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Greek Economic Growth since 1960

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by

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Abstract

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 2013. Alternatively, we decompose growth for a subset of that period into the contributions of TFP, and capital and labor services. Recent Greek economic history is a succession of long periods of boom with long periods of stagnation or depression. The decisive factor of influence on economic growth during the last fifty-three years has been TFP. 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. Furthermore, the performance of TFP proves to have been the main culprit for the fourteen-year recession from 1980 to 1993 as well as for the current depression.

JEL classification: E32, N10, O40

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

1. Summary of results

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.

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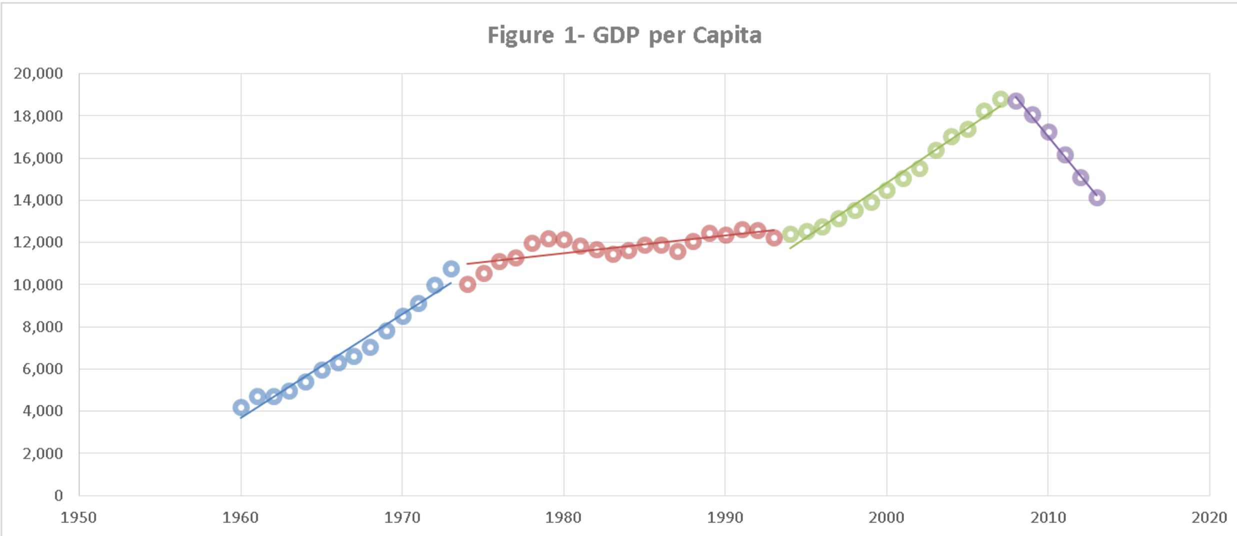

Source: Authors' calculations

In this paper, we aim at four 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 2013. 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 2013. Third, we contrast the two methodologies to uncover any differences in the implied decomposition of growth. Fourth, we classify different periods of economic growth using the "eyeball metric" (as in Figure 1) and statistical techniques.

Starting with the fourth 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* (2008-2013). 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 8.08% over the period 1960-1973 was due to TFP and capital input contributing by 5.71% and 2.51% respectively. The "*Great Expansion*" was mostly a phenomenon of rapid catch-up in economic

[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.

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 3.38%, 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 1.11%, 4.6 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 (-0.13% and -0.07%). Over the period 1980-1993 the Greek economy sank into a fourteen year-long recession, as the GDP rate of change plunged to 0.71%. Capital accumulation slowed down dramatically, now contributing 0.83% to GDP growth while TFP subtracted from growth (-0.58%). The situation was partially offset by an improvement in labor input (0.47%).

During the period 1994-2007 the economy recovered partially. The growth rate of output averaged 3.62% as all three inputs improved (0.65%, 1.11% and 1.85% 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 2008-2013, GDP dropped at an annual rate of 4.37% on average. This was due to labor input decreases (-2.31% per annum) and TFP decreases (-2.44% per annum), while net capital formation dropped to the lowest average level of all periods since 1960 (+0.38% per annum).

Our results indicate that the decisive factor of influence on economic growth during the last fifty three years has been TFP. Its contribution to growth in output varies from 33% to 71% 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 1.92% (standard methodology) or 1.63% (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 is lower by 15.10% to 18.85% when quality changes are accounted for. The qualitative conclusions do not change.

In section 2, we outline the standard growth accounting methodology and discuss the data. In section 3, we present the results using capital stock and hours worked, while in section 4 we decompose output growth into capital and labor services and TFP growth. 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.

[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).

2. 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:

$$\Delta \text{LnY}_t = g_t + S_{K,t} * \Delta \text{LnK}_t + S_{L,t} * \Delta \text{LnL}_t \tag{3}$$

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 2005 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)**:** $$\boldsymbol{Stock_{end}^{t} = Stock_{begin}^{t} + I_t - \delta * (Stock_{begin}^{t} + \frac{I_t}{2})} \quad \textbf{(4)}$$

Consumption of Fixed Capital: $$\boldsymbol{\delta(Stock_{begin}^{t} + \frac{I_t}{2})} \quad \textbf{(5)}$$

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[5].

