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Sweden From a Neoclassical Perspective

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Abstract

Since the mid-1970s, detrended output per working age person in Sweden has declined. In this paper, the sources of the decline are investigated using the Neoclassical growth model under the assumption of perfect foresight. The model is quite successful in accounting for changes in output per working age person during the period 1976-2004, suggesting that TFP can account for a significant share of the changes in output. The model is less successful, however, in accounting for changes in both capital and labour. Capital inputs are underestimated over most of the period while labour inputs are overestimated, especially during the latter years. In particular, the divergence of labour inputs from those observed in the data appears to be persisting, suggesting that a structural shift in the labour market has taken place. Further research is directed towards including extensions to the model in order to account for the observed discrepancies, as well as modelling the underlying sources of TFP.

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1. Introduction

The Neoclassical framework has been used extensively in the past in describing macroeconomic phenomena. Only recently, however, has the model been used in an attempt to explain depressions. Cole and Ohanian (1999) first applied the model when studying the Great Depression in the United States. Since then, a full volume has been produced containing similar studies on a number of depressions in various countries.[1] The general approach of these studies is to compare actual data to the results produced by the model.

In brief, the model assumes that changes in output per working age person can be decomposed into changes in labour inputs, capital inputs and technological factor productivity (TFP). By accounting for the differences between the model and actual data, the aim is to decipher which components – labour, capital or TFP – are consistent with the predictions of the model and which components have either fallen short of or exceeded the outcomes that the model predicts. Once these components are established, further research can be directed towards extending the model in order to account for actual data more accurately and thereafter, studying in closer detail the policies affecting those components that resulted in the decline in output.

Changes in real Gross Domestic Product (GDP) per working age person (N) is used as the measure for economic growth in order to maintain consistency with the theoretical economy, where it is assumed that every working age person is capable of contributing to output. The model relates this measure to a generally accepted trend growth rate, which is assumed to be the rate at which all economies would grow in steady state[2]. This rate essentially represents the stock of world knowledge growing smoothly over time, which is not attributable to a specific country (Kehoe and Prescott, 2002). It is estimated to be 2% per year, which corresponds to the growth in real GDP per working age person of the United States during the period 1920-2000. This value is used because the U.S. is a large, stable and diverse economy and was the industrial leader during that time period.

In this paper, the same methodology as described above is used to study the Swedish economy. Sweden was chosen because despite the "Swedish model" performing successfully post World War II, the high growth rate came to an end at some point during the mid-seventies. Since, then and until the recovery after the crisis of the 1990s, economic growth has been slow, which is why focus has been kept on Sweden from a long-term perspective. Furthermore, an analysis on the Swedish economy of this type using the Neoclassical framework has not previously been carried out, contributing to the originality of this study.

Figure 1 in Appendix A plots an index of detrended (by 2%) output per working age person for Sweden during the period 1950-2004. The figure depicts a significant decline in growth from the mid-

[1] See Kehoe and Prescott (2002) for a comprehensive description of the methodology as well as of the papers included in the volume.

[2] Where "steady state refers to a condition when key variables are not changing", (Mankiw, 2003).

seventies onwards compared to the strong increase that took place during the preceding years. This decline is interesting as it signifies that Sweden has actually lost in terms of productivity relative to a standard measure of growth (i.e., the reference stable economy of the U.S.) during the latter years.

In previous studies, they define a depression according to whether a substantial deviation of growth in real GDP per working age person from the trend growth rate has taken place. More specifically, a given time period is defined as a depression if the following two conditions are met (Kehoe and Prescott, 2002):

1) The deviation must be sufficiently large – at least 20% below trend.

2) The deviation must occur rapidly – detrended output per working age person must fall at least 15% within the first decade of the depression

These studies then proceed by illustrating that the economy in question has experienced a depression according to the conditions above. In observing Figure 1 of the Swedish economy, it is evident that a depression satisfying these conditions has not taken place. Detrended output per working age person has fallen at most 15% over a period of almost 20 years. Despite the decline not strictly adhering to the above conditions, however, it does reveal a persistent downward trend and one worth investigating with the Neoclassical framework. It is this observation that forms the premise for this thesis.

More formally, the aim of this investigation is to:

1) Apply the Neoclassical methodology used in such papers included in the volume "Great Depressions of the 20th Century" to the Swedish economy over a long-term perspective.

2) Compare the model with actual outcomes of the economy during the period we have modelled; and

3) Establish which underlying components have caused the discrepancies between model and actual outcomes.

The study will continue as follows. Section 2 provides a brief summary of the relevant literature. In Section 3, a growth accounting exercise is carried out using data on GDP, population, capital stocks, employment and total hours worked. This will provide the basis for the comparison with the model. Section 4 outlines the assumptions of the Neoclassical growth model, calibrates the necessary parameters and describes how the model is solved. Finally, in Section 5 the results are presented as well as a comparison with our growth accounting exercise, and in Section 6, conclusions are drawn and suggestions for future research are provided.

2. Literature Overview

Most of the studies reviewed in this overview are included in the volume "Great Depressions of the 20th Century", compiled by Kehoe and Prescott (2002). The volume includes studies on the great depressions in Canada, France, Germany, Italy and the United Kingdom during the interwar period, and in Argentina, Chile and Mexico during the 1980's. Also included are two studies not often classified as "great" depressions but are still somewhat regarded as depressions. These refer to Italy during the interwar period and Japan during the 1990's. Another study of relevance that is not included in the volume applies the model to New Zealand and Switzerland (Kehoe and Ruhl, 2003) from the 1970s onwards.

Assumptions regarding expectations

Although the same basic model is used in all these studies, different assumptions are made regarding expectations and uncertainty. Some papers assume that economic agents have perfect foresight. In other words, technological progress in the economy is known with absolute certainty (i.e. TFP is exogenous). Making this assumption is appealing as it is then possible to use standard numerical methods to solve the model. Alternatively, it can be assumed that economic agents form their expectations about the future in a rational way. Models incorporating this assumption prove more complicated to solve. A method based on the stochastic model in Kydland and Prescott (1982) can be used and computed using the numerical methods described in Hansen and Prescott (1995). Since the perfect foresight assumption provides simplicity to an already complicated analysis, this thesis will make use of this assumption.

