On the Causality Between Saving and Growth: Long- and Short Run Dynamics and Country Heterogeneity*

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Abstract

The temporal interdependence between saving and output has been in focus in a number of recent empirical studies. Results from these studies have compelled some authors to question the traditional notion of a causal chain where saving leads growth through capital accumulation. This paper contributes to this literature. As opposed to the previous studies, which have mainly utilised panel-estimation methods, the tests of causal chains here are carried out in time-series settings. Saving and GDP are estimated in bivariate vector autoregressive or vector error-correction models for Sweden, UK, and USA, and tests of Granger non-causality are performed within the estimated systems. The main results show that the causal chains linking saving and output differ across countries, and also that causality associated with adjustments to long-run relations might go in different directions than causality associated with short-term disturbances.

Keywords: saving; growth; Granger-causality; cointegration; VAR; VECM
JEL classification: C32; E21; O40; O57

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1 Introduction

"…neither the proportion of income saved nor the rate of growth of productivity per man (nor, of course, the rate of increase in population) are independent variables with respect to the rate of increase in production;…" Kaldor (1960, p.259).

The close relationship between the saving rate of the economy and the growth rate is a stylised feature which has been well documented in a number of empirical investigations. In fact, it is one of the few, if not the only, relationship which can not be erased when other possible growth influences are conditioned on[1]. This is a result which has been found in several sensitivity analyses in the growth literature, e.g. Levine and Renelt (1992) and Sala-i-Martin (1997). Although it is emphasised that no causality should be inferred from this positive contemporaneous correlation, little is said about the causal links between the variables other than that they most likely are jointly determined. The close connection between saving and growth has also been a key finding in the empirical saving literature; the possibility that country differences in saving rates could be explained by differences in growth rates was recognised early.

Recently, a couple of articles have dealt with the question of the temporal interdependence between the growth rate and the saving rate.[2] These papers have looked more closely on what theory predicts regarding the timing of movements of saving and growth, and to what extent this is confirmed or rejected by empirical facts. The results from these studies have urged some authors to call for a reinterpretation of the traditional notion of a growth-capital accumulation relationship where capital accumulation supposedly leads growth. The present paper is a contribution to this literature. Previous studies have mainly relied on cross-section or panel data to examine the causal relationship. The point of departure here is to exploit time-series features and the information contained in the long-run relationship between the variables. Hence, saving and growth are modelled bivariately in vector autoregressive (VAR) or vector error-correction (VEC) models for three countries - Sweden, UK, and USA - and causality tests are then performed within these systems.

[1] The saving rate and the investment rate are used almost interchangeably in this literature, often with reference to the high degree of correlation between the variables. This paper focuses on the gross saving rate except where indicated.

[2] See Carroll and Weil (1994), King and Levine (1994), Blomström, Lipsey, and Zejan (1996), Paxson (1996), In and Doucouliagos (1997), Deaton (1997), Sinha and Sinha (1998), Vanhoudt (1998).

The main results are that the temporal relationship between saving and GDP differs across countries. There is evidence of a causal chain linking higher saving to larger output but some countries also have causality running in the opposite direction. Furthermore, there are different channels through which the variables influence each other intertemporally. Dynamics associated with adjustments to a long-run stationary relationship between the variables might have different temporal dependencies than dynamics associated with other short-run stochastic shocks. These results suggest that the complex mechanics determining output and saving will aggregate differently for separate countries, and that the question of whether growth generates saving or vice versa ultimately depends on the sources and magnitudes of the various shocks and policies which influence different countries, as well as their history, institutions etc. Whether it might be possible to find common growth/saving patterns for groups of countries, which share economic, demographic, or institutional features, is an open question and one worth exploring. At any rate, empirical work on the growth-saving nexus would benefit if this heterogeneity were exploited instead of ignored.

The structure of the rest of the paper is the following; section 2 recapitulates some predictions from theory regarding the dynamic relationship between saving and growth, and previous empirical findings are reviewed shortly. Section 3 contains a brief description of Granger-causality testing in VAR/VECMs. The empirical analysis is carried out in section 4, where tests are performed in estimated VAR/VECMs of GDP and saving. These results are then discussed in the fifth and final section.

2 Saving and growth in theory and practice

In theory

Although there are ample empirical evidence of the strong correlation between saving and growth, theory offers little guidance to the true nature of this relationship. Intertemporal consumption theory, for example, has always explored the relationship between income growth and saving. Even though such models frequently are tested on aggregate data, they are almost always partial-equilibrium by nature, which is a natural restriction while exploring complex consumer behaviour. However, one of the drawbacks of leaving general-equilibrium considerations aside is that some links between saving and growth, e.g. the ”mechanical” link through capital accumulation, is neglected. Still, the direction of the relationship is ambiguous even within the partial-equilibrium models.

