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Modeling the economic growth of Greece

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Senior Honors Thesis in Economics

Modeling the Economic Growth of Greece

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Modeling the Economic Growth of Greece

I. Introduction

What is the growth experience of the Greek economy? How can economic growth for a country like Greece be explained? What are the determinants of economic growth? Can economic growth in Greece be modeled? These are a few among the many questions I had before I undertook this project. I wanted to examine and understand the Greek economy. I wanted also to examine key economic variables in order to comprehend the overall structure of the Greek economy. The Greek economy is quite interesting since it is considered an emerging market by many financial institutions. I agree with this notion of Greece as an “emerging market” since I believe that Greece great potential for future growth.

The objective of this project is to use an econometric model to examine economic growth in Greece. Using a growth model to investigate a country's economy one can obtain a more complete picture of the historical growth experience of a particular country by pinpointing the underlying causes for growth and recession at particular time periods. My main objective is to thus construct a growth model for the Greek economy, which is based on Solow's theory of economic growth. Solow was one of the first economists that attempted to examine growth within an economy through the use of a well-structure model that came to be known as the Solow model.
The general hypothesis was that the Greek economy can be modeled successfully. I also expected to find valuable results that ultimately can be used as tools for economic policymakers. The methodology behind the model constructed was based on Mankiw, Romer and Weil's article in 1992 "A Contribution to the Empirics of Economic Growth". (Mankiw; Romer; Weil 1992) Their article provided me with a basic textbook Solow model. Although in their article Mankiw, Romer and Weil used cross-country data to test the efficiency of the model among different countries, by modifying some of the original assumptions I constructed a time-series model that I applied to the Greek economy.

What this paper will show is that, overall, the methodology and Solow theory behind the work of Mankiw, Romer and Weil was found to be inappropriate for the Greek economy. Possible reasons for this, can be the fact that the Greek economy appears to have reached its steady state level for at least the last part of the period examined. Maybe it is due to the overall structure of the Greek economy or perhaps Solow's theory is just not applicable to the Greek economy. Furthermore the existing large trade deficit that the Greek economy experienced throughout the period examined is a great limitation in applying Solow's theory. In an attempt to further extent my application and understanding of Solow's theory I attempted to estimate the Solow residuals, as measures of technical change. The Solow residuals were successfully obtained using growth accounting theory.
II. Literature Review / Model description

i) Literature Review

In trying to create a growth model of the Greek economy, previous Solow-related economic literature was examined, as well as Solow's original articles. The following represents a thorough analysis of the literature examined.

In Solow's original body of thought, the steady-state level (long-run equilibrium) of income per capita for a particular economy can be determined from that country's population and saving rate. (Mankiw 1994)

![Diagram](attachment:image.png)

It is important in this section to clarify what the steady-state of capital is.

Looking at the above figure, the horizontal axis measures the stock of capital, the vertical axis measures output \( y=f(k) \). Also in the diagram \( f(k) \) represents output as a function of the stock of capital and \( sf(k) \) represents the amount of saving (\( S: \) saving ratio) and thus investment at each capital stock level and \( (n + \delta + g)k \) represents the combined rates of population growth (\( n \)), depreciation (\( \delta \)) and
technical change (g) and their effect on the stock of capital. In the diagram above k* represents the single capital stock at which the amount of investment equals the amount of depreciation, population growth and technological progress. That is, in the steady state (k*), investment \( \frac{s}{(k^*)} \) offsets the reduction in capital (k) due to depreciation, labor force growth and technological change. Obviously, k* represents a long run equilibrium since assuming constant saving any short run change in the rates of population growth (n), depreciation (δ) and technical change (g) will alter the structure of an economy. Furthermore, assuming that the combined rates remain constant, k* is considered the long run equilibrium because there is no motive for change in the level of capital stock since in the long run, ceteris paribus, the capital stock will return at the steady-state level. This can be demonstrated by the fact that in the long run equilibrium the steady state can be defined as \( \Delta k = 0 \), the following equation shows the long run equilibrium.

\[
\Delta k = sf(k) - (n + \delta + g)k \Rightarrow (\Delta k = 0)
\]

According to Solow's theory, assuming that a country has reached a steady state level of income per capita, alternations in the rate of saving and the combined rates (n + δ + g) can induce periods of high growth until a new steady state has been reached. (Solow 1956) I think one of the most important aspects of his theory is the effect of technical change on economic growth. Although
technical change is treated as exogenous in his model, one can identify and examine the magnitude of its effects. In his article in 1957, "Technical Change and the Aggregate Production Function", Solow estimated the magnitude of technical change for the United States, between 1909 and 1949. (Solow 1957) As he mentioned in the introduction of his article, he wanted to suggest an "elementary way of segregating variations in output per head due to technical change from those due to changes in the availability of capital per head. It is important to note here that Solow defines technical change as labor related technological progress. So the way he calculated the technical change, was by using the following kind of formula

\[
\frac{\Delta A}{A} = \frac{\Delta (Priv. \text{ Nonfarm GNP per manhour})}{(Priv. \text{ Nonfarm GNP per manhour})} - [\frac{\Delta (Employed Capital per manhour)}{(Employed Capital per manhour)}] \\
(Share of property in income) \times \frac{\Delta (Employed Capital per manhour)}{(Employed Capital per manhour)}
\]

In the above equation \( \Delta A / A \) represents the technical change. As is obvious, technical change, the way Solow defined it is purely labor related.

Further studies that stemmed from Solow's growth model showed that further augmentation, for instance including accumulation of human capital, can better explain economic growth. What I needed to find was an analytical framework that would fit my objective of creating a growth model appropriate for the Greek economy. I found the framework behind the work of Mankiw,
Romer and Weil: "A Contribution to the Empirics of Economic Growth", to be the most appropriate one.

In their article, Mankiw, Romer and Weil are basing their work on Robert Solow's article: "A Contribution to the Theory of Economic Growth". (Solow 1956) Mankiw, Romer and Weil argue that their results are consistent with Solow's predictions. That is, they found that the effects of population growth and saving on income per capita are indeed the ones Solow predicted in 1956. They believe though, by using cross-country data sets, the magnitude of the effects of population and saving to be over-predicted. Their paper focuses on the proposal to further augment the Solow model by including human capital as well as physical capital. According to their results, the human capital augmented Solow model provides an almost complete explanation of why some countries are richer and other are poorer. Although in their paper Mankiw, Romer, and Weil use cross-country data, I am going to use time series data of the Greek economy. In doing so I will have to modify some of the assumptions used. Following MRW's (Mankiw, Romer and Weil's) work, there are two models used in their paper, the textbook Solow model and their own (human capital) Augmented Solow model. I will attempt to test both frameworks if possible and choose the one that best suits my data for the Greek economy. Of course in using time series data I will have to modify some of the assumptions in order to examine the model and obtain valuable results.
Of course, other Solow related articles were examined like Walter Nonneman and Patrick Vanhoudt's article, "A further augmentation of the Solow Model and the Empirics of Economic Growth for OECD countries". (Nonneman; Vanhoudt 1996). In their article Nonneman and Vanhoudt based their work on Mankiw, Romer and Weil's article in 1992. Their augmentation of the Solow model focused on including a variable named the "accumulation of technological know-how" which according to their model can be endogenously determined. As they describe, "technological know-how" is in fact a form of capital. Furthermore, following Mankiw Romer and Weil they assume a Cobb-Douglas production function where instead of one type of capital there are m different types of capital to account for the different kinds of capital such as infrastructure, human capital and technological know-how. In estimating their equations, Nonneman and Vanhoudt basically use research and development data for estimating their technological know-how variable. Although their work seems to be quite interesting, I believe it is excessive to use such hard-to-obtain data, especially when Greece is not very sophisticated in the research and development area, being an emerging market.