The affect of the perfect foresight assumption on the outcome of the model has been discussed in the literature. Hayashi and Prescott (2002), for instance, argue that the perfect foresight assumption suffices for the purpose of their paper on Japan, as the key predictions of the model would have been more or less the same if expectations had been modelled in any rational way. On the other hand, the study of the Argentine economy, which applies the model using both the perfect foresight and rational expectations assumptions, reveals significant discrepancies in the results when applying each of the assumptions. The authors reason that when studying economies that are subject to substantial productivity shocks, the perfect foresight assumption will undoubtedly provide a poor approximation compared to the model with rational expectations. This is because households in the model assume future rental prices of capital to be similar to their historical average, and therefore act in such a way as to smooth consumption. If the household, on the other hand, knew that the economy would be hit by a large jump in productivity in the future, it would not deplete savings as quickly in order to smooth consumption but rather save more in order to reap the higher returns on capital in the future. Given that the Swedish economy is being studied from a long-run perspective, and the premise of the thesis lies on the observation of a long and slow decline in output during the observed time period, we would expect the perfect foresight assumption to be sufficient for the purpose of this thesis. It should be noted, however, that the crisis during the 1990s does depict one exceptional occasion where output has fluctuated substantially, suggesting that the perfect foresight assumption may not be sufficient during

this period. Despite this possibility, TFP shocks will be assumed to be exogenous and any shortcomings of the perfect foresight assumption will be referred to future investigation.

Summary of the relevant literature

For a brief summary of the findings of previous studies including the assumptions they make and level of success of the model, refer to Appendix C. For the relevance of this paper, this section will focus on the studies of New Zealand and Switzerland, Japan, Argentina, and Mexico and Chile, as most of these studies incorporate a somewhat long-term perspective (inline with this thesis), and all of them use the perfect foresight assumption that will be used in the application to the Swedish economy.

Kehoe and Ruhl's investigation of New Zealand and Switzerland (2003) reveals that the perfect foresight assumption provides a relatively sound basis for their model economies. Both economies experience falls in productivity affecting economic growth, which is captured by the model. The discrepancy between model and actual data that does exist is a result of the model not capturing a fall in hours worked. Despite this shortcoming, the model is regarded quite successful and the study concludes that changes in TFP can account for the depressed state of both economies from the 1970s onwards.

In Hayashi and Prescott's study of the Japanese economy (2002), the model also proves to be successful in tracing actual changes in output during the 1990s. In addition, this study includes the affects of varying workweek lengths and tax rates, which allows the model to incorporate changes in labour inputs (hours worked) and incentive schemes (taxes) in order to better account for the persistence of low economic growth.

Bergoeing *et al'*s study (2002) of Chile and Mexico during the 1980's provides results similar to the above. They start with the basic model, which is quite successful in comparison with actual data. The model is even more successful, however, when taxes are taken into account, as in Hayashi and Prescott's study. They conclude that changes in TFP can account for almost all changes in output. As opposed to merely theorising about the potential causes for the low level of TFP growth, the authors attempt to develop a more quantitative model to investigate the underlying causes of fluctuations in TFP.

Thus far, the Neoclassical model with the perfect foresight assumption has proved to be quite successful. Kydland and Zarazaga's study (2003) of the Argentine economy during the 1980s, however, does provide an illustration of the discussion above regarding the shortcomings of the perfect foresight assumption. When the authors assume perfect foresight, their results bare little resemblance to actual data. When expectations are modelled in a rational manner, their results prove to be highly successful.

In summary, the previous literature implies that the Neoclassical framework has been rather successful in accounting for changes in output, particularly when fluctuations in productivity have been limited and when additions to the model are incorporated that further account for changes in factor inputs.

3. Growth Accounting[3]

We begin by evaluating how changes in different factors affect changes in output. We base this growth accounting exercise on the Neoclassical framework in order to maintain consistency with our model. Aggregate technology is represented by the standard Cobb-Douglas function, which describes the maximum output that can be produced given the quantity of inputs:

$$Y_t = A_t K_t^{\theta} (Eh)_t^{(1-\theta)} \tag{1}$$

Y_t is output measured as real GDP, A_t is TFP, E_t is employment, h_t is the fraction of the time endowment devoted to work activities[4], θ is the capital share of output, and K_t is the capital stock.

TFP is derived as a residual by solving A_t for K_t, E_t, h_t and Y_t in equation (1). When this value of TFP fluctuates, the source of its fluctuation can be attributed to two different components: trend growth and TFP growth. As discussed previously, trend growth is assumed to be 2% and this parameter is represented by γ. TFP growth, on the other hand, is specific to the given economy and is determined by its institutions.

By dividing (1) by the working age population, N_t, and taking the natural logarithms, we obtain the following expression:

$$\ln \frac{Y_t}{N_t} = \frac{1}{1-\theta} \ln(A_t) + \frac{\theta}{1-\theta} \ln \frac{K_t}{Y_t} + \ln \frac{(Eh)_t}{N_t} \tag{2}$$

The individual terms in expression (2) provide the basis for the graphical representation of our growth accounting against which we plot and compare the results of our model. The first term on the right-hand side is the TFP component; the next term is the capital component, which comprises the capital-output ratio; and the last term is the labour component, which represents the share of total time devoted to working activities (henceforth denoted "hours worked"). In order to represent expression (2) in a more quantitative manner, it can be decomposed into average annual growth rates of output per working age person over a certain number of years, (s):

$$\frac{\ln(Y_{t+s}/N_{t+s}) - \ln(Y_t/N_t)}{s} = \frac{1}{1-\theta} \frac{\ln(A_{t+s}) - \ln(A_t)}{s} + \frac{\theta}{1-\theta} \frac{\ln(K_{t+s}/Y_{t+s}) - \ln(K_t/Y_t)}{s} + \frac{\ln((Eh)_{t+s}/N_{t+s}) - \ln((Eh)_t/N_t)}{s} \tag{3}$$

[3] Refer to Appendix D for a complete description of the data used in the growth accounting exercise and model that follows.