For example, in the so-called stripped-down version of the life-cycle model of saving (Modigliani and Brumberg, 1954, 1979) productivity growth will make younger, asset-accumulating cohorts better off relative to the retired cohorts who consume out of their wealth. Assuming the same saving rate across cohorts, there will be positive aggregate saving in the economy since the saving of the young will outweigh the dissaving of the retired.[3] Hence, a permanent increase in the growth rate will result in higher aggregate saving.[4] On the other hand, with the assumptions of the commonly used permanent income model (e.g. Flavin, 1981), saving will equal the expected present value of future declines in income. Consequently, the prediction from the theory, with the income process treated as known, will be that, to the extent that the expectations are realised, saving will temporally lead reductions in actual income growth (Deaton, 1992).[5]

Moving to the general equilibrium, the basic neo-classical model of growth predicts that steady-state growth will not depend on the saving rate, defined as the share of output used for gross capital accumulation, even though the steady-state output level will. Although a much-debated question, a large part of the growth dynamics might be of a transitional nature, and in the transition there is a relationship between the saving rate and the growth rate. However, Vanhoudt (1998) argues in a critique of the articles calling for a reinterpretation of the saving/growth relationship that the fact that a positive exogenous shock to the saving rate will result in an instantaneous jump in the growth rate does not necessarily mean a temporal relationship where the saving rate leads the growth rate with a positive sign. After an exogenous increase of the saving rate there will instead be a period of gradually falling growth rates as the economy moves along a new transition path towards the steady state corresponding to the new saving regime.

[3] The ‘Bentzel effect‘ (Bentzel, 1959; Modigliani, 1986).
[4] Carroll and Weil (1994) point out that in a modified version where household income growth is equal to the aggregate plus a household-specific growth rate, exogenous increases in aggregate growth will actually make households save less under reasonable parameter values.
[5] Even though richer models including liquidity constraints, precautionary saving etc. generally leave the relationship between growth and saving dependent on the configuration of the specific model, Carroll and Weil

This argument might be valid as far as the neo-classical growth model of a Solow-Swan type goes. Leaving the assumption of an exogenous saving rate and adding a demand side to the growth model, as in a neo-classical model of a Ramsey-Cass-Koopmans type, makes the relationship between the saving rate and the growth rate even less clear. This is emphasised in a simulation by Carroll and Weil (1994), who show that the temporal relationship between the saving rate and the growth rate will differ depending on parameter values, and which parameters are changed.[6] This point can easily be illustrated by a simple Ramsey model where the technology is Cobb-Douglas and the utility function of the representative household exhibit constant intertemporal elasticity of substitution. With this set-up, the following two optimality conditions, together with the relevant transversality conditions, will govern the development of the economy, where equation (2.1) is derived from the maximisation of a representative household's intertemporal utility and (2.2) is the resource constraint for the economy:

$$\dot{c}/c = (1/\theta)(\alpha k^{\alpha-1} - \delta - \rho - \theta x) \tag{2.1}$$

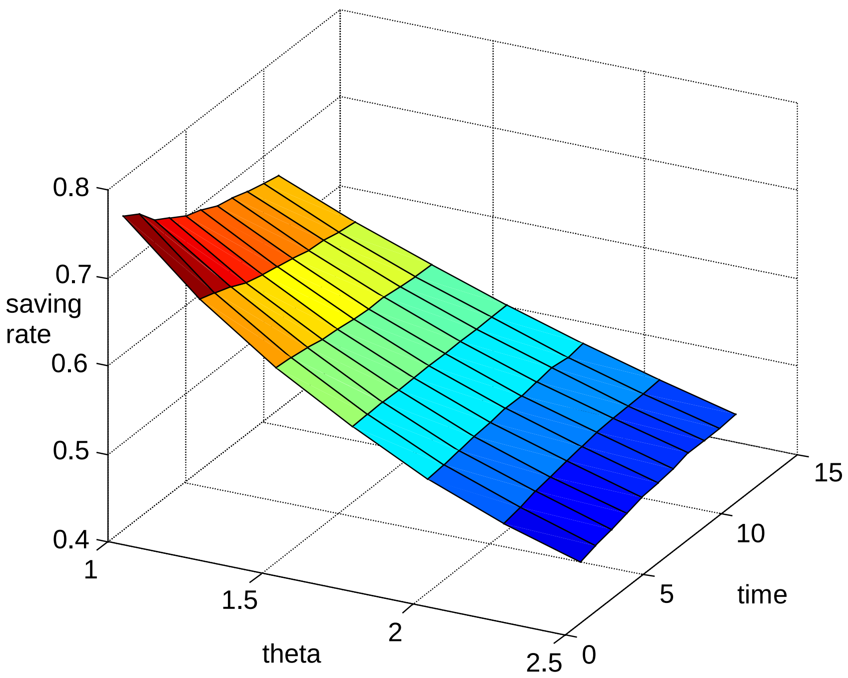
$$\dot{k} = k^{\alpha} - c - (x + n + \delta)k \tag{2.2}$$

The notation is the following: c and k are consumption and capital (per effective worker) respectively, with a dot over the variable indicating a differentiation with respect to time, $1/\theta$ is the elasticity of substitution, $\alpha k^{\alpha-1}$ the marginal product of capital where α is the capital share, δ a depreciation factor, and ρ the rate of time preference. Exogenous growth rates of technology and workforce are denoted x and n respectively. The intuition behind the differential equations is that the household chooses a consumption profile which rises or falls over time depending on whether the rate of return to saving, $\alpha k^{\alpha-1} - \delta$, is larger or smaller than the effective rate time preference, $\rho - \theta x$, with the willingness to substitute consumption intertemporally, $1/\theta$, determining the responsiveness to this difference. The second equation is the resource constraint for the economy with the change in the capital stock, and thus output, equal to output minus consumption and the effective rate of depreciation.