One of the most interesting conclusions throughout my research of previous literature is the fact that in all Solow-related cross-country data analyses the conventional approach seems to be setting $\delta + g = 0.05$ ($\delta = 0.03$ & $g = 0.02$). That is, throughout these studies both the depreciation rate and the rate of technological progress are assumed to be constant and equal to 0.03 and 0.02.
respectively. One of the greatest problems with my research was the lack of a
time-series application of the Solow model in the available literature. As
mentioned before, I will base my model on Mankiw, Romer and Weil's article, by
modifying some of the assumptions in order to examine the Greek economy
between 1960 and the present.

ii) Model description

As I previously stated I am basing my model on the work of
Mankiw, Romer and Weil's. Following is an analytical description of the two
models used in their article.

Following Mankiw, Romer and Weil (MRW), there are two models
examined in their paper that I intend to use, the "Textbook Solow Model" and
the "Augmented Solow Model." I will specify both models before I proceed into
any estimation.

1) The Textbook Solow Model

Saving, population growth and technological progress and depreciation
are assumed to be exogenously determined in MRW's article and thus constant,
but all these assumptions, except from the one about depreciation, will be later
relaxed in regressing the appropriate equations. There are two inputs under this
model's theory, Capital and Labor. Assuming that they are both paid their
marginal products, we have the following Cobb-Douglas production at time $t$: 
\[ Y_t = K_t^\alpha (A_t L_t)^{1-\alpha} \quad (1) \quad 0 < \alpha < 1 \]

where:
Y: Output
K: Capital
L: Labor
A: Level of Technology (labor-augmenting)

The above Cobb-Douglas production function exhibits constant returns to scale.

A and L are also assumed to grow exogenously at rates \( n \) (population growth) and \( g \) (technological progress), thus we have:
\[ L_t = L_0 e^{nt} \quad (2) \quad \text{and} \quad A_t = A_0 e^{gt} \quad (3) \]

Therefore \( A_t L_t \), the number of effective units of labor, grows at rate \( n+g \). Using this production function production I am basically assuming that labor and technology are directly correlated and therefore technological progress (or technical change) is labor-augmenting.

This model assumes that a constant fraction of output, \( s \), is invested.

Defining \( k \) as the stock of capital per effective unit of labor, \( k = \frac{K_t}{A_t L_t} \), and \( y \) as the level of output per effective unit of labor, \( y = \frac{Y_t}{A_t L_t} \), both \( k \) and \( y \) are now measured in efficiency units \( (A_t L_t) \) so equation (1) can be transformed in the following way:

\[
(1) \Rightarrow Y_t = K_t^\alpha (A_t L_t) \frac{1}{(A_t L_t)^\alpha} \Rightarrow \text{(dividing both sides by } A_t L_t) \]
\[
\frac{Y_t}{A_t L_t} = \frac{K_t^\alpha}{(A_t L_t)^\alpha} \Rightarrow y_t = k_t^\alpha \quad (4)
\]
Thus the evolution of $k$ is governed by the following equation, previously discussed in section II:

$$k_t = s y_t - (n + \delta + g)k_t \Rightarrow \text{using (4)}$$

$$k_t = s k_t^a - (n + \delta + g)k_t \text{ (5)}$$

where:
- $\delta$: Rate of Depreciation
- $n$: Rate of Population Growth
- $g$: Rate of Technological progress

This equation, (5), implies that $k$ can converge to the steady state $k^*$. As previously described in section II, at the steady-state of capital there is no change in the capital stock, thus $\Delta k = 0$, so we have the following equation that defines the steady-state of capital:

$$k_t = s k_t^a - (n + \delta + g)k_t \Rightarrow \text{ (but since } \Delta k = 0, \text{ at the steady - state level)}$$

$$s k_t^a - (n + \delta + g)k^* = 0 \Rightarrow$$

$$sk_t^a = (n + \delta + g)k^* \Rightarrow$$

$$k^* = \left[ \frac{s}{(n + \delta + g)} \right]^{\frac{1}{1-a}} \text{ (6)}$$

The steady state capital to labor ratio is positively related to the rate of saving ($s$) and negatively related to the rate of population growth ($n$), rate of depreciation ($\delta$) and rate of technological progress ($g$).

Since we want to examine the impact of saving and population growth on real income, substituting equation (6) into the Cobb-Douglas production function and taking logs we can get an equation for the steady state income per capita, thus we have
(4) \( y_i = k_i^\alpha \Rightarrow \ln y_i = \alpha \cdot \ln k_i = \alpha \cdot \ln \left[ s/(n + \delta + g) \right]^{1 - \alpha} \Rightarrow \)

\[
\ln y_i = \alpha \left[ \frac{1}{1 - \alpha} \cdot \left[ \ln(s) - \ln(n + \delta + g) \right] \right] \Rightarrow
\]

\[
\ln \left( \frac{Y_i}{A_i L_i} \right) = \left( \frac{\alpha}{1 - \alpha} \right) \ln(s) - \left( \frac{\alpha}{1 - \alpha} \right) \ln(n + \delta + g) \Rightarrow
\]

\[
\ln \left( \frac{Y_i}{L_i} \right) = \ln A_i + \left( \frac{\alpha}{1 - \alpha} \right) \ln(s) - \left( \frac{\alpha}{1 - \alpha} \right) \ln(n + \delta + g) \Rightarrow
\]

\[
\ln \left( \frac{Y_i}{L_i} \right) = \ln A_0 + gt + \left( \frac{\alpha}{1 - \alpha} \right) \ln(s) - \left( \frac{\alpha}{1 - \alpha} \right) \ln(n + \delta + g) \quad (7)
\]

Since under the assumptions of the model the factors of production are paid their marginal products, the model predicts the signs but also the magnitudes of the coefficients on saving and population growth, thus the signs are predicted to be equal in magnitude and opposite in sign.

In the case of MRW’s paper, the authors had to make assumptions about the differences among different countries, such as different resource endowments, climate, institutions e.t.c. In contrast, for my model I have country-specific data that helps estimate variables and thus having tangible variables I don’t have to deal with many of the problems that arise from cross-country data. Thus given MRW’s assumption:

\[
\ln A_0 = a + \varepsilon
\]

where:
- \( a \): constant
- \( \varepsilon \): country-specific shock
For my data set E is equal to zero since there are no country-specific shocks.

Thus we have:

\[
\ln \left( \frac{Y}{L} \right) = a + \left( \frac{\alpha}{1-\alpha} \right) \ln(s) - \left( \frac{\alpha}{1-\alpha} \right) \ln(n + \delta + g) + \epsilon \Rightarrow \\
\ln \left( \frac{Y}{L} \right) = a + \left( \frac{\alpha}{1-\alpha} \right) \ln(s_f) - \left( \frac{\alpha}{1-\alpha} \right) \ln(n_r + \delta + g) \quad (8)
\]

I will therefore estimate equation (8) using the Ordinary Least Squares method with and without imposing the restriction that the coefficients on ln(s) and ln(n+\delta+g) are equal in magnitude and opposite in sign. In my model, unlike MRW’s, the rate of saving (s) and the rate of population growth (n) is endogenously determined. Also another estimation of the equations will occur using the “Solow residual” as the rate of technological progress or technical change. (More about this on Section V)

2) The Augmented Growth Model

Under this model human-capital accumulation is added to the Solow growth mode. According to MRW human capital can potentially alter the theoretical modeling and empirical analysis of economic growth. I will test this model too because I believe the human capital to be of great importance to a developing economy like Greece.