[4] The calculation of h_t assumes that the maximum number of work hours available is 15 per day, for 7 days a week and 52 weeks a year. Therefore: h_t = (Total hours worked) / (Employment x 15 x 7 x 52).

We present the results of this decomposition in the first column of Appendix B. Our growth accounting covers the period 1976-2004, since this is the period that will be modelled in Section 4.[5] The sub periods have been chosen by visual inspection of Figure 1 in Appendix A with the intention of grouping periods of similar growth together. The first sub-period (1976-1983) exhibits a fall in output followed by a small recovery (1984-1989), and then the crisis of the 1990s, followed by another recovery during the latter half of the 1990s and early 2000s.

During 1976-1983, GDP grew on average 0.282% per year, of which 0.168% can be accounted for by growth in the TFP component. Despite the remaining difference being small, the labour and capital components have still changed rather significantly. The capital component grew on average 0,945% per year and the labour component fell 0.832%. During 1984-1989, TFP and GDP grew faster than trend growth, while labour and capital fluctuated by less than 1% and practically offset each other. During 1990-1997, despite TFP growing at around 0,727% per year on average, GDP stagnated as a result of a drop in the labour component. This can be expected since the period coincides with the crisis of the 1990s. The subsequent period displays a recovery from the crisis and reports faster-than-trend growth of TFP of 2,841%, which is offset by capital and labour leaving GDP growth near trend.

This growth accounting exercise has demonstrated the importance of productivity shocks in accounting for GDP growth. Contributions from capital and, in particular, labour, are not insignificant, however. The aim of our model in Section 4 is to investigate to what extent these exogenous changes in productivity can account for the findings of our growth accounting exercise.

[5] Section 4.2 provides a more detailed discussion of how the modelling period was determined.

4. The Neoclassical Growth Model

4.1 Overview and assumptions of the model

The model economy comprises two types of agents – households and firms. The representative household maximises its discounted lifetime utility by making consumption-savings and labour-leisure decisions. The representative firm competes in a perfectly competitive market and maximises output by choosing labour and capital inputs.

Beginning with the firm and in accordance with our growth accounting exercise, we use the Cobb-Douglas function to describe a firm's production possibilities:

$$Y_t = AK_t^{\theta}(Eh)_t^{1-\theta} \tag{4}$$

From (4), the expressions for wages and rental prices can be derived by computing the marginal products with respect to labour and capital respectively:

$$\frac{\partial Y_t}{\partial (Eh)_t} = MP(Eh)_t = w_t = (1-\theta)A_t K_t^{\theta}(Eh)_t^{-\theta} = \frac{(1-\theta)Y_t}{(Eh)_t} \tag{5}$$

$$\frac{\partial Y_t}{\partial K_t} = MPK_t = r_t = \theta A_t K_t^{\theta-1} L^{1-\theta} = \frac{\theta Y_t}{K_t} \tag{6}$$

These are the two first-order conditions for the firm when maximising output. In keeping with the decision of the firm, the capital stock is described by the following relationship:

$$K_{t+1} = (1-\delta)K_t + X_t \tag{7}$$

X_t is investments in period t and δ is the depreciation rate. Expression (7) implies that the capital stock in the next period is equal to the sum of investments and the capital stock (after depreciation) in the current period.

Focusing on the representative household, it is assumed that the following expression represents preferences:

$$\sum_{t=0}^{\infty} \beta^t (1+\eta)^t (U_t(c_t)) \tag{8}$$

β is the time discount parameter, η is the annual growth rate of the working age population and $U_t(c_t)$ is the household utility function. We use the same utility function as in Kydland and Zarazaga (2003), which is given by:

$$U_t(c_t) = \frac{(c_t^{\alpha}(1-l_t)^{1-\alpha})^{1-\sigma}}{1-\sigma} \tag{9}$$

Here, c_t describes consumption per working age person, α is the elasticity of substitution parameter for the household's consumption decision, l_t is the fraction of the time endowment devoted

to working activities[6], and σ is the coefficient of constant risk aversion. Substituting $U_t(c_t)$ into expression (8), we obtain the following:

$$\sum_{t=0}^{\infty} \beta^t (1+\eta)^t \frac{\left[c_t^{\alpha}(1-l_t)^{1-\alpha}\right]^{1-\sigma}}{(1-\sigma)} \tag{10}$$

Households maximise this function each period subject to their budget constraint:

$$c_t = w_t l_t + (1 + r_t - \delta)k_t - k_{t+1} \tag{11}$$

This implies that consumption per household equals labour income (the first term on the right-hand side of the equation), plus capital income on capital invested in the current period (the second term), less capital invested in the subsequent period (last term). Given that households use savings and employment as their decision variables, we can solve the utility maximisation problem subject to the budget constraint with respect to capital, k_{t+1}, and labour, l_t. These calculations result in the two household first order conditions:

$$\frac{\partial u}{\partial l_t} = -c_t^{\alpha(1-\sigma)} + \alpha(1-\sigma)c_t^{\alpha(1-\sigma)-1}w_t = 0 \tag{12}$$

$$\frac{\partial u}{\partial k_{t+1}} = -c_t^{\alpha(1-\sigma)-1} + \beta(1 + r_{t+1} - \delta)c_{t+1}^{\alpha(1-\sigma)-1} = 0 \tag{13}$$

We now have four first order conditions, two for the representative firm and two for the representative household, as well as a constraint on the capital stock. Furthermore, the economy as a whole is constrained by the following expression:

$$Y_t = C_t + X_t \tag{14}$$

Consumption and investments together equal total output (and net exports are assumed to equal zero). This identity essentially links the firm's decisions to those of the representative household.