(1994) argue that, theoretically, higher income growth should decrease saving for young consumers, and that this result holds for a number of different extensions of the life-cycle model.

[6] This will also be the case in endogenous growth models. In the AK-type of models (e.g. Rebelo, 1991) output in equilibrium will grow at a constant rate determined by the underlying behavioural parameters, and the gross saving rate will be constant and depend on the same parameters.

Figure 2.1 Transition paths for the saving rate in the Ramsey model for different θ



Notes: The setup of the Ramsey model, including parameter values, is the same as in Barro and Sala-i-Martin (1995) Ch.2. The transition paths are calculated using a MATLAB program provided by Casey B Mulligan downloaded from http://www.spc.uchicago.edu/users/cbm4/ramsy.m. Calculations and graph made in MATLAB 5.1.

With this set-up of the model, the saving rate will be constant, increase monotonically, or decrease monotonically during the transition towards the steady state depending on whether steady-state saving is equal to, larger than, or lower than the elasticity of substitution. This is illustrated in figure 2.1 above, where transition paths for the saving rate are plotted for different values of θ, the inverse of the intertemporal elasticity of substitution. For low values of θ, where the steady-state saving rate is lower than $1/\theta$, the saving rate is decreasing, for high values of θ it is increasing, and when the steady-state saving rate is equal to $1/\theta$ it is constant. The results of policy experiments in this model will therefore depend on the choice of initial parameter values as well as the experiment type; experiments resulting in long-lasting increases in steady-state values can be associated with increasing, constant, or decreasing saving rates during the transition.

In earlier investigations

Thus theory offers no immediate answer to the question of what we should expect the real causal relationship between saving and growth to be. It also shows that it is difficult to interpret the model in terms of causal chains. Exogenous one-time shocks to fundamental parameters will result in instantaneous changes of output and saving followed by gradual adjustments to new equilibria during which one observes correlative, not causal, patterns over time. Nevertheless, the strong connection between the two variables has been interpreted by some as evidence of a causal chain from saving to growth. This has, for example, been the ‘capital fundamentalist‘ view, a notion described and criticised in King and Levine (1994), according to which capital formation is the main driving force behind increased economic growth. Other authors have also challenged this view using different angles. Recently a couple of articles have focused on a particular prediction, namely the fact that for capital accumulation to be growth promoting, the investment rate should increase before the growth rate.

In the causality analysis by Blomström, Lipsey, and Zejan (1996), for example, the main finding is that GDP growth induces subsequent capital formation more than capital formation induces subsequent growth. This indicates a unidirectional temporal causality from higher economic growth to a higher capital formation rate. Hence, the arrow of causality is the opposite of what a capital fundamentalist would expect. In an extensive study, Carroll and Weil (1994) examine the relationship between saving and growth both on the aggregate and household level. In short, their results give more evidence in favour of a positive temporal causality from growth to saving rather than the other way around, i.e. higher growth precedes higher saving. Hence, their results also contradict the capital fundamentalist view on the aggregate level.

3 VAR/VECMs and causality tests

As was mentioned in the introduction, most of the previous studies of the aggregate saving/growth temporal relationship have utilised country panel data. This is the case in both the study by Blomström et al (1996) and the causality analysis by Carroll and Weil (1994) for example. Estimation of dynamic panel-data models with lags of the dependent variable included in the regressor set is associated with certain problems, and there are estimation procedures which deal with these (e.g. Baltagi, 1995). One of the major drawbacks in this context is the necessity to instrument the lagged dependent variable. In causality tests this is a severe limitation, since the timing of the variables is the main focus of the analysis. One advantage of using a VAR approach is that the causality tests can be carried out in a setting where variables are allowed to be determined simultaneously.

One important objection often raised to time-series studies of growth dynamics for individual countries is that the use of annual or quarterly time series makes it hard to discern long or medium-term transition dynamics since these data contain too much business-cycle noise. Therefore, five-year averages of the variables are often relied on in panel estimations of growth models to filter out the business cycles. Even though annual and quarterly data do contain a lot of short-run noise, a VECM should be a better solution to differentiate between long-term and short-term sources of fluctuations. Variations associated with adjustments to a long-term relationship, for example a stable transition path, will be estimated by the error-correction mechanism, while lagged changes of the variables pick up the short-term stochastic noise. Leaving business cycles in the data might actually be preferable to the five-year-average approach, since such a transformation might distort rather than eliminate business-cycle dynamics if, for example, the periodicity of the cycles differ from five years.

Furthermore, common estimation procedures to deal with the bias due to included fixed effects in dynamic panels involve transformations of the model, e.g. first differencing, which will eliminate the long-run variation in the variables one would like to explain. Recently it has also been suggested (e.g. Lee, Pesaran, and Smith, 1997) that the assumption of parameter homogeneity across countries might be too restrictive. Here, parameter homogeneity would imply that countries share a common temporal growth/saving relationship, something that is clearly rejected by the results below. The remainder of this section contains a discussion of the concept of Granger-causality in VAR/VECMs generally as well as in the approach used here.