For this model the Cobb-Douglas production function will be

\[
Y_t = K_t^\alpha H_t^\beta (A_t, L_t)^{1-\alpha-\beta} \quad (8)
\]

where:

H: Stock of Human Capital
Once again this Cobb-Douglas production function exhibits constant returns to scale. The rest of the variables are defined as in the previous model. Under this model the evolution of \( k \) is determined by the following two equations:

\[
k_i = s_k y_i - (n + \delta + g) k_i \quad (9a)
\]

\[
h_i = s_h y_i - (n + \delta + g) h_i \quad (9b)
\]

where:

\[ y = \frac{Y}{AL}, \quad k = \frac{K}{AL} \quad \text{and} \quad h = \frac{H}{AL} \]

are quantities per effective unit of labor.

Assuming that the same Cobb-Douglas production function applies to human & physical capital as well as consumption, a unit of consumption can be transformed costlessly to either human or physical capital. The model also assumes that the Cobb-Douglas production function exhibits decreasing returns to all capital, this means that \( \alpha + \beta < 1 \). As done in the previous model equations (9a) and (9b) imply that the economy converges to a steady state of capital defined by:

\[
k^* = \left( \frac{s_k^{a-\beta} s_h^{\beta}}{n + \delta + g} \right)^{\frac{1}{1-\alpha-\beta}} \quad (10a)
\]

\[
h^* = \left( \frac{s_k^{a-\beta} s_h^{\beta}}{n + \delta + g} \right)^{\frac{1}{1-\alpha-\beta}} \quad (10b)
\]

Substituting (10a) and (10b) into the Cobb-Douglas production function and taking logarithms gives us the following equation for the steady-state income per capita:
\[
\ln \left( \frac{Y}{L_i} \right) = \ln A_0 + gt - \left( \frac{\alpha + \beta}{1 - \alpha - \beta} \right) \ln(n + \delta + g) + \left( \frac{\alpha}{1 - \alpha} \right) \ln(s) + \left( \frac{\beta}{1 - \alpha} \right) \ln(s^*)
\] (11)

This equation shows the effect of population growth and accumulation of physical and human capital. As in the textbook Solow model, \(\alpha\) is physical capital’s share of income. Finding a reasonable value for \(\beta\) will depend on the minimum wage in Greece. For this model high population growth has a negative effect on income per capita because as MRW suggest “both physical and population capital must be spread more thinly over the population”.

MRW also provide an alternative way to determine the effect of human capital on income per capita. By combining equation (11) with equations (10a) and (10b)

\[
\ln \left( \frac{Y}{L_i} \right) = \ln A_0 + gt + \left( \frac{\alpha}{1 - \alpha} \right) \ln(s) - \left( \frac{\alpha}{1 - \alpha} \right) \ln(n + \delta + g) + \left( \frac{\beta}{1 - \alpha} \right) \ln(h^*)
\] (12)

Therefore the equation for income per capita becomes a function of the rate of investment in physical capital, the rate of population growth, and the level of human capital. The positive sign of the coefficient of \(h^*\) is justified from MRW by stating that one should expect the human capital to be positively correlated with the saving rate and negatively correlated with population growth.

Thus in order to examine the efficiency of this model one needs estimate both equation (11) and (12). The point of estimating both of these equations as stated by MRW is to determine whether the available data on human capital, for a particular country, corresponds more closely to the rate of accumulation or to
the level of human capital. Of course the measurement of human capital presents great difficulties, especially since a large part of investment in education takes the form of forgone earnings on the part of students. As MRW observe it is difficult to overcome such a problem because the forgone earnings are related to the amount of human capital that each worker has.

Unfortunately, the available data on human capital was not appropriate since it was measured in a five-year period basis and it was not applicable, since the rest of the variables are measured on a yearly basis. Future research on measuring the Augmented human capital model for Greece, should be established, since as I previously stated, the human capital is particularly important as a determinant of income per capita for a developing economy like Greece. Obtaining the appropriate data could ultimately make MRW's augmented model described above applicable to the Greek economy.
III. The Greek Economy – Past Economic Performance / Current Events

A. Past economic performance

Looking at some key variables in the Greek economy one can get a better understanding of the past economic performance of the country. One of the key variables to look at is the Real Gross Domestic Product of Greece.

1) Real Gross Domestic Product

Looking at Figure 1a, the Gross Domestic Product is plotted over time, with yearly estimates. GDP is measured in millions of 1990 drachma in order to account for the effects of inflation, which can over or underestimate the actual GDP at a particular point in time. The sample examined contains data from 1960 up to 1995. As we can see from the graph the Greek GDP started from a low of 3393.59 million (1990) drachmas in 1960 reaching an all-time high of 14222.7
million (1990) drachmas in 1995. Throughout the data we can notice two recessions, decreases in GDP (shaded areas in the graph). A major one from 1973 to 1974 where the GDP fell from 8855.37 to 8533.19 million (1990) drachmas, and a minor one from 1986 to 1987 where GDP fell from 12170.08 to 12113.84 million (1990) drachmas.

In order to get a better look at the progression of GDP over the years annual growth rates have been calculated and are demonstrated in Figure 1b. Looking at the latter figure above one can notice that in the beginning of the period examined the growth rates tended to be higher than the most recent ones. That is, the highest growth rate, of 11.15% is being observed at the very beginning of the period, between 1960 and 1961, whereas the lowest growth rates, of 0.03% and 0.23%, are observed at the end of the period, from 1989 to 1990 and from 1992 to 1993 respectively. The negative growth rates observed are directly
associated with the periods of economic recession discussed above. Overall though the Gross Domestic Product of Greece has had a relatively healthy upward trend with no great pitfalls. As years progress though, it seems that GDP has been increasing at decreasing rate, which decreasing rate tends to increase in magnitude. Looking more closely at the growth rates one can distinguish two different periods in my sample. The first period ranging from 1960 up to 1980 and a second period ranging from 1980 to the 1995. Obviously 1980 marks a shift in trend which could be attributed from the change in political structure. PASOK the Greek socialist party won the elections in 1982 and obviously there were radical changes (as will be demonstrated from further investigation of key economic variables) in policy making which changed the trend of the economy.

2) Government Final Consumption Expenditure

![Figure 2a. General Government Consumption Expenditure](image)
Figure 2a represents the General Government Consumption Expenditure (or Government Spending), once again it is measured in 1990 drachma to compensate for the inflation effects. The available data contains yearly estimates and runs from 1960 up to 1995. Looking at the graph we see that government spending in Greece started from a low of 445.39 in 1960 and reached an all-time high of 2101.51 million (1990) drachmas in 1995. Overall, government spending in Greece seems to have an upward trend, except from two periods of decline, a minor decline from 1787.92 to 1773.28 million in 1985 and 1986, respectively, and a major one from 1990 up to 1992, where government spending declined from 2007.01 to 1908.82 million (1990) drachmas.

Figure 2b. Growth of General Government Consumption Expenditure

As before, looking at figure 2b, one can look at the growth in government spending in Greece. The highest growth rates are observed between 1973 and 1974, 12.08%, and between 1974 and 1975, 11.94%, it is not a coincidence that this
coincides with the period following the recession, decline in GDP in 1973. This could be possibly explained by expansionary fiscal policy, since such a policy would be needed to bring the economy back on its feet. The three negative growth rates are observed in the following periods 1984-85, 1990-91 and 1991-92 and they coincide with the periods of decline in government spending. The biggest decline in magnitude was then between 1991 and 1992 (-3.41%). Overall, growth in government spending seems to be decreasing in magnitude, this indicates that policy makers in Greece are attempting to decrease their deficits over time and thus avoid increasing the Greek Debt as much. The truth is that the Greek debt has been a problem for the Greek economy since it has been increasing in size over time.