Using these conditions, we calibrate the model over a certain time period, which we assume to represent a "normal" period in the economy. This "normal" period refers to a period when the economy is on a balanced growth[7] path, i.e. there is constancy in the parameters and certain ratios. More specifically, on a balanced growth path, output, consumption and the capital stock grow at the rate $(1+\eta)(1+\gamma)$ where γ is the trend growth rate and η is the growth rate of the working age population and rate at which employment is assumed to grow. This implies that output per working age person (Y/N) grows at the trend growth rate $(1+\gamma)$ while hours worked (Eh/N) and the capital-output ratio (K/Y)

[6] Note the following relationship (which is consistent with the growth accounting exercise) when calibrating the model: $(Eh)_t / N_t = l_t$. It should be noted that E is the decision variable while h is a constant parameter, calculated as in footnote 4 by using data on total hours worked.

[7] Balanced growth in our model is essentially steady state as described in footnote 2 but with an economy experiencing economic growth.

remains constant. Once the relevant parameters are calibrated, they can be used to solve the model for the period of interest, as they are assumed to remain constant over time.

4.2 Calibration

The purpose of this investigation rests on the observation that Sweden experienced a decrease in output per working age person from the mid-1970s onwards, even before the occurrence of the crisis during the 1990s. The period we wish to model, therefore, should begin at some point in time during the mid-seventies while data used to calibrate the model may include data from 1950 onwards, depending on when or during which years we assume that the economy reflects a balanced growth path. We started observing data from 1950 because it is the first year in which a complete dataset was available.

In order to establish the starting period for our model, we adopt the approach of Kydland and Zarazaga (2003) who choose the point in time when Argentina's output per working age person reached a peak and thereafter started to decline. From a casual visual inspection of Figure 1, this would appear to be between 1975 and 1976. To confirm this observation, the hypothesis that a structural break exists between the two time periods 1950-1975 and 1976-2004 was carried out using the Chow Test. The test is documented in Appendix E and the results reveal that a structural break between the two periods has indeed occurred.

It should be noted, however, that because we are studying Sweden from a long-term perspective, finding the exact breakage point is not of utmost importance. Average growth in output per working age person over each of the periods remains significantly different, irrespective of whether the break is adjusted up or down a year, and it is reasonable to assume that the Chow Test will provide the same result given these adjustments.

In order to calibrate the model, we need to find expressions for the parameters β, α and δ that reflect the economy being on a balanced growth path. These values are then used in the model because they are assumed to remain constant over time. By rearranging (12) and (13), we obtain the following:

$$\beta = \frac{c_{t+1}^{1-\alpha(\sigma-1)}}{c_t^{1-\alpha(\sigma-1)}(1+r_{t+1}-\delta)} \tag{15}$$

$$\alpha = \frac{c_t}{c_t + w_t(1-l_t)} \tag{16}$$

Given that consumption grows on average at the rate $(1+\eta)(1+\gamma)$ per year and the working age population grows on average at $(1+\eta)$ on a balanced growth path, we can substitute these assumptions into (15) and calibrate β using:

$$\beta = \frac{(1+\gamma)^{1-\alpha(\sigma-1)}}{(1+r_{t+1}-\delta)} \tag{17}$$

The capital stock is derived by expression (8). In accordance with Section 4.1, the capital stock grows on average at $(1+\eta)(1+\gamma)$ per year. Substituting this condition into (8) and rearranging, the following condition for the depreciation rate is obtained:

$$\delta = \frac{X}{K} - (1+\eta)(1+\gamma) + 1 \tag{18}$$

We now have a set of conditions that can be used to calibrate the model. Before proceeding with the technicalities of the model, it is necessary to discuss which years to use for the calibration.

As mentioned previously, the parameters α and β must be calibrated during a period in which we assume the economy to be on a balanced growth path. If we once again refer to Figure 1, we see that during the 1950s and 1960s, detrended GDP grew unusually quickly before reaching its peak in 1976. In the model, an economy that finds itself below its balanced growth path will tend to accumulate capital until it reaches balanced growth. Once this level is reached, investments as a share of output per effective worker exactly offsets the decline in capital per effective worker attributable to capital depreciation, population growth and growth in labour augmenting productivity. Given these characteristics, we would expect the economy to be closer to its balanced growth path towards the end of the reference period instead of the beginning if the economy is still accumulating capital in relation to output. This suggests that our parameters should be calibrated using data from say 1975, as opposed to average values over 1950-1975.

This reasoning is inline with what we observe in our data. The capital-output ratio, for instance, is around 1,6 in 1950, but increases steadily over the years and halts at around 2 during the early 1970s. The same applies to hours worked (Eh / N). This value starts at around 0,255 in 1950 but decreases steadily over the years, reaching around 0,22 at the beginning of the 1970s where it settles. The parameters α and β are subsequently calibrated according to conditions (16) and (17) above for the year 1975.

The capital share parameter requires more detailed data of the national accounts, which is why a value is assumed as in most of the other papers in the volume by Kehoe and Prescott (2002). We shall use the average of the adjusted values for the labour share (i.e. $1 - \theta$) in Gollin (2002), which is based on the 1992 edition of the United Nations *National Accounts Statistics*.[8]

The depreciation rate is calculated according to (18). Investment as a share of capital varied rather systematically around its mean value during 1950-1975, which is why the average value over this period is used as opposed to the value in 1975.

[8] Kehoe & Ruhl (2003) assume θ = 0,3 in their paper on New Zealand and Switzerland while Kydland and Zarazaga (2003) assume 0,4 in their paper on Argentina. Gollin (2002) provides values of labour shares for a number of countries and suggests possible adjustments that lead to both over and under estimates of the labour share. In order to compensate for the shortcomings of these adjustments, the average value is taken so that $1-\theta$ = 0,6952, which is inline with Gollin's conclusion that labour shares should lie between 0,65 and 0,8.

It is assumed that the working age population after 2004 grows at the same rate as it did between 2003 and 2004 (the last two years of our modelling period) producing a value for η, which is used to estimate values of N_t after 2004.

The coefficient of constant relative risk aversion, σ, is chosen to be equal to 2, the same as in Kydland and Zarazaga (2003). This is the value set in similar studies for the United States.