Granger non-causality

Simplified, the concept of Granger non-causality can be described as when the past of a variable X_t contains no information about another variable Y_t, which is not already contained in the past of Y_t itself. Testing this is usually implemented by a test of the significance of lags of X_t in a regression of Y_t on lagged Y_t and X_t. Provided we are confident X_t contains information about Y_t which is not available in other variables, and assume that cause occurs before effect, we can say that Y_t is 'Granger-caused' by X_t if the coefficients on the lags of X_t in the regression are significantly non-zero.[7]

Tests of causality based on the concepts of Granger (1969) and Sims (1972) have been used frequently in econometrics to test dynamic hypotheses in both single-equation and system settings. The increasing use of cointegration testing and error-correction, or equilibrium-correction, models (ECM) has modified the causality tests since cointegrating relationships, or error-correction terms, open an additional channel through which variables might be connected in a Granger-causal chain. With cointegrated variables, a system has a VECM representation that makes the variables a function of the disequilibrium of the long-term relationship between the levels. Consequently, some or all of the variables must be Granger-caused by the disequilibrium term, and the current change in a Granger-caused variable will partly be the result of its adjustment to the trend value of the other variables in the system (Granger, 1988).

VAR/VEC-modelling

To fix ideas, let s_t denote the logarithm of saving and y_t the logarithm of GDP. Then let $Z_t = (s_t, y_t)'$, t = 1, …, T, define a vector of the time series which is generated by a p^{th} order VAR:

$$\begin{bmatrix} s_t \\ y_t \end{bmatrix} = \begin{bmatrix} a_{11}^1 & a_{12}^1 \\ a_{21}^1 & a_{22}^1 \end{bmatrix} \begin{bmatrix} s_{t-1} \\ y_{t-1} \end{bmatrix} + \ldots + \begin{bmatrix} a_{11}^p & a_{12}^p \\ a_{21}^p & a_{22}^p \end{bmatrix} \begin{bmatrix} s_{t-p} \\ y_{t-p} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}$$

or

$$Z_t = A_1 Z_{t-1} + \ldots + A_p Z_{t-p} + \varepsilon_t$$

or

$$Z_t = \mathrm{A}(L) Z_{t\text{-}1} + \varepsilon_t, \qquad A(L) = \sum_{i=1}^{p} A_i L^{i-1} \tag{3.1}$$

where L is the lag operator and, for simplicity of the illustration, deterministic trends, constant, seasonal and intervention dummies are ignored. The error term, ε_t, is assumed to be iid (0, $\Sigma_{\varepsilon\varepsilon}$) with the covariance matrix $\Sigma_{\varepsilon\varepsilon}$ positive definite. Equivalently, this model can be rewritten as:

$$\Delta Z_t = B(L)\Delta Z_{t-1} - \Pi Z_{t-1} + \varepsilon_t \tag{3.2}$$

where $\Delta = 1 - L$ is the first-difference operator, and

$$B(L) = \sum_{i=1}^{p\text{-}1} B_i L^{i-1}, \quad B_i = -\sum_{j=i+1}^{p} A_j \quad i = 1, \ldots, p\text{-}1, \quad \Pi = I_2 - A, \quad A = A(1)$$

With the proper set of conditions (e.g. Toda and Phillips, 1994) for the stochastic properties of Z_t, equation (3.2) can be interpreted as a VECM. One of the assumptions is that Π has reduced rank, so that $I - A = \Pi = \alpha\beta'$, where α and β are 2×1 vectors. If Z_t is stationary, then A must be invertible, since this is a condition for stationarity, and hence of full rank 2. Hence, Π will also have full rank. Suppose on the other hand Z_t is I(1), then ΔZ_t is I(0) and the term ΠZ_t determines whether specification (3.2) is balanced and only consists of stationary terms. If there is no cointegration then ΠZ_t can only be stationary if Π is zero, i.e. has rank zero, so that $A = I$. If Z_t is I(1) but exhibit cointegration, then (3.2) will be balanced and a VECM, Π will have the reduced rank 1, and we can write $\Pi = \alpha\beta'$.

[7] Granger (1988) suggests the term ‘prima facie‘ caused, since a test can not condition on all other information available at time *t*. Note that this ”temporal” interpretation of causality is not uncontroversial. See for example Zellner (1988), and that entire issue of *Journal of Econometrics* for discussions and alternative definitions.

With this assumption, the cointegrating relationship is proportional to the column of β, and $\beta' Z_{t-1}$ is a stationary variable. Note that we have a single cointegrating vector in this bivariate case. The vector α can be interpreted as a vector of adjustment coefficients, which measure how strongly the deviation from equilibrium feed back into the system. Testing for cointegration in the system (3.2) can be performed according to the Johansen (1988) approach where ΔZ_t and Z_{t-1} in (3.2) are first regressed on the other components of the VECM and the coefficients are then estimated using maximum likelihood subject to the constraint that $\Pi = \alpha\beta'$ for various assumptions of the column rank. Tests for cointegration are based on the estimated eigenvalues of the Π -matrix, where the testing is done sequentially so that the null of rank 0 is tested against the alternative of rank 1 first, and rank 1 against rank 2 next.