3) Gross Fixed Capital Formation
Figure 3a displays Gross Fixed Capital Formation in Greece, which actually represents the level of investment. The available data contains yearly estimates and runs from 1960 up to 1995. The level of investment started from a low of 981.41 million (1990) drachmas in 1960 and reached a high of 3301.42 million (1990) drachmas in 1995. What is interesting about this figure is that the all-time high level of investment was reached in 1973 where gross fixed capital formation reached 3373.26 million (1990) drachmas. Looking closely at figure 3a it seems that starting from 1960 the level of investment has been increasing somewhat steadily and rapidly up to 1973 but has lost its strong upward trend thereafter since the level of investment has been ranging between 3350 and 2500 ever since. Once again it is not a coincidence that this change has occurred after the recession of 1973, where the recession obviously reduced investment activity. Of course there are many periods of decreasing investment activities (shaded areas in figure 3a). In order to examine better the magnitudes of investment activity from year to year one must look at the growth rates in investment.
Looking at figure 3b, one can see the annual growth rates of gross fixed capital formation. The two highest growth rates are observed between 1963 and 1964 with a growth of 20.69%, and between 1967 and 1968 with a growth of 21.35%. All negative growth rates are associated with periods of decreasing investment activity. As mentioned before in 1973 gross fixed capital formation reached its highest level, but after which it lost its upward trend, one can see this between 1973 and 1974, where the growth rate was -25.57%, which was the largest in magnitude negative growth rate ever observed. The change in trend can be seen from the fact that the growth rates after the 1973 recession have been a lot smaller in magnitude and because they seem to be offsetting one another.

Overall though, it seems that investment in Greece bloomed between 1960 and 1973, and has been somewhat stagnant thereafter.
4) Private Final Consumption Expenditure

Figure 4a represents private (including households and non-profit institutions) final consumption expenditure in Greece. The data available ranges from 1960 up to 1995 and contains yearly estimates of private consumption in Greece. As always the data is measured in constant 1990 drachmas in order to avoid for inflation effects. Private consumption in Greece started from a low of 2519.98 million (1990) drachmas in 1960 and reached an all-time high of 10390.41 in 1995. Clearly private consumption in Greece has a strong upward trend. This understandable considering the fact that since 1960 Greeks have always enjoyed a good life consuming, sometimes more than they should be. This positive effect in consumption possibly stems from the fact that Greeks never came to grip with the huge debt accumulated over the years.
Figure 4b. Growth of Private Final Consumption Expenditure

Figure 4b, shows the growth rates from year to year in private consumption. Immediately one can observe the fact that there is not one negative growth rate throughout the period examined. In the beginning of the period examined consumption was excessive, as we can see from the high growth rates observed. Private consumption seem to be decreasing in magnitude in the most recent years. Between 1973 and 1974 the growth rate of personal consumption during that period was one of the lowest observed (0.67%), obviously this is also a result of the 1973 recession. Again we can see a pre-'80s and post-'80s phenomenon due to the change in political structure (PASOK comes in rule in 1982).
5) Imports/Exports of Goods and Services

Figure 5a. Imports/Exports of Goods & Services

Figure 5a represents the imports and exports of goods and services in Greece. The data available ranges from 1960 up to 1995 and contains yearly estimates of the imports and exports in Greece. As always, the data is measured in constant 1990 drachmas in order to account for inflation effects. Imports in Greece started from a low of 343.9 million (1990) drachmas in 1960 and reached an all-time high of 4581.93 in 1995. Exports in Greece started from a low of 167.36 million (1990) drachmas in 1960 and reached an all-time high of 2742.28 in 1995. Clearly both imports and exports in Greece have a strong upward trend. Overall imports have always exceeded exports in magnitude, and the difference seems to have been increasing over time, which means that Greece is an import-based country.
In order to get a better understanding of both imports and exports, individual growth rates need be examined.

Figure 5b demonstrates the growth of imports over time. There are three negative growth rates that coincide with periods where imports declined, the highest one being between 1973 and 1974, the period of recession, for which the growth rate was -16.29%. Quite interesting is the fact that the highest positive growth rate was between 1972 and 1973, the period right before the 1973 recession. There doesn’t seem to be though any special pattern in the magnitudes of growth rates for imports.

Looking at Figure 5c, one can examine the growth of exports over time. There are four negative growth rates associated with periods where exports declined, the largest in magnitude being between 1981 and 1982 where the rate was -7.19%. 

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The highest positive growth rate occurred between 1965 and 1966 and was equal to 34.42%. Also after the 1973 recession the positive growth rate was the smallest in magnitude and was equal to 0.12%.

Figure 5d represents the net exports (exports - imports) on a yearly basis.

Looking at the graph, net exports have been negative throughout the period of
investigation (1960-95). This demonstrates the fact that exports have always been less than imports in the period examined, in other words throughout the period examined there exists a trade deficit. The downward trend of next exports shows that the gap between exports and imports has been increasing in magnitude throughout time. That is, the trade deficit has been increasing over time. Overall, the trade deficit demonstrates the fact that Greece has always been dominated by its imports and is becoming overly dependent on foreign goods as time progresses.

Two other indicators of economic performance that need to be examined, aside national income (GDP) and its components, are the unemployment and inflation rate.

Figure 6. Greek Unemployment Rate.

Figure 6, represents the unemployment rate of Greece. The unemployment rate was calculated using the following formula
Unemployment Rate = \( \frac{\text{Registered Unemployment}}{\text{Labor Force}} \times 100 \)

Looking at figure 6, the unemployment rate started from 2.07% in 1961 and ended with an all-time high of 4.31% at the end of the period examined (1995). The lowest unemployment rate was observed in 1973 where the unemployment rate was only 0.64%. Once again, as result of the 1973 recession, the unemployment began to increase somewhat steadily with a strong upward trend. Also the pre-'80s and post-'80s phenomenon once again becomes apparent due to the change in political structure (PASOK comes in rule in 1982). After 1980 we see sharp increases in unemployment which can be attributed to the change in political structure (PASOK comes in rule in 1982).
Figure 7 represents the inflation rate in Greece. The inflation rate was calculated using the following formula, where CPI stands for Consumer Price Index:

\[ \text{Inflation Rate} = \frac{CPI_t - CPI_{t-1}}{CPI_{t-1}} \times 100 \]

Looking at figure 7, inflation started from a low of 2.89% in 1961, and reached 8.94% in 1995. The only negative inflation, therefore deflation rate, observed was in 1962 and was equal to -0.65%. Without surprise, the highest inflation rate was observed in 1974, right after the depression of 1973, and it was equal to 26.63%. Ever since the inflation has been fluctuating back and forth from 12 to 25%, up until the last periods were there seems to be an attempt to decrease the inflation rate.