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.

3. Results

Figure 1 above 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 7.51%. 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 3.12% 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 -4.62%.

We will now use equation (3) 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:

[5] Details are provided in section 4.

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	8.08%	-0.13%	0.13%	-0.26%	2.51%	5.71%
1974-1979	3.38%	-0.07%	0.35%	-0.42%	2.33%	1.11%
1980-1993	0.71%	0.47%	0.47%	0.00%	0.83%	-0.58%
1994-2007	3.62%	0.65%	0.89%	-0.24%	1.11%	1.85%
2008-2013	-4.37%	-2.31%	-2.24%	-0.07%	0.38%	-2.44%

Source: Authors' calculations

During the 60s and until 1973 GDP growth averaged 8.08% annually thanks to strong TFP growth and capital accumulation. After the first oil shock started a period of tapered growth for the following 6 years, during which growth slowed down to 3.38%. The main culprit was the drastic reduction in TFP growth (averaging 1.1% annually). In 1980, Greece entered a prolonged recession that lasted for fourteen years. Capital accumulation rates fell dramatically to 0.83% 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 the labor factor which for the first time has a positive, though small, contribution of 0.47%. 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 1.85%, the highest in 20 years. Finally, in 2008, after 14 consecutive years of growth, the Greek economy went on a long downward slide as a result of the global financial crisis and its own sovereign debt crisis. GDP fell by an average of 4.37% annually until 2013. Unemployment rose and total employment and TFP fell dramatically.

Figure 2 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 8.40%, while on the other hand, the slowdown that followed during 1974-1979 can be ascribed to a deterioration of TFP, as it dropped from 5.71% to 1.11%.

The 14-year recession that ensued saw labor productivity decline at 0.10% each year as a result of TFP and capital deepening contributing by -0.58% and 0.49% 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 2.61% as capital deepening and TFP improved (0.75% and 1.85% respectively). Finally, from 2008 to 2013 labor productivity declined at a rate of -0.60% and TFP plunged at the rate of -2.44%. Capital, however, deepened as a result of total hours worked decreasing. It is sensible to claim that a large part of the drop in TFP is a measurement error due to lack of correction for capital and labor utilization, which, undoubtedly, fell sharply during the period. Unfortunately, we do not have utilization data.

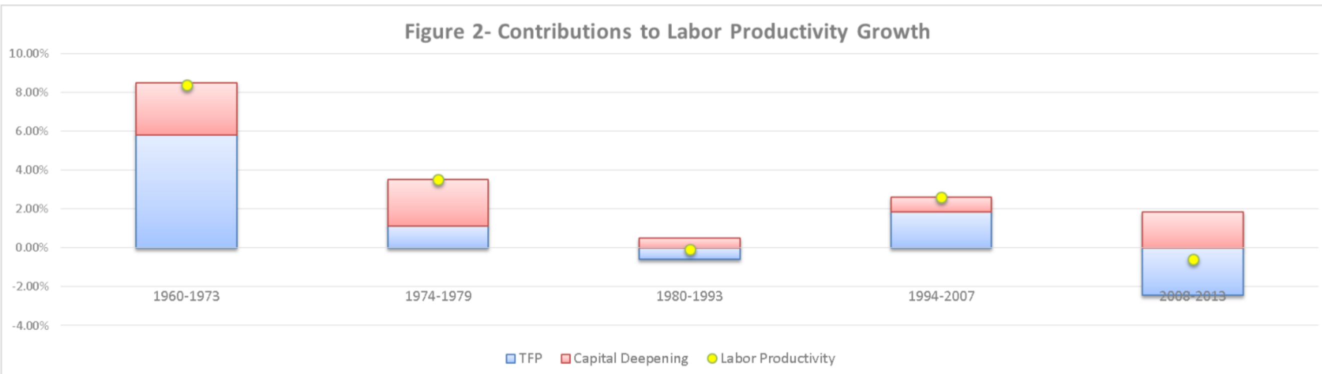

Table 2

Labor Productivity Decomposition

	1961-1973	1974-1979	1980-1993	1994-2007	2008-2013
Labor Productivity	8.40%	3.51%	-0.10%	2.61%	-0.60%
Capital Deepening	2.69%	2.40%	0.49%	0.75%	1.84%
TFP	5.71%	1.11%	-0.58%	1.85%	-2.44%

Our breakdown of the data into separate growth periods was motivated by casual inspection of the figures and results presented above. 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 only two breakpoints for the growth rate of GDP per capita: in 1974 and 2007. 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 a typical ADF test and the Perron (1997) test, which allows for the possibility of one structural break. Interestingly, under the constraint of only one possible break in the time series of growth of GDP per capita, the Perron (1997) test picks the year 1993. For more details on these tests, see section 5 of Appendix A.