Causality-testing in VAR/VEC models

Since we are interested in testing whether GDP is Granger-caused by gross saving, let us first rewrite (3.2) in a more explicit form where the assumption of cointegration has been added:

$$\begin{bmatrix} \Delta s_t \\ \Delta y_t \end{bmatrix} = \begin{bmatrix} b_{11}^{1} & b_{12}^{1} \\ b_{21}^{1} & b_{22}^{1} \end{bmatrix} \begin{bmatrix} \Delta s_{t-1} \\ \Delta y_{t-1} \end{bmatrix} + \ldots + \begin{bmatrix} b_{11}^{p-1} & b_{12}^{p-1} \\ b_{21}^{p-1} & b_{22}^{p-1} \end{bmatrix} \begin{bmatrix} \Delta s_{t-p-1} \\ \Delta y_{t-p-1} \end{bmatrix} + \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} \begin{bmatrix} \beta_1 & \beta_2 \end{bmatrix} \begin{bmatrix} s_{t-1} \\ y_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \qquad (3.2')$$

The null hypothesis of noncausality of s on y can be expressed as restrictions on the parameters in the following way: $b_{21}^{1} = \ldots = b_{21}^{p-1} = 0,\ \alpha_2 = 0$. The two parts of the test have somewhat misleadingly been labelled tests of ‘short-run‘ and ‘long-run‘ Granger-noncausality in the literature. Long-run should not be interpreted in a temporal sense here - deviations from equilibrium are of course partially corrected between each short period - but in a ”mechanical” sense. If there is unidirectional causality, say from saving to GDP, then in the short term deviations from the long-term equilibrium implied by the cointegrating relationship will feed back on changes in GDP in order to re-establish the long-term equilibrium. If GDP is driven directly by this equilibrium ”error”, then it is responding to this feedback. If not, it is responding to short-term stochastic shocks. The test of the elements in B gives an indication of the ”short-term” causal effects, whereas significance of the relevant element in Π indicates ”long-term” causal effects. (Masih and Masih, 1996)

Note however that no unambiguous statements can be made about the direction of the long-run causality from the significance of the error-correction mechanism in the separate equations. Since it is relative changes between the variables that result in disequilibria, a positive α -coefficient in the output equation is not direct evidence of a causal chain from saving to output. This interpretation, that an increase in saving relative output causes output growth, is consistent with the estimate, but output could also increase if saving in the previous period decreased less than output did. A *non*-significant α -coefficient in the output equation indicates lack of a relation. In this case, any changes in saving associated with adjustments to the long-run relationship do not induce output changes, at least not directly through the ECM.

Modelling approach

The approach for causality analysis used here follows the sequential procedures suggested in Toda and Phillips (1994)[8]. Given an estimated reduced rank of 1, which in this bivariate case is a sufficient condition for standard asymptotic properties, long-run Granger non-causality is first examined by a LR-test of $\alpha_i = 0$, the relevant element in α. Short-run non-causality is then tested by a Wald-test of the non-significance of the elements in the short-run parameter matrices B_i, $i = 1 \ldots p-1$. This procedure integrates naturally with the modelling strategy outlined by Doornik and Hendry (1997), and implemented in the econometric package PcFiml, which starts with the development of a data-congruent VAR by a general-to-specific approach in which lag length, trends, and impulse dummies are determined. This model is then used for cointegration tests, where α and β are estimated by Johansen's procedure. Depending on the underlying economic hypotheses the modelling can then proceed with further tests of restrictions on elements in α and β, and the short-run parameters of the model.

[8] A number of other ways of performing Granger non-causality tests in VAR/VECMs have been suggested recently. Some involve Wald tests of coefficients in the *A*-matrix in (3.1) or the *B* and Π-matrices in (3.2). Generally, it has been shown that Wald tests on coefficients of both VARs in levels and VECMs may have non-standard asymptotic properties in case of integrated variables, but will be asymptotically valid given sufficient rank conditions on, in the VECM case, submatrices of both α and β (e.g. Toda and Phillips, 1993). In response to this, a number of methods have been devised to take care of the problem and make the Wald test work. Among these are the "augmented" VAR approach (e.g. Toda and Yamamoto, 1995), and the "Fully Modified" VAR approach of Phillips (1995).

The disadvantage of this procedure is that the sequence itself is largely arbitrary; it is not clear in which order the determination of lag length, deterministic trends, cointegrating rank etc. should be carried out, and the results might vary depending on the sequence used.[9] There is also the risk of introducing pre-test bias in the estimations; for example the Granger-noncausality test is performed conditional on estimation of cointegration rank and vectors (Dolado and Lütkepohl, 1996). However, there are some studies based on Monte-Carlo studies that advocate causality testing in VEC-settings rather than the usual VAR-approach (Mosconi and Giannini, 1992; Toda and Phillips, 1994; Zapata and Rambaldi, 1997).

Finally, there is no claim that the model estimated below is of a structural type - there is no assumption about a particular underlying economic model here. However, one testable hypothesis is that the stationary combination of saving and output is $s_t - y_t$, the logarithm of the saving rate, so that the cointegrating vector will be $\beta' = [1 \quad -1]$. This ”structural” hypothesis has been tested in a number of investigations (e.g. King et al, 1991; Neusser, 1991), since it is the implication of a stochastic version of the neo-classical growth model where the traditional deterministic model is modified to include technological progress which evolves according to a random walk with drift. Given the particulars of this model output, consumption, and investment in steady state will share the technological stochastic trend, i.e. will be cointegrated, and the ‘great ratios‘ - the consumption share and investment share of output - will be stationary. Another reason to test this hypothesis is that this cointegrating vector, if accepted, also will allow a test of whether the saving *rate* Granger-causes GDP *growth* in the VECM representation, while simultaneously considering the long-run features of total gross saving and GDP.