The following table summarises the values of our parameters:

Parameter	θ	δ	β	α	γ	η	σ
Value	0,3048	0,0975	0,9714	0,2333	0,0200	0,0047	2

With regards to the robustness of the data used in this study, it is inevitable that data issues will arise, especially when different data sources have been used. All sources and adjustments that have been made are reported in Appendix C. Minor discrepancies in the comparative data are not expected to affect the overall results of this investigation, however, as we are investigating the overall performance of the economy over a long period of time. Of more importance are the assumptions made regarding the various parameters and growth rates, which have been discussed extensively throughout this thesis.

4.3 Solving the Model

The model is solved using an algorithm first developed by Sami Alpanda and Pedro Amaral in Matlab code.[9] In short, the algorithm uses two first difference equations in the variables labour (expression 12) and capital (expression 13) in periods t and $t+1$ respectively. Since the initial capital stock is given (for period t), it needs to solve for labour in t in order to put the economy on the saddle path. It does this by using an initial guess for labour and computing the values of all endogenous variables for 100 periods[10]. If this path is explosive, the programme will choose another initial guess that produces an implosive path. Bisecting between the previous two initial guesses results in another guess. This process continues until the difference between the paths produced is negligible and the path being computed is a unique saddle path solution, i.e. a path of solutions that is neither implosive nor explosive. The following series and values are required as inputs for these computations:

- The parameters $\alpha, \beta, \delta, \gamma, \eta, \theta$ and σ.
- The initial capital stock, i.e. K_{1976}.

[9] The same code has been used in Hayashi and Prescott (2002) and Kydland and Zarazaga (2003) and was kindly passed on by Carlos Zarazaga for use in this thesis.

[10] A finite number of periods is used in order for a unique solution to be computed, but at the same time ensure that there are enough periods within which the economy can reach a balanced growth path.

- The actual series of A_t until 2004, after which A_t grows by $(1+\gamma)^{1-\theta}$ to complete the 100 periods required by the algorithm.[11]
- The actual series of N_t until 2004, after which N_t grows by $(1+\eta)$.[12]
- The actual series for h_t, the fraction of endowed hours devoted to working activities (refer to footnote 4), where the average value over 1976-2004 is used for after 2004.

Before proceeding to the model, it is necessary to conjecture about possible outcomes of this study given the knowledge acquired thus far. From Figure 1, it can be seen that TFP follows a fairly similar path to GDP per working age person. Therefore, given the perfect foresight assumption, if the economy after the 1970s finds itself near the balanced growth path, we would expect the model to be quite successful in capturing changes in output per working age person. When the economy is exposed to productivity shocks, the capital-output ratio and fraction of hours worked should adjust accordingly and then return to their balanced growth values. The growth accounting exercise, however, concluded that changes in these components were quite significant throughout the modelling period, even when TFP and output were growing at a similar rate. This leads us to the hypothesis that there are likely to be discrepancies between model and data, in particular with respect to the labour and capital inputs.

[11] Note that the TFP component $A_t^{\frac{1}{1-\theta}}$ grows at (1+γ) on balanced growth, implying the stated growth rate for A_t.

[12] Note that the working age population includes the portion of the population between 15 and 64 years of age; refer to Appendix D for further details.

5. Results

Comparison with growth accounting exercise

We begin with a quantitative comparison of our results with the growth accounting exercise. The second column of the decomposition in Appendix B provides the results of our model. During 1976-1983, output grew at 0,130% on average per year in our model as opposed to 0,282% in the growth accounting. Despite this value not being too far off, we notice slight discrepancies in the factor input components: growth in capital has been underestimated while growth in the labour component has been overestimated.

During 1984-1989, the model once again produces quite close results for output growth (2,798% instead of 3,917% in the data). The discrepancy, however, is mainly attributable to growth in the capital component being underestimated since the change in the labour component is on par with the data.

During the 1990s, it is evident that the model underestimates the extent of the crisis by still predicting some growth (0,181% compared to -0,022% in the data). We can conclude from this observation that the TFP factor cannot account for the entire collapse in output during this period. By looking at the factor inputs, we see that growth in the capital component is once again underestimated but this is offset by the labour component being substantially overestimated compared to the data, signifying the model's failure to fully capture the downfall in hours worked that was prevalent during this period.

The subsequent recovery during 1998-2004 reveals similarities with previous studies.[13] The model, although not particularly far off in magnitude in its prediction of output during the crisis, bounces back far quicker than prescribed by the data. This is largely due to the model predicting a rapid recovery in the labour market and return of the capital-output ratio to its balanced growth value.

Observing the changes during the period as a whole, we see that output per working age person in the model was expected to grow around 1,432% on average per year as opposed to 1,253% according to the data, given that changes in the TFP component are the same in both series. Although these values are not considerably different from one another, the corresponding values for the capital and labour components are notably different from the data. The significant underestimation of growth in the capital-output ratio and the model's inability to predict a drop in hours worked, have conveniently offset each other to produce quite favourable values for output per working age person.

Observations from the graphical representation

A graphical representation of the results can be found in Appendix A. From Figure 2, which plots output of the model against the data, we see that the model does indeed follow the contours of the data quite well, and not only resembles the data when averaged out over periods of similar growth as in

[13] Refer to the literature summary in Appendix C.

the comparison with the growth accounting exercise above. This confirms the importance of technology shocks in predicting the growth path. As described earlier, the discrepancies we do observe are mainly attributable to the capital-output ratio being underestimated, in particular from the mid-eighties onwards (see Figures 3 and 5) and hours worked being overestimated (Figure 4): first during the early 1980s and then once again when it fails to capture the full brunt of the collapse during the 1990s. These discrepancies in capital and labour, however, are larger than one would assume if one just focused on Figure 1, since they offset each other somewhat.

6. Conclusions and Discussion

Main findings

In conclusion, the Neoclassical growth model assuming perfect foresight of TFP is both successful and unsuccessful in accounting for the developments in the Swedish economy from the mid-1970s onwards. It manages to trace changes in output quite well over most of the period, which can be explained by the importance of the TFP component. On the other hand, it can only account for changes in the labour component less than half the time, and the capital component was underestimated during the entire period. Fortunately, these divergences have managed to offset each other to a certain degree in order to produce a series of output that is quite impressive.