Table 3

Breakpoint Test

	ADF Test Schwarz Criterion	**Perron (97)**	**Bai-Perron**		
			sequential	**global**	**information criteria**
Labor Productivity growth rate	Stationarity	stationarity with break in 1973	break in 1974	rejects the null of no breaks, global optimizers for one break: 1974	one break
GDP per Capita growth rate	Stationarity	stationarity with break in 1993	break in 1974	rejects the null of no breaks, global optimizers for two breaks: 1974, 2007	two breaks
TFP growth rate	Stationarity	stationarity with break in 1974	break in 1974	rejects the null of no breaks, global optimizers for one break: 1974	one break

Based on these results, figures 3, 4 and 5 depict labor productivity (levels and growth rates) and TFP growth rates, each with a structural break in 1974 and the corresponding trend lines.

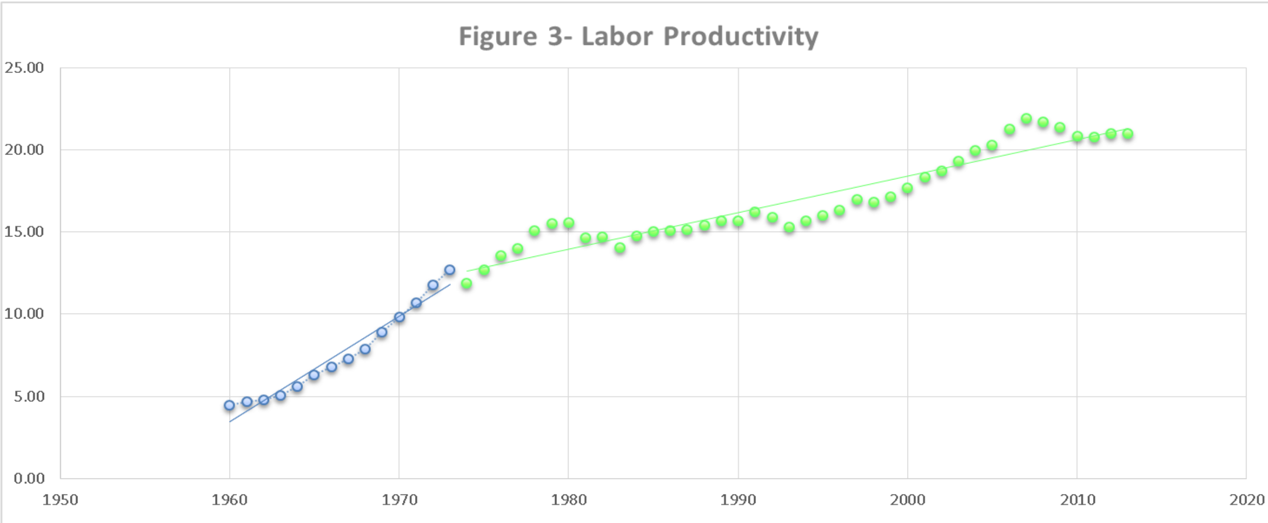
Figure 3- Labor Productivity
25.00
20.00
15.00
10.00
5.00
0.00
1950
1960
1970
1980
1990
2000
2010
2020

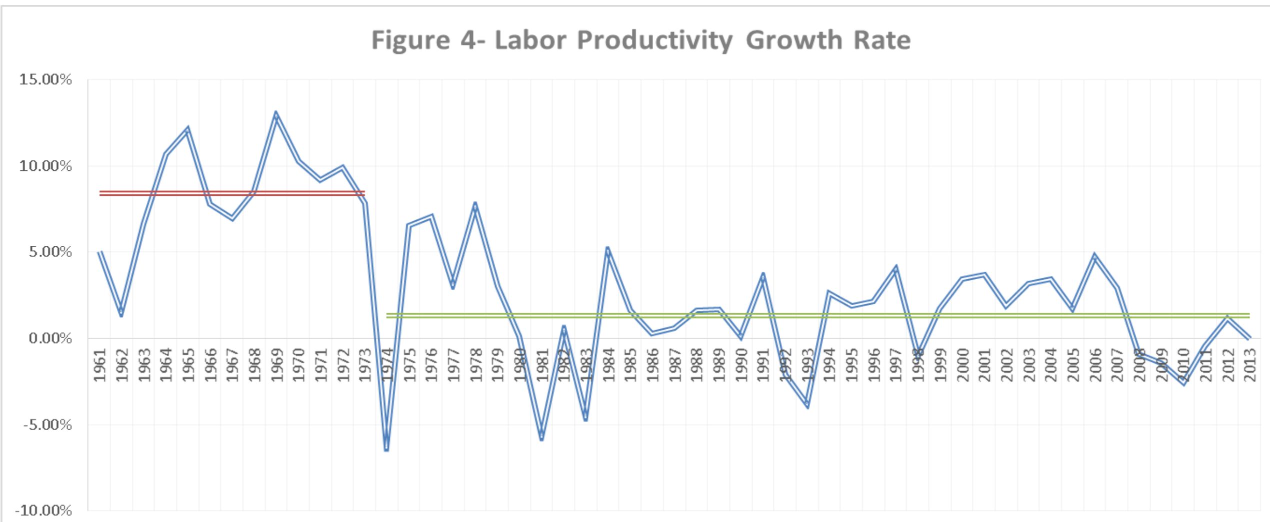
Figure 4- Labor Productivity Growth Rate
15.00%
10.00%
5.00%
0.00%
-5.00%
-10.00%