[9] Instead of the sequential procedure, Pesaran and Smith (1998) have suggested estimating a range of specifications combining all relevant combinations of lag length, deterministic trends, cointegration rank etc, and

4 Saving and growth - causality tests

This section will start with a brief description of the data, followed by cointegration tests using the Johansen (1988) approach. The Granger non-causality tests are then carried out conditional on the results of the cointegration analysis. Tests for long-run causality are integrated with the cointegration analysis since this involves testing restrictions on the impact coefficients, which are estimated together with the cointegration vector. The short-run tests are then made in a stationary system, i.e. reduced to an I(0) representation by differencing and using cointegrating combinations. Finally, some results from tests using alternative variables and data are discussed.

Data

The estimations below are performed on annual data for real GDP and real gross saving for three countries: USA (1950 - 1997), UK (1952 - 1996), and Sweden (1950 - 1996). The gross saving measure is defined as fixed capital formation plus net exports, and is deflated using the implicit GDP deflator.[10] Estimations with a pure investment variable have also been made as a comparison, and these results are discussed in the next section. The choice to use annual data is admittedly open for criticism; even though we are only dealing with bivariate systems, approximately 50 observations might not give a satisfactory number of degrees of freedom. Unfortunately, quarterly data is not without problems either. First, using seasonally adjusted data, which in many cases are the only quarterly data available, is undesirable since the smoothing of seasonal filters could distort the temporal relationships between the variables. Second, there are some studies which emphasise the importance of having a long time span rather than a high frequency of observations (e.g. Hakkio and Rush, 1991). This is especially relevant for Sweden, since quarterly data only are available from 1970 at best. In order to investigate the sensitivity of the results with annual data estimations with quarterly data have also been made. Those results are commented on in section 5.

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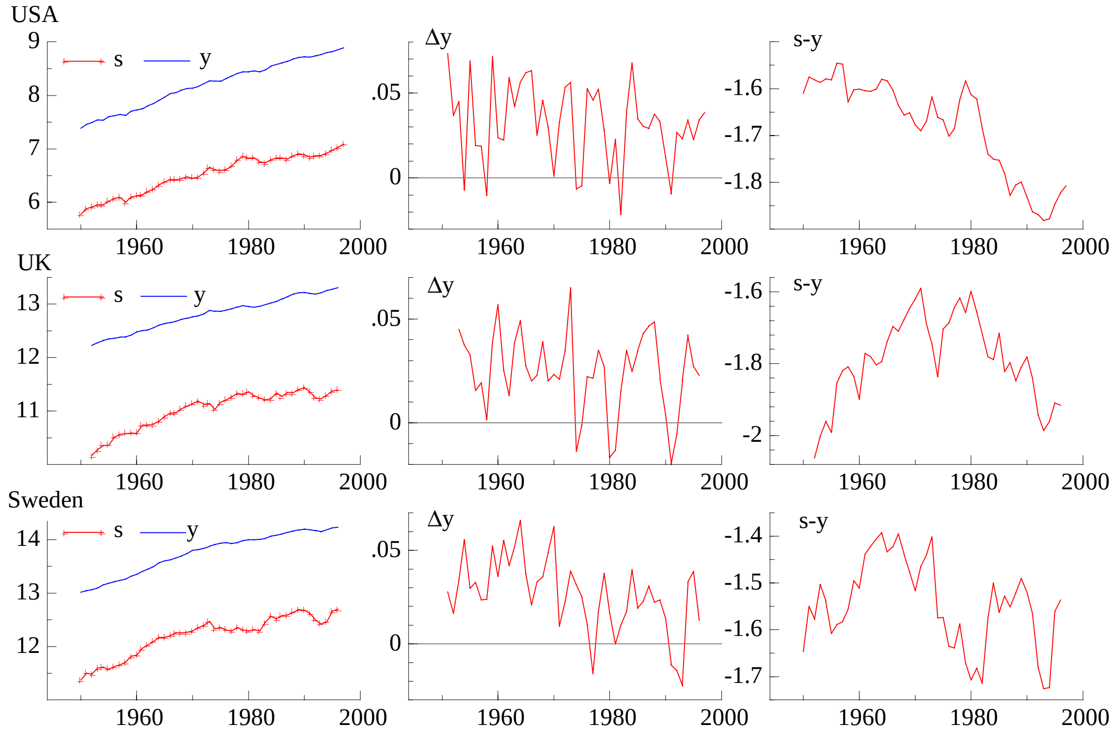
then select the ”best” model according to some statistical information criterion in combination with economic judgement of the models.

[10] Data for the US were collected from the NIPA tables and extracted from G 7.0 by Inforum, University of Maryland (http://www.inform.umd.edu/EdRes/Topic/Economics/EconData/index.html). Note that government investment were separated from consumption expenditures and included in the gross saving measure. UK data are from the OECD National Accounts. The Swedish data were provided by Statistics Sweden (SCB) and the Swedish Central Bank.