Finally looking at all the variables examined together, the tremendously high economic growth that was observed during the beginning of the period examined, was due to the fact that Greece was rebuilding herself after the wars during the 1940s. The following table represents periods of growth divide in appropriate periods of post-war history. (Pirounakis 1997)

<table>
<thead>
<tr>
<th>Period</th>
<th>Growth Rate (%)</th>
<th>Period</th>
<th>Growth Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1951-1958 (Reconstruction, repression, yet parliamentary rule; period ends with the Left securing 24.4% of the vote in national elections)</td>
<td>6.3</td>
<td>1975-1981 (Restoration of parliamentary order, rise of populism; expansion of public sector)</td>
<td>3.7</td>
</tr>
<tr>
<td>1959-1966 (Political turmoil; struggle for democracy)</td>
<td>6.4</td>
<td>1982-1989 (First period of PASOK rule; rampant populism; further expansion of public sector; period ends with three general elections in less than a year)</td>
<td>2.2</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Military dictatorship; ends with the Turkish invasion of Cyprus in July)</td>
<td>(Both main parties under fiscal &amp; EMU convergence constraints; political cost considerations still paramount)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.5</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


The apparent recession observed in 1973 was due to a great oil shock that occurred that time, and which obviously effected negatively the economic activity in Greece. The tremendous economic growth that Greece experienced in the earlier periods can be demonstrated from the following facts. From a sample of 24 OECD countries it was observed that between 1966 and 1970 the Greek growth rate in real GDP was only topped by Japan's growth rate, also the Greek growth rate between 1966 and 1990 was the seventh highest observed. Yet, between 1986 and 1990, the more recent periods, the growth rate was ranked 21st out of the 24 countries included in the sample. (Pirounakis 1997)

B. Current Events

Greece is currently facing one of its greatest challenges, the European Monetary Union. The country and its ministers are currently struggling to assure Greece's entry in the EMU. Overall, Greece shows signs of confidence in entering the EMU. The Socialist government, currently in command, under the hands of the economy minister, Yannos Papantoniou, makes a strong case for meeting the criteria and conditions for economic and monetary union by 1999 which was initially the final deadline. In November 25, 1997, Yannos
Papantoniou was quoted saying that "We intend to comply with the criterion on the budget deficit in 1998 and on inflation in 1999." (Financial Times, Nov. 25, 1997) On March 16, 1998 news came about Greece's devaluation, which occurred on March 14, 1998 when the drachma was devalued by 13.8% under the ERM (Exchange Rate Mechanism) entry terms which were negotiated between the Greek government and the EU monetary committee. The exchange rate was set to 375 drachma to the Ecu. Using a new reform package set by the EU monetary committee, the new deadline was set on January 1, 2001. The package was intended to account for the effects of devaluation on the inflation rate and budget deficit and thus help in ensuring Greece's entry by the year 2001. The economy minister, Papantoniou thought that the adjustment of the drachma's exchange level was "large enough to bring a significant improvement in competitiveness but not so large as to cause a big jump in inflation." (Financial Times, March 16, 1998) The Greek central bank governor Lucas Papademos, was set to be the defendant of the Greece's central ERM rate, in that he wouldn't allow it to diverge substantially. Following the drachma's entry to the European exchange rate mechanism, the stock market in Greece showed signs of confidence that Greece is on track for joining the "Euro-Club". Furthermore, Greeks stocks rose 7% after drachma's ERM move. Confidence was so big that economic growth is forecasted to beat last year's 3.5%. Signs from every direction demonstrated the general belief that Greece's competitiveness is on the rise. A month after
Greece’s devaluation, the overall performance was outstanding. Greek shares kept rising, suggesting an even faster growth in the future.

Of course, the greatest fears associated with the ERM entry and devaluation are inflation and fear of yet another devaluation, but so far the Greek government does a great job easing expectations for yet another devaluation. So far so good, but the following two years will be critical on Greece’s economic future and opportunities. If Greece misses its chance to make it on time in 2001, the results would be devastating.
IV. The Solow Residual / Capital's share in output

One of the interesting aspects about Solow's research as mentioned before is the effect of technical change on economic growth. Although technical change is treated as exogenous in his model, one can still identify and examine the magnitude of its effects. In 1957 Solow calculated technical change for the United States. (Solow 1957) The "Solow residual", as it has come to be known, can be estimated through a process called growth accounting. The growth accounting progress goes as follows:

We can estimate \( \hat{\phi} \) as \( \frac{\Delta A}{A} \). Thus we have the following growth accounting formula (Mankiw 1994) that will enable us to this:

\[
\frac{\Delta Y}{Y} = \alpha \frac{\Delta K}{K} + (1 - \alpha) \frac{\Delta L}{L} + \frac{\Delta A}{A} \implies (1s)
\]

\[
\frac{\Delta A}{A} = \frac{\Delta Y}{Y} - \alpha \frac{\Delta K}{K} - (1 - \alpha) \frac{\Delta L}{L} \implies (2s)
\]

Where:
Y: Output (GDP)
K: Capital
L: Labor

The above equations will enable me to identify and estimate the magnitudes of the three sources of growth, specifically:

1) The growth due to the change in the amount of capital. \( (\Delta K / K) \)
2) The growth due to the change in the amount of Labor. \( (\Delta L / L) \)
3) The growth due to changes in total factor productivity \( (\Delta A / A - \text{Solow residual}) \)
Unlike Solow, instead of calculating the Solow residuals one by one, year by year, I estimated a regression using equation (1s). That is, I run a time series regression using my available data. I calculated and used the growth rates of GDP to represent the growth in output, the growth rates of gross fixed capital formation to represent the growth in capital and the growth rates of the labor force to represent the growth in the amount of labor. After I estimated the regression I took the resulting residuals, which are the Solow residuals and I plotted them over time.

Figure A. Solow Residual of Greece

![Figure A](image)

Figure A plots the residuals that in fact represent technical change. The estimates are available on a yearly basis and they represent technical change levels for those years. Looking at the graph we can see that technical change started from an all-time high of 11.11%, in 1960, and ended at 2% at the end of
the period examined (1995). The lowest level of technical change observed at the graph was in 1974, right after the 1973 recession and it was equal to -3.53%.

Overall technical change has decreased from 1960 and has been varying around a mean of 2% thereafter. This result is of great importance since the conventional approach in many cross-sectional studies, using Solow theory of growth, like the one performed by Mankiw, Romer and Weil, seems to be setting "g", the level of technological progress, equal to 0.2 (2%). Thus it seems that the estimates of technical change seem to be quite on target for the most recent periods.

The equation used to obtain the residuals also provided me with an estimate of capital’s share (α) in output.

<table>
<thead>
<tr>
<th>Table 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>LS // Dependent Variable is ROGGDP</td>
</tr>
<tr>
<td>Sample (adjusted): 1961 1995</td>
</tr>
<tr>
<td>Included observations: 35 after adjusting endpoints</td>
</tr>
<tr>
<td>ROGGDP = C(1)*ROGI + (1-C(1))*ROGLF</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C(1)</td>
<td>0.437628</td>
<td>0.063065</td>
<td>6.939318</td>
</tr>
<tr>
<td>R-squared</td>
<td>-0.13612</td>
<td>Mean dependent var</td>
<td>0.042407</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>-0.13612</td>
<td>S.D. dependent var</td>
<td>0.03636</td>
</tr>
<tr>
<td>S.E. of regression</td>
<td>0.038756</td>
<td>Akaike info criterion</td>
<td>-6.472798</td>
</tr>
<tr>
<td>Sum squared resid</td>
<td>0.051068</td>
<td>Schwarz criterion</td>
<td>-6.428359</td>
</tr>
<tr>
<td>Log likelihood</td>
<td>64.61111</td>
<td>Durbin-Watson stat</td>
<td>1.329397</td>
</tr>
</tbody>
</table>

Thus, using accounting theory, the capital’s share in income was found to be equal to 0.43, and the result is statistically significant, meaning that throughout the period examined (1960-1995) a 1% increase in the growth of capital would result in a 0.43% increase in the growth of output. Growth accounting assumes
constant returns to scale which means that a 1% increase in the amount of labor would result in a 0.56% (1-α = 0.562372) increase in the growth of output.
V. Results: Model Application / Estimated Regressions and Outputs