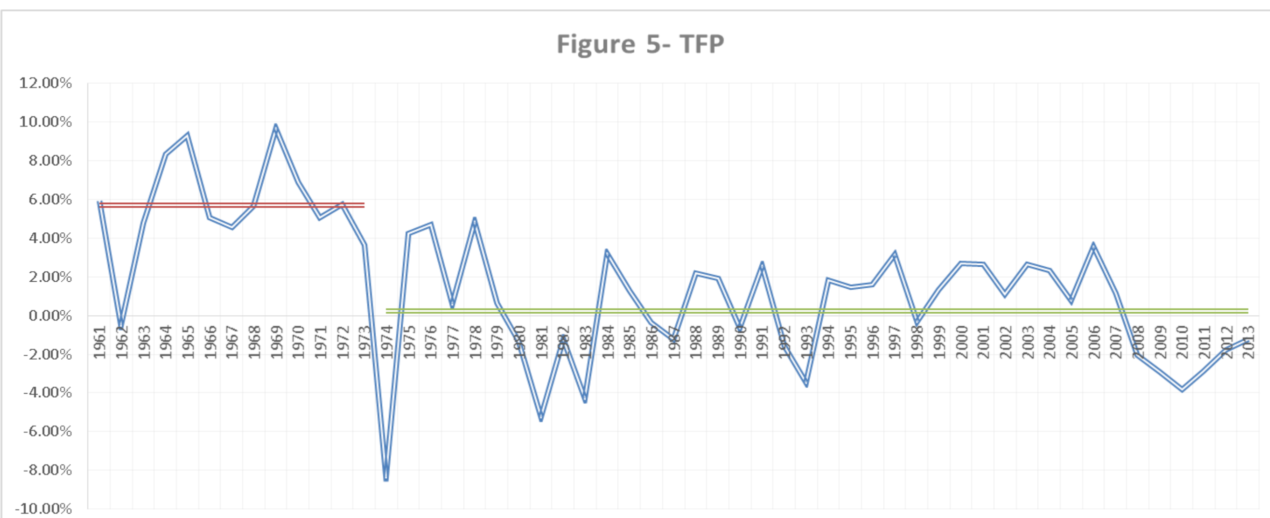
Figure 5- TFP
12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
0.00%
-2.00%
-4.00%
-6.00%
-8.00%
-10.00%

4. 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 1997-2013[7]. This is, admittedly, a very limited time period. Still, comparing the results from the two methods during the years 1997 -2013 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 4 contains the results split in two separate periods: 1997-2007 (which is a subset of the "Recovery") and 2008-2013. Looking at this new data we can observe that, over both examined periods, compositional changes in the amount of total hours worked have had a small, positive influence on growth (0.21% and 0.37%). Any quality changes, however, in the productive capital stock seem to have had a barely noticeable effect. As a result, when we compare these findings with those in Table 1 (which, for convenience, are also given in Table 5 below, averaged over corresponding periods) we notice that, moving from capital and

[7] We concluded that no reliable data could be used to decompose growth before 1997.

labor services to capital stocks and total hours worked overestimates the contribution of TFP by 15.10% in the first period and underestimates it by 18.85% in the second period. In other words, the two methodologies do not result in substantially different decompositions.

Table 4

Growth Decomposition with Capital and Labor Services

	GDP	Labour Input	Labour Input breaks into: Total Employment	Average Hours Worked	Labor Composition	Capital Services	Capital Services break into: Net/Productive capital Stock	Quality Effect	TFP
Average 1997-2007	4.02%	1.04%	0.92%	-0.09%	0.21%	1.35%	1.28%	0.07%	1.63%
Average 2008-2013	-4.37%	-1.94%	-2.24%	-0.07%	0.37%	0.47%	0.51%	-0.04%	-2.90%

Source: Authors' calculations

Table 5

Growth Decomposition with Capital Stocks and Total Hours Worked

	GDP	Labour Input	Labor Input breaks into: Total Employment	Average Hours Worked	Net Capital Stock	TFP
Average 1997-2007	4.02%	0.83%	0.92%	-0.09%	1.27%	1.92%
Average 2008-2013	-4.37%	-2.31%	-2.24%	-0.07%	0.38%	-2.44%

Source: Authors' calculations

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Appendix A

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.

A.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.

Equation (4) of section 2 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:

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

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[8]. 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.

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[8] 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.

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.