The sample of countries is somewhat random, although the countries do have different enough economic and institutional features to make comparisons of the growth/saving relationship interesting. Comparing the UK and the US in this context is interesting because of the countries' dissimilar evolution of the personal saving rate in the post-war period (e.g. Attanasio, 1997). The comparison between the US and the UK on the one hand, and Sweden on the other hand can be regarded as the classical study of large vs. small open economies. One can expect the saving/growth relationship to differ between more or less open economies; in the textbook example of a closed economy, total saving will be identical to total investment, whereas a small open economy, which has negligible influence on the world economy, need not have any close correlation between the evolution of the capital stock and total saving. Figure 4.1 below graphs the time series for GDP, gross saving, the growth rate of GDP, and the saving rate for the three countries.

Figure 4.1
Log of GDP and gross saving, GDP growth rate, log of saving rate for USA, UK and Sweden - post-war period.



Notes: Time-series plots for the US (1950-1997), the UK (1952-1996), and Sweden (1950-1996). As above, s is the logarithm of gross saving, y is the logarithm of GDP. The growth rate of GDP is denoted Δy, and s-y is the logarithm of the gross saving share of GDP. All variables in national currencies.

Judging by a quick inspection of the first and second columns of the graph the countries' output and growth rate experiences during the post-war period are quite similar. Particularly a comparison of the growth rate of GDP across countries in the second column shows fluctuations which appear to be rather well synchronised, even though the impact of shocks differ across the three countries. There are, however, some periods when the Swedish development lags the development of the other two countries. As a contrast, the third column of the graph confirms the difference in the (logarithms) of the saving rates, which according to the graph does not just apply to personal saving rates but total saving rates as well. It is also apparent from the plots of the saving rates that this particular linear combination of gross saving and GDP need not be a prime candidate for a cointegrating relationship for this period as it seems unlikely that it can be considered a stationary variable, at least for the US and the UK.

The choice to focus on total gross saving in the estimations below merits further comments since the usual procedure in growth empirics, and in the causality analyses mentioned in the introduction, is to focus on the gross saving *rate*. Whether or not it is meaningful to test a share variable for unit roots is a question sometimes raised in the literature, but regardless of position in that matter there is the question of balancing the regression, i.e. making sure the growth rate and the saving rate have the same order of integration. Since the logarithm of the saving rate is a linear combination of s_t and y_t, both potentially non-stationary judging by figure 4.1, the saving rate is stationary if the linear combination $s_t - y_t$ is stationary, and this is ultimately an empirical question. So from a time-series perspective the natural point of departure is to start with the totals of the variables, and test hypotheses on linear combinations of them.

Cointegration analysis

Table 4.1 below shows the results from the cointegration analysis in the preferred VAR-model for the different countries.[11] We can see that the results are quite mixed. Somewhat surprisingly, there does not seem to be a cointegrating relationship between y_t and s_t in the US for this particular time period. This means we can carry on with the causality analysis in a VAR-setting using the first differences of GDP and gross saving; there is no information on a long-run relationship between the level variables that is neglected by doing so. For the UK and Sweden there is evidence of cointegration between the variables. However, a LR-test of the hypothesis that it is the rate between the variables that is stationary is firmly rejected for the UK; the cointegration relationship includes a time trend and a much larger (in absolute terms) coefficient on GDP. For Sweden the saving rate is close to being a stationary variable. However, a LR-test rejects the restriction of a zero trend coefficient, which means that the stationary combination of saving and output also need to include a time trend.

Table 4.1 Cointegration analysis

	USA			UK			Sweden		
	s_t	y_t	*trend*	s_t	y_t	*trend*	s_t	y_t	*trend*
Est β'	-	-	-	1.0	-4.0	0.074	1.0	-1.0	-0.003
LR_{trend}						13.5*			6.5*
LR_{s-y}					21.0*			0.4	

Rank	USA			UK			Sweden		
	L	Trace-stat	EV-stat	L	Trace-stat	EV-stat	L	Trace-stat	EV-stat
r = 0	353.9	18.0	15.4	326.6	32.6*	30.2*	319.0	38.6*	34.4*
r = 1	361.6	2.7	2.7	341.8	2.3	2.3	336.2	4.2	4.2
r = 2	362.9			342.9			338.3		

*Notes: Est β' gives the restricted cointegrating vectors used in the VECM estimations. LR_{trend} is a likelihood-ratio test of the hypothesis that the trend coefficient is zero, while LR_{s-y} tests the hypothesis that the coefficients on s_t and y_t are 1 and -1. Superscript * indicates that the test is significant on the 5%-level. L is the likelihood value with the rank assumption imposed. Trace-stat and EV-stat are the trace statistic and maximum eigenvalue statistic of cointegration. The test of the null hypothesis of different ranks is made sequentially. First r = 0 is tested and then $r \leq 1$, so that a significant test of r = 0 and non-significant test of r = 1 means that the hypothesis of r = 1 is not rejected. As above, * indicates a significant test on the 5%-level. All multivariate estimation performed in PcFiml 9.0 (Doornik and Hendry, 1997).*

[11] The preferred specification was chosen according to both high information criteria, using the Hannan-Quinn and Schwarz measures, and congruence of the residuals. This resulted in a lag length of 2 for the UK VAR-model, and 1 for the US and Swedish models. The trend was restricted to the cointegration space in the standard way. A number of impulse dummies were also included in the regressions in order to deal with residual outliers. More detailed output of the estimations are available from the author on request.