Before I talk about the estimated regressions and outputs, I will provide some important preliminary notes. First of all, I will investigate whether the data supports the Solow model's predictions concerning the determinants of the standard of living. Specifically I will examine whether high saving rates have a positive effect on real income and whether high values of $n + g + \delta$ have a negative effect on real income. Secondly, when Mankiw, Romer and Weil did their cross-country application of the model they had to make assumptions about the differences among different countries, such as different resource endowments, climate, institutions, etc. In contrast, in applying the model to Greece I have country-specific, time-series data that helps estimate variables so there is no need for such assumptions. Thirdly, it is important to note here that in the cross-sectional studies examined the conventional approach seems to be setting the rate of technical change ($g$) equal to 0.02 and the rate of depreciation ($\delta$) equal to 0.03. I will do the same since according to my previous analysis of the Solow residual, I essentially found the average rate of technical change to be equal to 0.02, at least for the last, most recent years. I will also do the same for the depreciation rate since it is quite hard to estimate and I don't believe I have the right data to do so. Finally, saving ($s$) and the rate of population growth ($n$) are assumed to be constant under the Solow model assumptions. In my modified model both the rate of saving and population growth will become
active variables in the estimation progress since data for those variables are available. I will apply the textbook Solow model by applying the following:

\[
\ln \left( \frac{Y_t}{L_t} \right) = \ln A_0 + gt + \left( \frac{\alpha}{1 - \alpha} \right) \ln(s_t) - \left( \frac{\alpha}{1 - \alpha} \right) \ln(n_t + \delta + g) \quad (7)
\]

Under the assumptions of the model the factors of production are paid their marginal products, therefore the model predicts the signs but also the magnitudes of the coefficients on saving and population growth, that is the magnitudes are predicted to be equal and the signs are predicted to be opposite.

Capital's share was estimated to be \( a = 0.437628 \), therefore if the model is correct the elasticities of \( Y/L \) with respect to saving \( s \) and \( (n + \delta + g) \) will be approximately \( \alpha/(1-\alpha) = 0.778182 \) and \(-0.778182\) respectively. If my OLS estimates of the coefficients are substantially different from these values, then I can reject the joint hypothesis that both the Solow model and my identifying assumption are correct. Equation (7) basically represents my empirical specification for this model and I can estimate it using ordinary least squares method.

i) Data and Samples:

All data collected for Greece are from the Haver Databases, (© Haver Analytics, inc). All variables describing the different aspects of the Greek economy are obtained from this database. Now in estimating the regressions the following variables are included:
Y is measured annually and in million of 1990 drachma, as real GDP.

\[ s = \frac{I}{Y} \]
is measured annually and in million of 1990 drachma as the average share of real investment in real GDP.

n is measured annually and in thousands as the average rate of growth of the labor force

g is measured by the Solow residual (previously obtained data)

ii) Analysis of the estimation process:

a) Simple OLSQ Estimation

The unconstrained equation to be estimated is the following:

\[
\ln \left( \frac{Y_t}{L_t} \right) = \beta_0 + \beta_1 \ln \left( \frac{I_t}{Y_t} \right) - \beta_2 \ln (n_t + \delta + g) + \epsilon_t
\]

As said previously \( \delta + g \) is assumed here to equal 0.05 (Javier Andrés; Rafael Doménech; César Molinas, 1996), since it is the conventional approach. The following is the OLSQ estimation output from running the above equation:

**Equation 1: Unconstrained Equation (not corrected for AR(1) disturbances):**

LS // Dependent Variable is LOG(C174GDP1990/C174LF)

Sample(adjusted): 1961 1995

Included observations: 35 after adjusting endpoints

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>1.752729</td>
<td>0.743213</td>
<td>2.358312</td>
<td>0.0246</td>
</tr>
<tr>
<td>LOG(C174LC/C174GDP1990)</td>
<td>-0.667644</td>
<td>0.282276</td>
<td>-2.365217</td>
<td>0.0242</td>
</tr>
<tr>
<td>LOG(ROGLF+.03+.02)</td>
<td>0.579253</td>
<td>0.172721</td>
<td>3.353697</td>
<td>0.0021</td>
</tr>
</tbody>
</table>
| R-squared                 | 0.473697    | Mean dependent var | 0.909034
| Adjusted R-squared        | 0.440803    | S.D. dependent var | 0.363149
| S.E. of regression        | 0.271561    | Akaike info criterion | -2.525322
| Sum squared resid         | 2.359849    | Schwarz criterion   | -2.392006
| Log likelihood            | -2.469715   | F-statistic        | 14.40076
| Durbin-Watson stat        | 0.592434    | Prob(F-statistic)  | 0.000035      |

40
As one can see from the results, the coefficients are indeed opposite in sign but the signs are interchanged. That is, they are reversed since the sign on saving is negative when in fact it is supposed to be positive whereas the sign for \((n + \delta + g)\) is positive when in fact it was supposed to be negative. As far as the magnitudes are concerned they appear to be somewhat close to being equal but deviate a lot from the pre-estimated ones \((+/ - 0.778182)\) but. Although both estimates of the coefficients are statistically significant, the Durbin-Watson statistic signals that the problem of autocorrelation exists since it is not equal or near to 2.

Autocorrelation exists since the error terms are autocorrelated because:

\[
\ln A_t = \ln A_0 + gt \\
(\beta_0) \quad (\epsilon_t)
\]

In order to correct for autocorrelated disturbances I will use an AR(1) process next and repeat OLSQ estimation and use Hypothesis testing (Wald test) where:

\[
H_0 : \beta_1 = -\beta_1
\]

Both the estimation output and the Wald test are presented below:

**Equation 2: Correcting for Autocorrelated Disturbances**

Sample(adjusted): 1962 1995

Included observations: 34 after adjusting endpoints

Convergence achieved after 7 iterations

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>1.644287</td>
<td>0.175131</td>
<td>9.38887</td>
<td>0</td>
</tr>
<tr>
<td>LOG(C174IC/C174GDP1990)</td>
<td>0.208924</td>
<td>0.075645</td>
<td>2.761923</td>
<td>0.0097</td>
</tr>
<tr>
<td>LOG(ROGLF+.03+.02)</td>
<td>-0.002116</td>
<td>0.016987</td>
<td>-0.124555</td>
<td>0.9017</td>
</tr>
<tr>
<td>AR(1)</td>
<td>0.925891</td>
<td>0.014167</td>
<td>65.35584</td>
<td>0</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.9933012</td>
<td>Mean dependent var</td>
<td>0.934715</td>
<td></td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.992313</td>
<td>S.D. dependent var</td>
<td>0.3348</td>
<td></td>
</tr>
<tr>
<td>S.E. of regression</td>
<td>0.029354</td>
<td>Akaike info criterion</td>
<td>-6.94655</td>
<td></td>
</tr>
<tr>
<td>Sum squared resid</td>
<td>0.025849</td>
<td>Schwarz criterion</td>
<td>-6.766978</td>
<td></td>
</tr>
<tr>
<td>Log likelihood</td>
<td>73.84745</td>
<td>F-statistic</td>
<td>1421.009</td>
<td></td>
</tr>
<tr>
<td>Durbin-Watson stat</td>
<td>1.746796</td>
<td>Prob(F-statistic)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Inverted AR Roots</td>
<td>0.92</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Looking at the estimation output above one can immediately notice the improved near-two Durbin-Watson statistic, which shows that the autocorrelation problem has been corrected. Next looking at the estimates of the coefficients we see that although the coefficients have opposite sign as predicted, the magnitudes still remain substantially different from one another. The magnitudes are also significantly different from 0.778182, which was the pre-estimated of the coefficients based on capital’s share. Further more, only one of the coefficients is statistically significant, the one for saving. The R-squared appears to be extremely high but that is irrelevant because of the AR(1) process.

\[
\text{Wald Test:} \quad \text{Equation: SOLOW2} \\
\text{Null Hypothesis: } C(2) = -C(3) \\
\begin{array}{l|c|c}
\text{F-statistic} & 7.18935 & \text{Probability} \quad 0.011803 \\
\text{Chi-square} & 7.18935 & \text{Probability} \quad 0.007334 \\
\end{array}
\]

According to the hypothesis testing output above, we reject the null hypothesis that the magnitudes of the coefficients are equal in magnitude and opposite in sign.