Predictive power

At this point in time, the predictive power of the model is weak at best. This can already be observed towards the end of the observation period, where output in the model is approaching its new balanced growth path and actual data is still on the decline. The actual capital-output ratio, however, seems to be approaching the assumed value of 2, mainly as a result of the size of the capital stock approaching that of the model. The real concern with respect to long-run predictive power is whether the value assumed for hours worked in 1975 is in fact plausible in the future. As we see from Figure 4, hours worked appears to have settled into a new balanced growth level of less than 0,20. If this value does in fact represent a new level of balanced growth, then a structural shift has occurred rendering the value originally assumed for hours worked to be outdated. As a result, the model will not be able to account for the effects that this new value will have on the series of output.

At least two reasons may exist for this structural shift: a) the assumption that the working age population is the share of the population between the ages 15-64 is out of date and must be adjusted (to account for people taking more time to educate themselves, for example), or b) less people in that age group that should be working are not working, possibly due to overly generous unemployment benefits or labour market rigidities. The only other explanation would be to assume that the labour market has not fully recovered from the crisis of the 1990s, which in all circumstances seems unlikely.

Future research

The main drawback is the model's inability to account for policy decisions that affect capital and labour inputs. Additions that take these policies into account are bound to improve the results. In particular, the next step would be to include taxes as in Hayashi and Prescott (2002) and Bergoeing *et al* (2003), who include an income tax on capital income in order to incorporate the affects of fiscal reforms. If data showed that taxes on labour income varied over the time period, including a tax of this type would also account for a portion of the discrepancy in the labour factor. The aim would be to include as many aspects as possible in order to account for most of the changes in factor inputs, making the model as accurate as possible. If the fluctuations in factor inputs can be accounted for and a reasonably good fit of model to data is obtained, this would imply that the TFP factor is responsible for

most of the fluctuations in output. Further research can then be directed towards modelling the sources of fluctuations in TFP in order to delve deeper into the underlying causes of depressions.