A.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:

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

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 ΔLnB_t as a Törnqvist index:

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

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 $U_{i,t}$ to denote the rental price of asset type *i* in time *t* and $K_{i,t}$ is the corresponding productive stock, so that $U_{i,t} * K_{i,t}$ 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.

A.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 1997-2013, 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:

$$\mathbf{\Delta LnL_t = \sum_{j=1}^{6} \overline{s_{j,t}} * \Delta LnH_{j,t}} \quad , \qquad \textbf{(9)}$$

where:

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

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[9]. This 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.

[9] 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 (WIOD 2012) who holds earnings relative to those of medium-skill workers constant.

A.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:

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

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

where $w_t * L_t$ is the total remuneration of labor in time t, which includes the compensation of both employees and self-employed) and $w_{t-1} * L_{t-1}$ are the total user costs of capital in time t. The sum of the remuneration of capital and labor should equal gross value added[10].

A.5 Structural break analysis

Structural change occurs in many time series for any number of reasons, including economic crises, changes in institutional arrangements, policy changes and regime shifts. Several methodologies have been developed over the last 20 years as the literature has progressed from a priori assumptions for the occurrence of a break to endogenously calculating its place in time. In this section, we explain our estimations based primarily on the Bai-Perron technique.

Research on determining structural breaks has been closely related with unit root testing. In time series analysis an important test called the Augmented Dickey- Fuller (ADF) test has been widely used to check for the existence of unit root. Nelson and Plosser (1982), using the ADF test on 14 macroeconomic variables of the American economy, argued that most macroeconomic time series contain a unit root. However, Perron (1989) challenged their results and showed that when a structural break which has not been accounted for is present, then the ADF test is biased towards non-rejection of the null hypothesis of the existence of unit root. Perron deals with this problem by introducing a single, exogenous structural break in the ADF test, in both the null and

[10] 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

the alternative hypothesis. Since then the literature has moved on to consider multiple structural breaks and estimating them endogenously.

In addition to the ADF test, we also carry out the Perron (1997) test. This test checks for stationarity and at the same time investigates the existence of one single structural break endogenously. Breaks can be sought in the intercept, the trend or both. Typically, this test has been criticized as being biased towards rejecting the null hypothesis of a unit root to the alternative of (trend) stationarity with breaks because the former does not allow for a break.

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.

A.6 Annual Results

Table 6

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	13,20%	5,90%	6,22%	-0,31%	1,39%	5,91%
1962	0,36%	-0,82%	-0,53%	-0,29%	1,68%	-0,50%
1963	5,40%	-0,82%	-0,53%	-0,29%	1,40%	4,81%
1964	9,41%	-0,79%	-0,52%	-0,28%	1,87%	9,61%
1965	10,77%	-0,78%	-0,51%	-0,27%	2,23%	9,32%
1966	6,49%	-0,78%	-0,51%	-0,27%	2,21%	5,07%
1967	5,67%	-0,80%	-0,52%	-0,27%	1,90%	4,57%
1968	7,20%	-0,82%	-0,54%	-0,28%	2,35%	5,67%
1969	11,56%	-0,81%	-0,53%	-0,28%	2,72%	9,65%
1970	8,93%	-0,73%	-0,48%	-0,25%	2,77%	6,89%
1971	7,84%	-0,66%	-0,44%	-0,22%	3,41%	5,09%
1972	10,16%	0,12%	0,34%	-0,22%	4,31%	5,73%
1973	8,09%	0,11%	0,32%	-0,21%	4,34%	3,65%
1974	-6,44%	-0,08%	0,30%	-0,38%	1,98%	-8,34%
1975	6,37%	-0,09%	0,31%	-0,39%	2,23%	4,23%
1976	6,85%	-0,09%	0,32%	-0,40%	2,26%	4,68%
1977	2,94%	-0,10%	0,33%	-0,42%	2,45%	0,59%
1978	7,25%	-0,20%	0,24%	-0,44%	2,59%	4,86%
1979	3,28%	0,16%	0,61%	-0,45%	2,47%	0,65%
1980	0,68%	0,32%	0,76%	-0,44%	1,66%	-1,30%
1981	-1,55%	2,47%	2,91%	-0,44%	1,22%	-5,25%
1982	-1,13%	-0,93%	-0,47%	-0,46%	1,01%	-1,21%
1983	-1,08%	2,13%	0,64%	1,48%	1,07%	-4,27%
1984	2,01%	-1,74%	0,22%	-1,96%	0,57%	3,18%
1985	2,51%	0,50%	0,59%	-0,08%	0,74%	1,26%
1986	0,52%	0,14%	0,21%	-0,07%	0,72%	-0,34%
1987	-2,26%	-1,62%	-0,05%	-1,57%	0,57%	-1,21%
1988	4,29%	1,49%	0,93%	0,56%	0,60%	2,20%
1989	3,80%	1,20%	0,22%	0,98%	0,69%	1,91%
1990	0,00%	-0,08%	0,79%	-0,87%	0,72%	-0,63%
1991	3,10%	-0,24%	-1,38%	1,14%	0,80%	2,54%
1992	0,70%	1,60%	0,83%	0,77%	0,70%	-1,60%
1993	-1,60%	1,27%	0,35%	0,92%	0,58%	-3,45%
1994	2,00%	-0,32%	1,06%	-1,37%	0,49%	1,83%
1995	2,10%	0,14%	0,53%	-0,40%	0,52%	1,45%
1996	2,36%	0,14%	0,76%	-0,62%	0,62%	1,60%
1997	3,64%	-0,24%	-0,20%	-0,04%	0,70%	3,17%
1998	3,36%	2,81%	2,84%	-0,03%	0,86%	-0,30%
1999	3,42%	1,07%	0,29%	0,78%	1,03%	1,32%
2000	4,48%	0,66%	0,96%	-0,30%	1,14%	2,68%
2001	4,20%	0,32%	0,09%	0,23%	1,22%	2,66%
2002	3,44%	0,99%	1,34%	-0,35%	1,34%	1,11%
2003	5,94%	1,75%	1,49%	0,25%	1,53%	2,67%
2004	4,37%	0,56%	0,65%	-0,09%	1,48%	2,33%
2005	2,28%	0,35%	0,58%	-0,23%	1,17%	0,76%
2006	5,51%	0,48%	1,21%	-0,73%	1,46%	3,57%
2007	3,54%	0,39%	0,81%	-0,43%	2,02%	1,13%
2008	-0,21%	0,45%	0,68%	-0,23%	1,37%	-2,03%
2009	-3,14%	-1,12%	-0,72%	-0,40%	0,88%	-2,90%
2010	-4,94%	-1,59%	-1,75%	0,15%	0,48%	-3,83%
2011	-7,10%	-4,33%	-4,38%	0,06%	0,10%	-2,88%
2012	-6,98%	-5,02%	-4,94%	-0,08%	-0,20%	-1,76%
2013	-3,86%	-2,25%	-2,32%	0,06%	-0,38%	-1,22%

