change in log population + change in log participation rate
+ change in log employment rate + change in log hours per week
+ change in log labor quality

Figures 7 and 8 show the cumulative contribution of each component to total output shortfall by year.

Data Sources

Code	Variable
A1	Gross domestic product (nominal)
A2	GDP deflator
A3	Gross operating surplus and gross mixed income
A4	Consumer price index
A5	Total dependent employment
A6	Total self-employed
A7	Total employment, Full-time, Part-time employment
A8	Earnings
A9	Compensation of employees
A10	Gross value added
A11	Other taxes less other subsidies on production
A12	Gross fixed capital formation by type of asset
A13	Gross fixed capital formation, deflators
A14	Average Hours Actually Worked

The data was collected from:

A1, A2, A3, A9, A10, A11, A12, A13 : http://www.oecd-ilibrary.org/ → Statistics → Databases → OECD National Accounts Statistics → Aggregate National Accounts → Gross Domestic Product

A5, A6, A7: http://www.oecd-ilibrary.org/ → Statistics → Databases → OECD Economic Outlook: Statistics and Projections → OECD Economic Outlook No.102

A4: http://www.oecd-ilibrary.org/ → Statistics → Databases → OECD Factbook Statistics → OECD Factbook

A8: http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/ →Statistics Database → Population and Social Conditions →Labor Market → Earnings →Structure of Earnings Survey 2006, 2010

A7: http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/ →Statistics Database → Population and Social Conditions →Labor Market → Employment and Unemployment → LFS series - Detailed annual survey results → Full-time and part-time employment - LFS series → Full-time and part-time employment by sex, age and highest level of education attained

A14: http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/ →Statistics Database → Population and Social Conditions → Labor Market → LFS series - Detailed annual survey results ➔Working time - LFS series ➔ Average number of actual weekly hours of work in main job, by sex, professional status, full-time/part-time and economic activity