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8. Appendix

A. Figures

Figure 1: Detrended GDP per Working-Age Person and TFP component

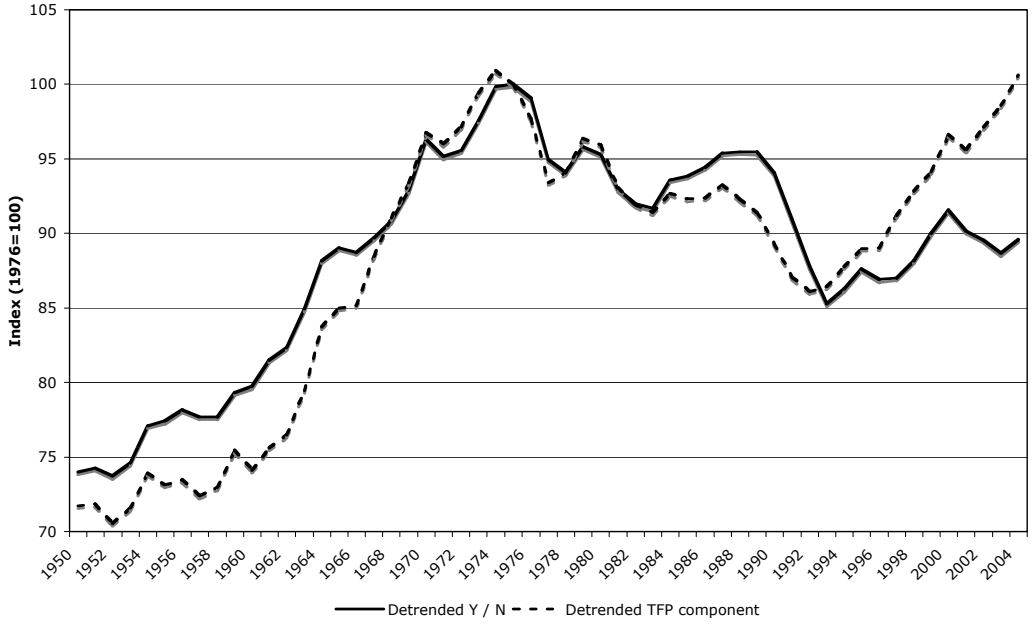


Figure 2: Detrended GDP per Working-Age Person – Model vs. Data

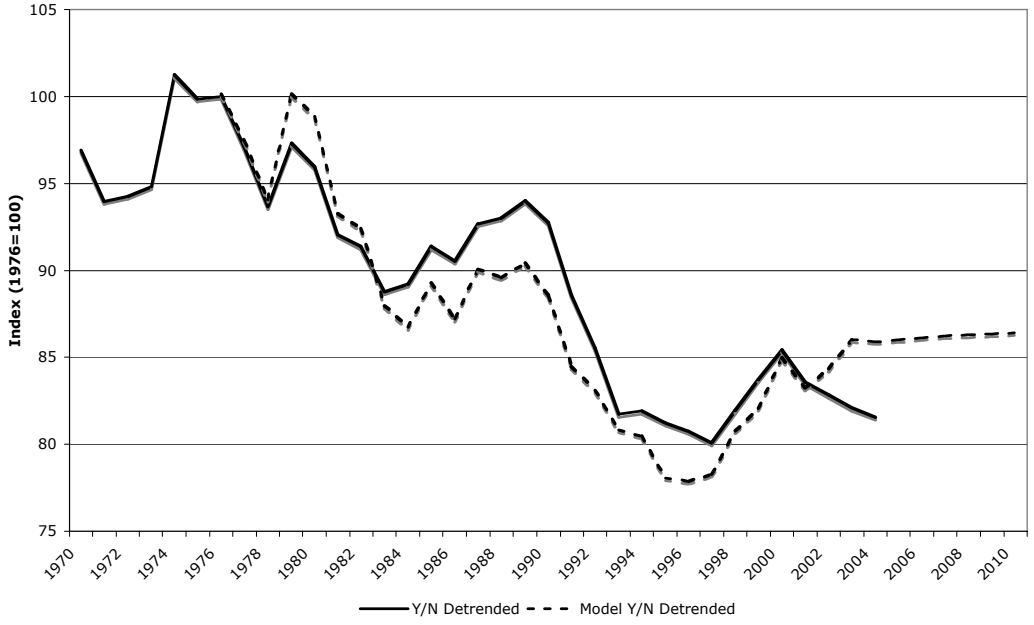


Figure 3: Capital-Output Ratio – Model vs. Data

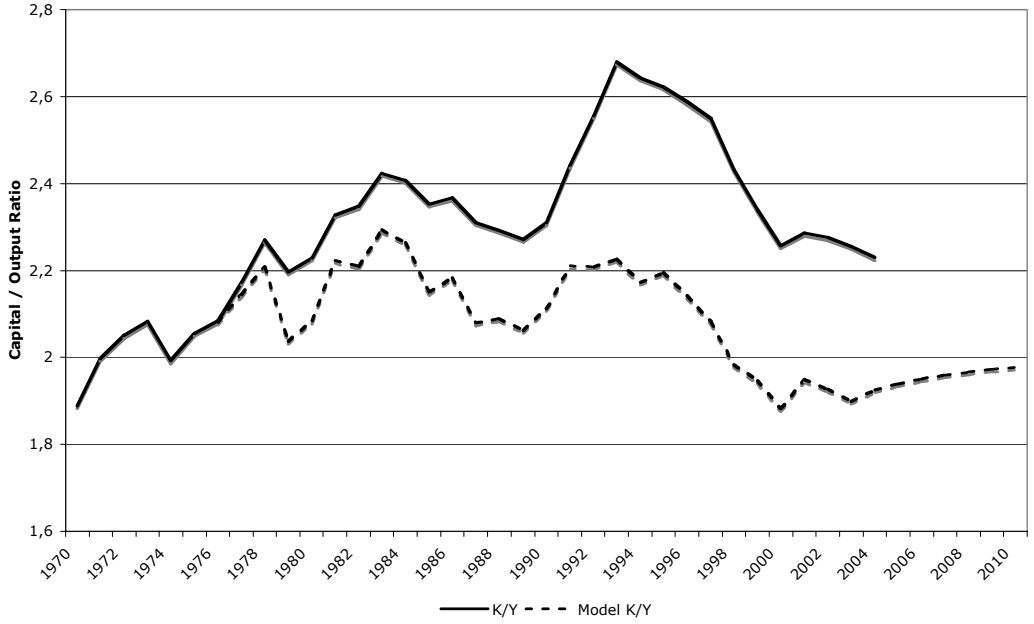


Figure 4: Employment-Working Population Ratio – Model vs. Data



Figure 5: Path of Capital Stocks – Model vs. Data



B. Decomposition.[14]

Years:	***Data***	***Model***
1976-1983		
Change in Y / N	0,282%	0,130%
Due to TFP Component	0,168%	0,168%
Due to K / Y	0,945%	0,606%
Due to Eh / N	-0,832%	-0,645%
1984-1989		
Change in Y / N	3,017%	2,798%
Due to TFP Component	2,642%	2,642%
Due to K / Y	-0,538%	-0,887%
Due to Eh / N	0,912%	1,042%
1990-1997		
Change in Y / N	-0,022%	0,181%
Due to TFP Component	0,737%	0,737%
Due to K / Y	0,631%	0,054%
Due to Eh / N	-1,391%	-0,611%
1998-2004		
Change in Y / N	1,904%	2,998%
Due to TFP Component	2,841%	2,841%
Due to K / Y	-0,633%	-0,213%
Due to L / N	-0,304%	0,370%
1976-2004		
Change in Y / N	1,253%	1,432%
Due to TFP Component	1,556%	1,556%
Due to K / Y	0,106%	-0,122%
Due to L / N	-0,410%	-0,003%

[14] Note that each change in *Y/N* is equal to the sum of the changes in the TFP component, *K/Y* and *(Eh)/N*.

C. Literature Summary

The following summary comprises:

- **Study & Method**: The name, authors and main assumptions of the study in question
- **Time Period:** The time period to which each study refers; if the model explains the depression and subsequent recovery by different factors, the period has been divided into two in order to decipher between these factors
- **Key Factor:** Those relevant for describing the depression and subsequent recovery in the model
- **Comments:** Additional information and level of success of model

Study & Method	***Time Period***	***Key Factor***	***Comments***
Canada *Amaral & Macgee (2001)* - TFP modelled as a stochastic process	1929-1933 1934-1939	TFP TFP	Slow recovery to trend due to low TFP. Model unable to explain unusual path of TFP → Model not particularly successful.
France *Beaudry & Portier (2001)* - TFP modelled as a stochastic process	1929-1938	Labour	Smooth decline relative to trend resulting in a lower balanced growth path caused by changed institutional factors in labour market. Movement in inputs sufficient to account for changes in output → Model quite successful.
Germany *Fisher & Hornstein (2001)* - Perfect foresight of TFP, additions to incorporate affects of real wage rigidities	1928-1932 1933-1937	TFP Labour Other	Labour market issues dominate primarily as a result of real wages set above market clearing levels. Increased government spending caused the slow recovery → Model highly successful.
Italy *Perri & Quadrini (2001)* - Perfect foresight of TFP, additions to incorporate affects of trade restrictions	1929-1939	Labour Other	Model predicts slow-down due to real wage rigidities and trade restrictions, which is consistent with sectoral data → Model quite successful
United Kingdom *Cole & Ohanian (1999 & 2002)* - Use ratios of F.O.C.s	1920-1939	Labour	Labour market issues dominate primarily as a result of generous unemployment benefits and sector shocks, which is consistent with previous research. → Model quite successful