Table 7
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	3,64%	-0,10%	-0,20%	-0,04%	0,14%	0,11%	0,74%	-0,64%	3,63%
1998	3,36%	3,20%	2,84%	-0,03%	0,39%	0,50%	0,90%	-0,39%	-0,34%
1999	3,42%	1,22%	0,29%	0,78%	0,14%	0,94%	1,08%	-0,14%	1,26%
2000	4,48%	0,66%	0,96%	-0,30%	0,01%	1,31%	1,23%	0,08%	2,50%
2001	4,20%	0,40%	0,09%	0,23%	0,08%	1,44%	1,33%	0,11%	2,36%
2002	3,44%	1,26%	1,34%	-0,35%	0,28%	1,62%	1,38%	0,25%	0,56%
2003	5,94%	1,90%	1,49%	0,25%	0,15%	1,89%	1,51%	0,39%	2,15%
2004	4,37%	1,38%	0,65%	-0,09%	0,82%	1,91%	1,57%	0,33%	1,08%
2005	2,28%	0,32%	0,58%	-0,23%	-0,02%	1,52%	1,32%	0,20%	0,44%
2006	5,51%	0,65%	1,21%	-0,73%	0,18%	1,48%	1,32%	0,17%	3,38%
2007	3,54%	0,52%	0,81%	-0,43%	0,14%	2,12%	1,74%	0,38%	0,90%
2008	-0,21%	0,62%	0,68%	-0,23%	0,17%	2,06%	1,64%	0,42%	-2,89%
2009	-3,14%	-1,13%	-0,72%	-0,40%	-0,01%	1,23%	1,03%	0,20%	-3,24%
2010	-4,94%	-1,25%	-1,75%	0,15%	0,35%	0,59%	0,58%	0,01%	-4,29%
2011	-7,10%	-3,76%	-4,38%	0,06%	0,57%	0,04%	0,22%	-0,17%	-3,39%
2012	-6,98%	-4,54%	-4,94%	-0,08%	0,48%	-0,42%	-0,10%	-0,32%	-2,02%
2013	-3,86%	-1,59%	-2,32%	0,06%	0,67%	-0,67%	-0,32%	-0,35%	-1,60%

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:

$$\mathbf{\Delta LnF_t = \Delta LnL_t - \Delta LnH_t} \qquad \textbf{(12)}$$

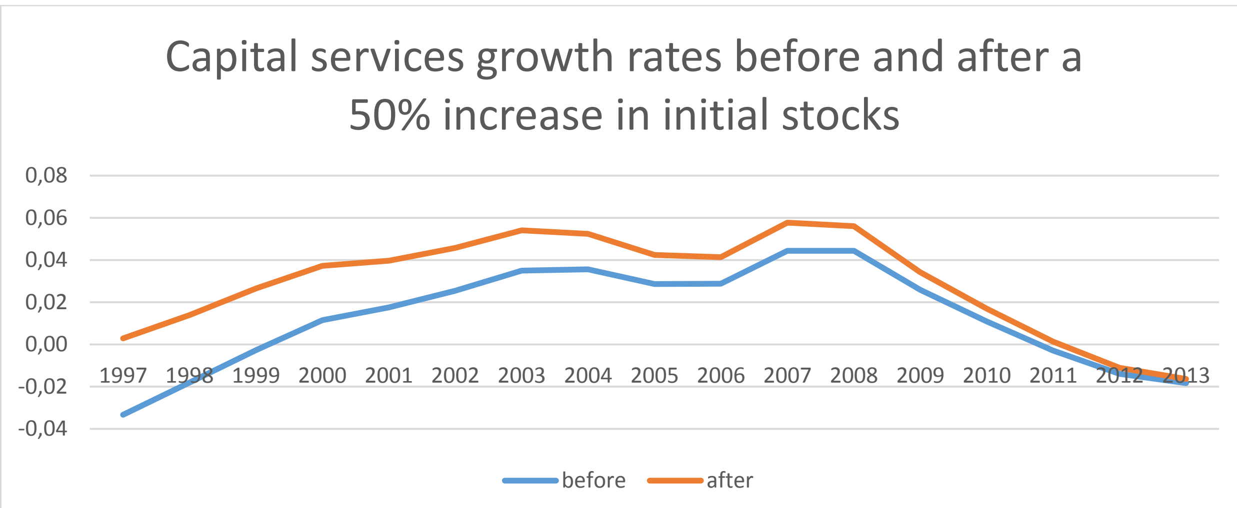
Equation 12 tells us that the rate of change of labor composition equals the rate of change of labor input minus that of total hours worked. In the same way, we decompose the growth of capital services into the growth of productive stock (which in our case is the same as net capital stock) and that of quality of capital (Q):

$$\mathbf{\Delta LnQ_t = \Delta LnL_t - \Delta LnK_t} \qquad \textbf{(13)}$$

Appendix B

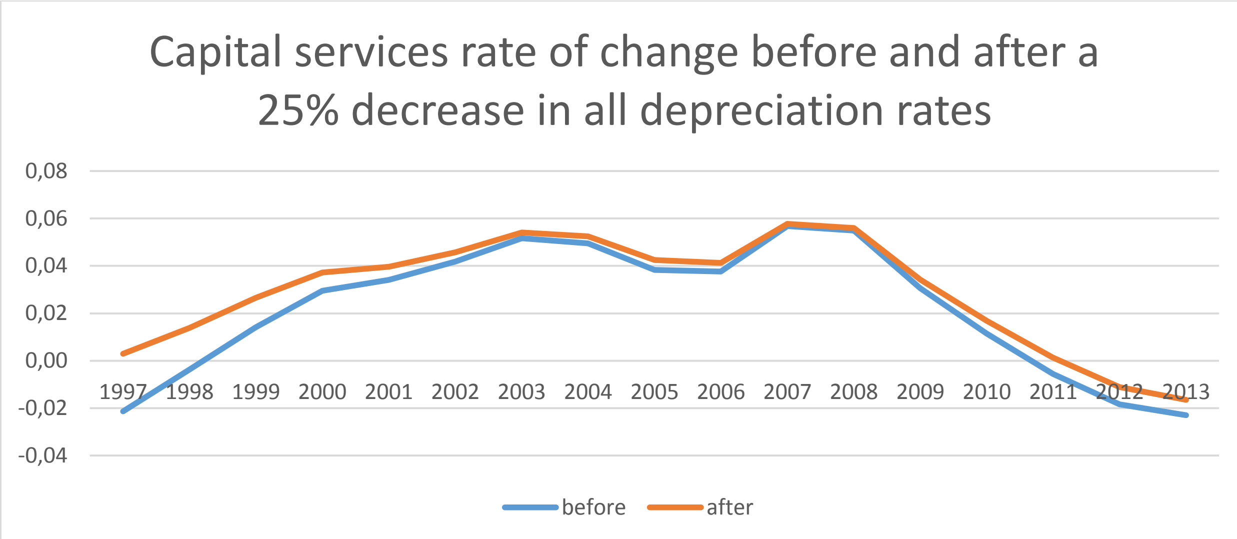
In this section we examine the robustness of our constructed measures of capital and labor services by repeating the calculations based on some alternative assumptions.

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:



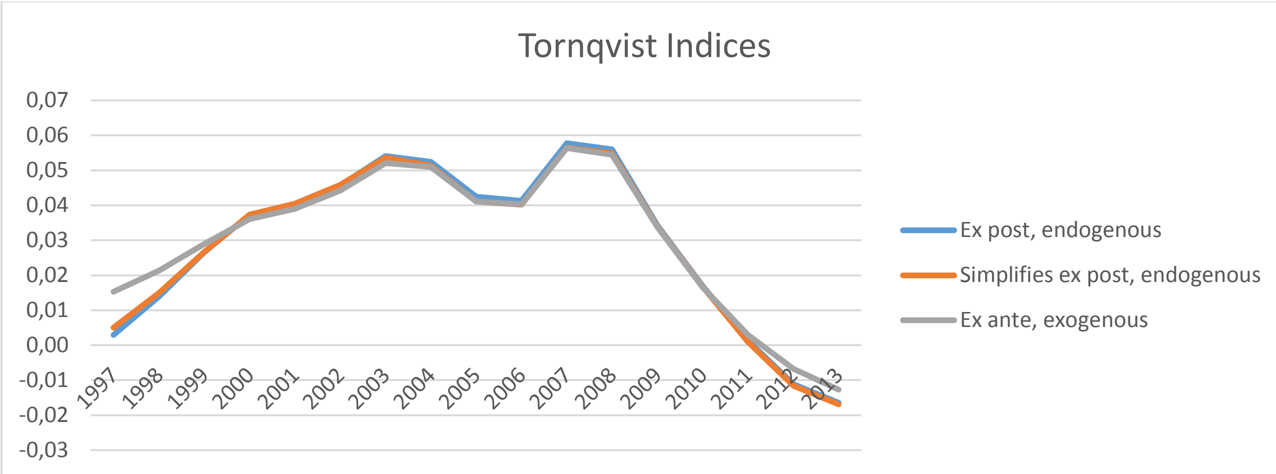
Raising the capital stocks of all assets results in an increase in capital services growth rates by 1.62% on average in comparison with our initial findings. The distance between the two curves is larger at the beginning and narrows towards the end of the period we examine.

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

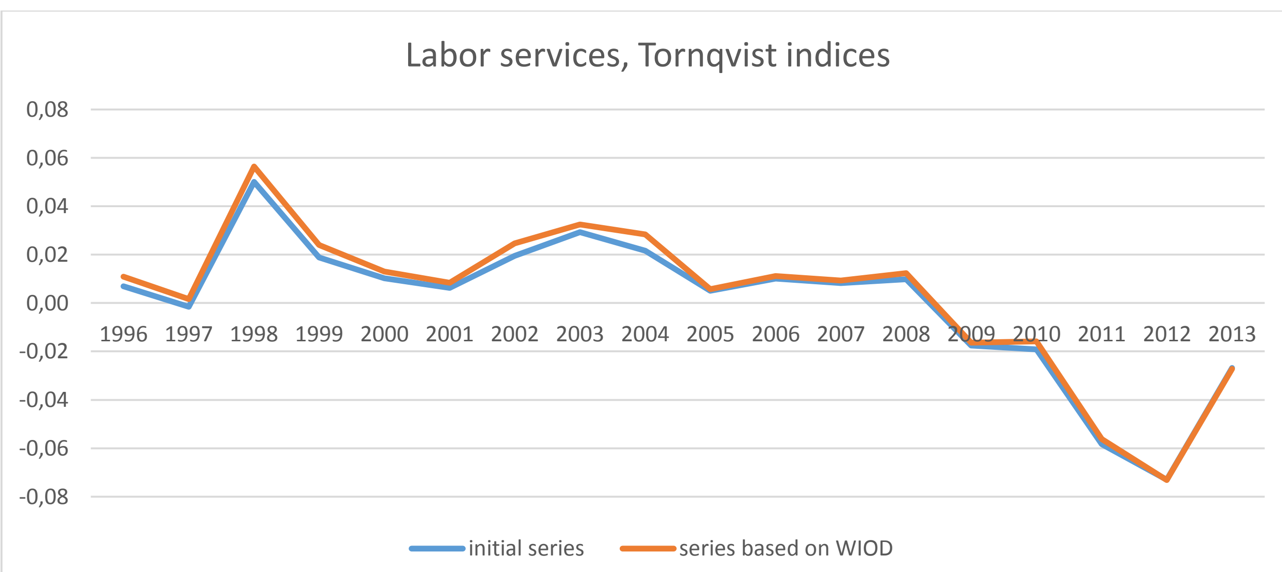


The increased depreciation rates cause our estimates to deviate by 0.69% on average.

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:



Finally, we consider the case where labor services are computed with an alternative set of data. For that purpose we make use of the shares in total labor compensation provided by the 2012, February release of the World Input-Output Database (WIOD). The shares concern three types of workers: low skilled, medium skilled and high skilled workers. These three correspond to the three categories of educational attainment in which we divided workers in section 2.2 and cover the years 1995-2009. We computed the shares for the years 2010-2013 by holding constant the implied relative wages of each group in 2009. A comparison of our findings below reveals very small differences.



Appendix C

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	WIOD Shares in Total Labor Compensation
A15	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 ➔ Access Database

A5, A6, A7: http://www.oecd-ilibrary.org/ ➔ Statistics ➔ Databases ➔ OECD Economic Outlook: Statistics and Projections ➔ OECD Economic Outlook No. 94 ➔ Access Database

A4: http://www.oecd-ilibrary.org/ ➔ Statistics ➔ Databases ➔ OECD Factbook Statistics ➔ OECD Factbook ➔ Access Database

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://www.wiod.org/new_site/database/seas.htm ➔Data ➔Socio Economic Accounts ➔ Greece

A15: **:** 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