Next I will estimate the following restricted equation:

\[
\ln \left( \frac{Y_t}{L_t} \right) = \beta_0 + \beta_1 \ln \left( \frac{I_t}{Y_t} \right) - \beta_1 \ln (n, + \delta + g) + \varepsilon_t
\]

The restricted equation will enable me to impose the restrictions that the coefficients are equal and opposite in sign, in order to further examine the model and whether it is applicable to the Greek economy. The estimation output for the above equation follows, the method used is Rho-differencing.
Equation 3: Restricted Equation

LS // Dependent Variable is LOG(C174GDP1990/C174LF)
Sample(adjusted): 1962 1995
Included observations: 34 after adjusting endpoints
Convergence achieved after 3 iterations

\[
\text{LOG}(\text{C174GDP1990}/\text{C174LF}) = C(3) \times \text{LOG}(\text{C174GDP1990(-1)}/\text{C174LF(-1)}) + C(1) \times (1-C(3)) + C(2) \times (\text{LOG}(\text{ROGLF+0.02}) - C(3) \times \text{LOG}(\text{ROGLF(-1)}+0.03+0.02))
\]

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C(3)</td>
<td>0.91593</td>
<td>0.015749</td>
<td>58.15763</td>
</tr>
<tr>
<td>C(1)</td>
<td>1.291865</td>
<td>0.099773</td>
<td>12.94811</td>
</tr>
<tr>
<td>C(2)</td>
<td>0.011754</td>
<td>0.018456</td>
<td>0.636858</td>
</tr>
</tbody>
</table>

R-squared: 0.991305
Mean dependent var: 0.934715
Adjusted R-squared: 0.990744
S.D. dependent var: 0.3348
S.E. of regression: 0.032211
Akaike info criterior: -6.786814
Schwarz criterion: -6.652135
Log likelihood: 70.13193
F-statistic: 1767.103
Prob(F-statistic): 0

According to the above output, C(2) basically represents the magnitude of the restricted coefficients, but that magnitude is significantly different in theory from the one observed. C(3) represents Rho in this equation.

b) Estimation using the Solow residual

Once again, like before, I will start with the estimation of the unconstrained equation, only this time \( g \) will also not remain constant, along with \( s \), \( g \) will now become a time-series variable. It is also important to notice, that following the conventional approach, \( \delta = 0.03 \) will remain set at that value. Maybe, including the estimate such equations will provide an insight on modeling the Greek economy. Below follows the related OLSQ estimation output for this equation:
Equation 4: Unconstrained Equation (Solow Residuals)
Sample(adjusted): 1961 1995
Included observations: 33
Excluded observations: 2 after adjusting endpoints

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>-0.5688</td>
<td>0.42951</td>
<td>-1.3243</td>
<td>0.1954</td>
</tr>
<tr>
<td>LOG(C174IC/C174GC)</td>
<td>-0.9305</td>
<td>0.284</td>
<td>-3.2764</td>
<td>0.0027</td>
</tr>
<tr>
<td>LOG(ROGLF+0.03+S)</td>
<td>-0.1033</td>
<td>0.09785</td>
<td>-1.0556</td>
<td>0.2996</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.30933</td>
<td></td>
<td></td>
<td>0.94419</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.26328</td>
<td></td>
<td></td>
<td>0.3374</td>
</tr>
<tr>
<td>S.E. of regression</td>
<td>0.28959</td>
<td></td>
<td></td>
<td>-2.392</td>
</tr>
<tr>
<td>Sum squared resid</td>
<td>2.51583</td>
<td></td>
<td></td>
<td>6.71792</td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-4.3562</td>
<td></td>
<td></td>
<td>0.00388</td>
</tr>
<tr>
<td>Durbin-Watson stat</td>
<td>0.1216</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Unfortunately, once again the output is not consistent with theory. The problem being primarily autocorrelation for the same reason described above, he is once again present and visible from the low Durbin-Watson statistic. Furthermore the estimated coefficients are neither opposite in sign, nor equal in magnitude.

Thus before I move on into any more detail, first the autocorrelation must be accounted for. So an AR(1) process will take place plus a hypothesis test (Wald Test) will be examined.

Equation 5: Correcting for autocorrelated disturbances
LS /// Dependent Variable is LOG(C174GDP1990/C174LF)
Sample(adjusted): 1964 1995
Included observations: 30
Excluded observations: 2 after adjusting endpoints
Convergence achieved after 6 iterations

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>1.86554</td>
<td>0.16363</td>
<td>11.4012</td>
<td>0</td>
</tr>
<tr>
<td>LOG(C174IC/C174GC)</td>
<td>0.33793</td>
<td>0.07715</td>
<td>4.38008</td>
<td>0.0002</td>
</tr>
<tr>
<td>LOG(ROGLF+0.03+S)</td>
<td>0.01747</td>
<td>0.00712</td>
<td>2.45225</td>
<td>0.0212</td>
</tr>
<tr>
<td>AR(1)</td>
<td>0.91587</td>
<td>0.01361</td>
<td>67.2771</td>
<td>0</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.98285</td>
<td></td>
<td></td>
<td>1.008393</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.99202</td>
<td></td>
<td></td>
<td>0.296145</td>
</tr>
<tr>
<td>S.E. of regression</td>
<td>0.02377</td>
<td></td>
<td></td>
<td>-7.3549</td>
</tr>
<tr>
<td>Sum squared resid</td>
<td>0.01469</td>
<td></td>
<td></td>
<td>-7.16807</td>
</tr>
<tr>
<td>Log likelihood</td>
<td>71.7553</td>
<td></td>
<td></td>
<td>1202.961</td>
</tr>
<tr>
<td>Durbin-Watson stat</td>
<td>1.41425</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Inverted AR Roots</td>
<td>0.92</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
According to the above estimation output, the auto-correlation has somewhat improved, looking at the Durbin-Watson statistic, it has increased and has become closer to two. The estimated coefficients, although both statistically significant, they still don’t comply with theory, since the coefficients are not opposite in sign and equal in magnitude. Looking at the hypothesis testing below, we once again reject the null hypothesis that the estimated coefficients are equal and opposite in magnitude.

<table>
<thead>
<tr>
<th>Wald Test:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equation: SOLOWRES2</td>
</tr>
<tr>
<td>Null Hypothesis:</td>
</tr>
<tr>
<td>C(2) = -C(3)</td>
</tr>
<tr>
<td>F-statistic</td>
</tr>
<tr>
<td>Chi-square</td>
</tr>
<tr>
<td>Probability</td>
</tr>
<tr>
<td>Probability</td>
</tr>
</tbody>
</table>

In trying to run a restricted equation for the one using a time series of Solow residual estimates negative logs and thus I was not able to estimate it.