United States *Cole & Ohanian (1999)* - TFP modelled as a stochastic process	1929-1933 1934-1939	TFP Other	Slow recovery to trend, most likely as a result of New Deal policies toward monopolies and the distribution of income. → Model successful in explaining downfall but not in explaining recovery
Argentina *Kydland & Zarazaga (2003)* - TFP modelled as a stochastic process - Perfect foresight of TFP	1979-1990 1991-1997	TFP Capital	Slow recovery to trend due to slow recovery of investment. → Model with rational expectations quite successful → Model with perfect foresight not successful
Chile *Bergoeing, Kehoe, Kehoe & Soto (2002)* - Perfect foresight of TFP	1980-1983 1983-1990	TFP TFP Capital	Fast recovery of capital-output ratio and faster recovery of output to trend than predicted by model. Authors point to earlier government policy reforms affecting banking system and bankruptcy procedures. → Model successful
Mexico *Bergoeing, Kehoe, Kehoe & Soto (2002)* - Perfect foresight of TFP	1980-1983 1983-1990	TFP TFP Capital	Fast recovery of capital-output ratio but slower recovery of output to trend than predicted by model. Authors point to lack of reforms affecting banking system and bankruptcy procedures. → Model successful
Switzerland *Kehoe & Ruhl (2003)* - Perfect foresight of TFP	1970-2000	TFP	Low productivity growth dominates → Model successful in explaining changes in output, does not capture entire change in labour inputs
New Zealand *Kehoe & Ruhl (2003)* - Perfect foresight of TFP	1970-2000	TFP	Low productivity growth dominates → Model successful in explaining changes in output, does not capture entire change in labour inputs
Japan *Hayashi & Prescott (2001)* - Perfect foresight of TFP, additions to incorporate effects of taxation and work-week lengths	1992-2000	TFP	Low productivity growth, possibly due to subsidisation of inefficient firms and declining industries. → Model successful in explaining output

D. Description of Data

Series	***Comments***
N_t	**Working age population** Number of total population aged 15-64 for years 1950-2004. *Source: Statistics Sweden, online database: www.scb.se*
L_t	**Total hours worked per week** Total hours worked for years 1950-2000. *Source: Edvinsson. www.historia.se* Edvinsson's series ends at year 2000. SCB produces data for 1987-2004 but the values for 1987-2000 do not correspond to those in Edvinsson. This is because Edvinsson makes a number of adjustments to his data.[15] These adjustments result in a more reliable series as the change in standards with respect to how statistics are reported that took place during 1990s is taken into account. When plotting the SCB data (1987-2004) against Edvinsson's for the period 1987-2000, it follows a very similar trend but on a different level. The SCB data is approximately 7,5% on average higher. To obtain values for the years 2001-2004, the SCB series has simply been adjusted downwards by approximately 7,5%. *Source: Statistics Sweden, online database: www.scb.se*
E_t	**Employment** Number of employed and self-employed for years 1950-2000. *Source: Edvinsson, www.historia.se* As with L_t above, Edvinsson's series ends at 2000. SCB produces data for 1993-2004 but for the years that overlap between the two data sources, a level effect exists. For 2001-2004, therefore, the SCB values have been adjusted downwards (for the same reasons stated in L_t) by the average of the absolute difference between the overlapping years in order maintain consistency. *Source: Statistics Sweden, online database: www.scb.se*
K_t	**Capital stock** For the years 1964-1996, the capital stocks are estimated as Structures + Equipment in 1991 prices. *Source: Statistics Sweden, Statistical reports: N 1981:2:5 for 1963-1980; and National Accounts, Appendix 3 for 1980-1994.* For the remaining years, 1950-1963 and 1997-2004, the capital stocks are derived using the relationship $K_{t+1} = (1 - \delta)K_t + X_t$. Investments ($X_t$) for 1950-2004 is calculated as the sum of gross fixed capital formation and changes in inventories (as in Kehoe and Ruhl (2003)), and then deflated using the GDP deflator (adjusted from index 2000=100 to 1991=100 in order to be consistent with the series of capital stocks). *Source: IFS, online database.* By using the capital stocks and the series of investments, an average depreciation rate (δ)

[15] See Edvinsson (2005) for a complete description of adjustments made to the labour series.

	can be calculated for the period 1964-1996. This depreciation rate is then used in the relationship above in order to calculate capital stocks for the remaining years (prior to 1964 and after 1996). Note: The construction of capital stocks has been carried out using the simplest of methods. Other papers suggest alternative methods to obtain more accurate capital stocks but these were not possible due to data limitations. For example, Kydland and Zarazaga (2003) use different rates of depreciation for different types of inventories; and Kehoe and Ruhl (2003) suggest that investments be deflated using the investment-deflator when considering capital accumulation and the GDP-deflator when deflating investments in terms of the labour-leisure trade-off.
$\mathbf{C_t}$	**Consumption** Total consumption in current prices is calculated as the sum of household consumption and public consumption. *Source: Statistics Sweden, online database: www.scb.se* To obtain consumption in real terms, total consumption is deflated with the same GDP deflator as the investment series (GDP-deflator adjusted from index 2000=100 to 1991=100). *Source: IFS, online database.*
$\mathbf{Y_t}$	**Gross Domestic Product** GDP is obtained using the values above for consumption and investments and the national accounts identity C+X.

E. Chow Test

To test if a structural break exists between output per working age person over 1950-1975 and 1976-2004, we regress output per working age person against time:

$$\ln \frac{Y_t}{N_t} = \beta_0 + \beta_1 t + \varepsilon_t$$

The test uses the F-statistic, which is computed according to the following:

$$F_{obs} = \frac{(RSS_R - RSS_{UR})/k}{RSS_{UR}/(n_1 + n_2 - 2k)}$$

Where:

- RSS_R – residual sum of squares for the regression over the entire sample (1950-2004)
- RSS_{UR} – sum of the residual sum of squares for two separate regressions run over the two time periods under observation (1950-1975 and 1976-2004)
- k – number of restrictions imposed on the regression
- n_1 and n_2 – sample sizes of first and second time periods respectively

The null hypothesis states that if $F_{obs} < F_{crit}$, the two time periods are not significantly different from each other and no structural break exists. The critical value at the 1% level is given by the following:

$$F_{crit} = F_{k,n_1+n_2} = F_{2,26+29} \approx 5{,}18$$

The following results are obtained using our data:

$$F_{obs} = \frac{(928{,}194 - 227{,}716)/2}{227{,}716/(26+29-4)} = 78{,}44064$$

Since $F_{obs} >>> F_{crit}$, the null hypothesis is rejected and a structural break exists at the 1% level.