Although the Solow model was not successfully applied to the Greek economy the results can be looked at independently of Solow’s theory. Looking at equation 2 independently one can see that after correcting for autocorrelated disturbances the results can be quite interesting. According to equation 2 a one percent increase in the investment rate will lead to approximately a 0.20 percent increase in income per capita and the result is obviously statistically significant from the t-statistic observed. Furthermore we can see that a change in the combined rates of population growth, depreciation and technological progress have no effect on income per capita since the coefficient is not statistically
significant from zero. Using the solow residual approach, looking at equation 5, autocorrelation disturbances appear to be still present but the both coefficients are statistically significant from zero. According to equation 5 then a one percent increase in the investment rate will lead to an approximately 0.34 percent increase in the income per capita level. Also once again any change in the combined rates \((n + \delta + g)\) will cause virtually no change in the level of income per capita.
VI. Limitations & Explanations

In trying to comprehend the possible reasons why the model didn’t work as well as I expected, many explanations can be given to the limitations observed by using MRW’s methodology:

1) Steady-state rule:

Probably the best reason, to my understanding as far as why the model didn’t work, might be the fact that the Greek economy, throughout the period examined hadn’t fully reached the steady-level of capital till the most recent periods. The steady-state of capital is that level of capital where there exists an equilibrium, no incentive for any change, it represents the long run equilibrium of the economy. According to Solow’s theory every economy will end up with a certain steady state of capital, regardless of the amount of capital it will begin with. It is a part of the assumptions of the Solow model though that an economy must be at the steady state. This might help explain why the model didn’t work as planned. I strongly believe though that the Greek economy has reached its steady state of capital for the last of the period examined. Looking back at the Solow residuals I’ve estimated in Figure A, one can see the residuals, amounts of technical change decreasing progressively and ranging around a mean of 0.02 for the most recent periods starting late 70s, early 80s. The mean 0.02, also happens to be the conventional setting for “g” in cross-country empirical studies of the Solow model. Also looking at the Gross Fixed Capital Formation we can observe
fixed capital to "form" by progressively increasing in amounts up to a level, a mean around which capital formation ranged over, starting from about 1973 up to the end of the period examined 1995. We can also observe in Figure 1b, the growth rates of GDP where, the growth rates started to level off with the progress of time. In part this also demonstrates the approach to a steady-state in output since the growth rates tend to remain constant when the steady-state level of capital has been reached. Only alternations in the rate of population growth, the rate depreciation and in the rate of technical change can change an economy's structure, since such alternations will establish a new steady-state level of capital.

2) Is Greek Economic Structure Appropriate?

The second reason I can think of why Solow's model assumptions and theory didn't apply is because the structure of the Greek economy might not be appropriate. That is to say, maybe there is something peculiar about the Greek economy been a developing country, on the edge of becoming developed. Also, perhaps the Greek economy is structured in such a different way that the original textbook Solow model is not applicable. There can be a crucial type capital that might be of great importance in determining the variation in income per capita for the Greek economy.
3) Solow’s theory is not perfect

Maybe Solow’s theory isn’t that perfect, since further studies that stemmed from his original body of thought have tried to augment his model. Maybe there are more variables needed to explain the variations in income, such as what Mankiw, Romer and Weil introduced in their paper, changes in income due to increases in human capital, which in their study proved to explain more of the cross-country variation in income. I would have tested the Solow model but the available education data didn’t allow it, besides it can be quite hard and in fact impossible to find a variable that would fully determine human capital in theoretical meaning.

4) Constant Returns to scale

The assumption of constant returns to scale makes math easier but it proclaims that variations in output are due to two and only two factors of production, labor and capital. This cannot be a very realistic assumption since it broadly defines the factors of production. Besides, GDP also represents income. For the Greek economy which an import based economy with a great trade deficit, income can be generated without the use of labor and capital.

5) Labor augmenting technology?

In Solow’s theory technology is viewed purely as labor related and thus augmenting. This assumption excludes other forms of technology that can
potentially alter economic growth within a country. For instance, technology
should also be capital augmenting since we live in a world of radical
 technological progress, where computers and technologies come and go due to
the great advances in computer science. New technologies that are introduced
can potentially make radical changes in the production process. Also sometimes
technology can have negative effects on the use of labor. For instance,
automobile companies no longer use labor to manufacture cars, since employees
in such companies are replaced by robotics. Such adversary effects are not
accounted by Solow’s theory.

6) Solow Model – Cross Country Model

Perhaps Solow’s Model should be strictly used for cross-sectional studies,
since in order to alter the model into a time series model I had to modify
assumptions that may have caused inconsistencies that complicated the results of
the model. For instance saving had to become a time-series variable, instead of a
constant and thus exogenously determined variable.

7) High trade deficit

Finally, I believe that the trade deficit had a lot to do with the poor
performance of my model. A large trade deficit for an economy can cause
complications in the application of Solow’s theory. That is, the large trade deficit
for Greece denotes the dominance of imports over exports. A trade deficit
though does not comply with Solow’s theory and assumptions because it means
that a large portion of the Greek output, as measured by GDP, is produced
abroad by the use of foreign factors of production.
VII. Conclusions / Lessons Obtained

This study has proved that the Solow model application to the Greek economy is not possible. The methodology behind the work of Mankiw, Romer and Weil appears to be inadequate or perhaps inappropriate for the Greek economy. The greatest limitations in applying Solow's theory to the Greek economy is the fact that the Greek economy was not at a steady state level of capital for the period examined and the large trade deficit which dominated the period examined did not comply with Solow's assumptions.

The Solow residuals were successfully computed using growth accounting theory. They also prove that the Greek economy hadn't reached the steady-state level of capital throughout the period examined. If at all, the Greek economy must have reached the steady-state level of capital for the second half of the period examined. Other variables that support this conclusion are the Gross Domestic Product and the Fixed Gross Capital Formation.

The Greek economy is an import-based country due the trade deficit visible throughout the period examined. This fact can also be considered a limitation to the application of Solow's theory since a large percentage of the income obtained each year is due to the imports sold within the country. This means that although imports contribute to increases in income, they should not be accounted as part of the Greek output each year. Therefore GDP for the Greek economy is an inaccurate measure of Greek output. A large part of the output is therefore produced by other countries, but included in Greece's GDP.
The Greek economy is approaching critical times and EMU is a dream that needs to be realized if Greeks want to observe periods of healthy economic growth in the near future. In order to achieve their goals and become a member of the EMU Greece has to maintain low, and in fact decrease even more inflation while it has to maintain low deficits.

Following Solow’s theory if Greece wants to increase income per capita in the future it has to save today. As Solow demonstrated, periods of high investment activities (saving) might suppress consumption and the well-being of Greeks today but will induce periods of high consumption and well-being in the future. As is evidenced by the regression outputs (equations 2 and 5 in section V) increases in the investment rates have a positive effect on income per capita. That is the regression outputs obtained suggest increases in the investment rate as an indisputable policy for increases in income per capita and thus for promoting economic growth in Greece. I believe I have learned a great deal about Solow’s theory and its application to economies around the world. I also learned a lot about the overall structure of the Greek economy, which is quite interesting and controversial.

Greece is an emerging and I strongly agree with this notion. Greece has great potential to improve since it has a lot of resources that it hasn’t fully taken advantage. If Greece wants to experience higher growth rates it will have to decrease its deficit. The large trade deficit shows the lack of Greece’s confidence in its own products. The deficit should be greatly reduced in the future since it
appears to be one of the biggest problems of Greece and policy makers in Greece should attempt to reduce it. Also the industry level in Greece is underdeveloped and needs to be examined and needs to be further developed. Finally Greece has to increase investment and when I say investment I mean investment in Greece and its industry.

Economic growth is a subject of the utmost importance for every economy. Suggestions for future research are to develop a country-specific model, based on Solow’s theory, one that would explain the patterns of growth and provide policymakers in various countries with tools for implementing economic policy.