Long-run Granger non-causality

Turning to the estimated α -coefficients and the tests of long-run Granger causality, we get mixed results again. The estimated α -vectors and the causality tests are displayed in table 4.2. Obviously, since the tests above did not indicate a cointegrated relationship for USA, no tests of long-run causality tests are performed. For the UK, both tests of the two elements in the α -vector are significant which indicates a bi-directional temporal dependence between the variables. So, the long-run Granger causality between GDP and gross saving is mutual. In the Swedish case a test of the significance of the impact coefficient in the saving equation could not be rejected, whereas a corresponding test of the coefficient in the output equation could. Hence, the results tend to favour a long-run causality that is unidirectional from gross saving to GDP. Changes in saving induced by disequilibria can, through the ECM, cause output growth, but the data does not indicate an arrow of causality in the opposite direction, i.e. saving dynamics can not directly be induced by equilibrating changes in output.

Table 4.2 Estimated α-vectors and long-run causality tests

Eq.	UK			Sweden		
	Coeff.	Std Error	LR-test	Coeff.	Std Error	LR-test
s_t	-0.35	0.06	27.6*	0.01	0.09	0.02
y_t	0.05	0.02	6.9*	0.11	0.02	26.5*
	mutual causality			causality from saving to GDP		

*Notes: LR-test is a likelihood-ratio test of the significance of the coefficient. Superscript * indicates significance on the 5%-level.*

From the test of the significance of the α -coefficient in the GDP equation one can also make comparisons with previous studies which focus on causality between the saving *rate* and GDP growth. Too much emphasis should not be put on such a comparison, however, since there are quite large differences regarding both methodology and data. But provided the estimated cointegration vector corresponds to the logarithm of the saving rate, $s_t - y_t$, the comparison is fairly straightforward: if the α -coefficient in the GDP equation is significant, the saving rate will lead GDP growth.

With another cointegrating vector a comparison is more far-fetched, and will have to be more in terms of whether a long-run stationary relationship between output and saving will lead output dynamics. Judging by the results from table 4.2 there is a temporal link from the ”saving rate” - for Sweden only modified to include a trend - to the growth rate, and in both countries a higher saving rate precedes a higher growth rate. The fact that this link is positive for both countries is at odds with some results in previous investigations (see section 2) but allows a straight-forward interpretation that positive saving shocks disrupt the long-run equilibrium upwards such that a higher growth rate is induced, at least temporarily.

Short-run Granger non-causality

Table 4.3 presents results from the VEC-regressions for the UK and Sweden, and the VAR-regression in first-differences for the US. As it turns out, these causal chains are the only ones that are statistically significant. The only fluctuations of output and saving which can be explained by changes in the other variable in the system are changes stemming from error-correction dynamics. Of course, this result is to some extent predetermined by the modelling procedure. In the Swedish case for example, the specification search favoured a VAR(1), which transforms into a VECM(0). Thus, short-run dynamics have already been rejected.

Table 4.3 Estimates from VAR/VEC regressions

Regressors	USA		UK		Sweden	
	Δs_t	Δy_t	Δs_t	Δy_t	Δs_t	Δy_t
constant	0.007	0.024*	-12.250*	1.695*	0.052	0.213*
	(0.012)	(0.007)	(2.127)	(0.744)	(0.141)	(0.030)
ECM_{t-1}			-0.320*	0.044*	0.013	0.115*
			(0.056)	(0.019)	(0.087)	(0.019)
Δs_{t-1}	-0.302	-0.233	-0.166	-0.047		
	(0.262)	(0.142)	(0.094)	(0.033)		
Δy_{t-1}	0.764	0.391	0.257	0.433*		
	(0.489)	(0.264)	(0.375)	(0.131)		
vec. F_{ar5}	0.43		1.42		0.94	
vec. F_{het}	0.77		0.49		0.45	
vec. χ^2_{norm}	2.15		1.25		2.82	

*Notes: std errors in parenthesis. The order of the lag length is consistent with the preferred VAR-models for each country, so that a VAR(p) is transformed to a VEC(p-1). ECM is the restricted estimated cointegrated relationship. The last three tests are vector diagnostic tests of the residuals from the estimations: vec. F_{ar5} is an F-test of up to 5^{th} order residual vector serial correlation, vec. F_{het} tests vector heteroscedasticity, and vec. χ^2_{norm} is a chi-square test of joint normality of the residuals. A * indicates significance on the 5%-level.*

So, in neither of the three countries do the lagged first difference of saving have significant explanatory power in the output equation and vice versa, at least using the traditional 5% significance level. This does not necessarily mean a total absence of short-run causal chains on the annual frequency. For both the US and the UK the lagged first-difference of saving do have some explanatory power for output dynamics, and border on statistical significance on the 10% level. This is also the case for lagged output growth in the saving equation in the US.

5 Discussion of results

There are two main results from the Granger non-causality tests above which have not attracted much attention in previous studies. The first is that the Granger-causality between saving and GDP is different across countries. For the UK and for Sweden, where standard tests indicate a long-term relationship between the variables, the temporal interdependence differs. In the UK, there is a bi-directional causality between GDP and gross saving in that long-run equilibrating adjustments precede changes in both variables. In the Swedish case, the temporal dependence is more unidirectional in its nature since saving dynamics can lead output growth, but adjustments of output to correct a disequilibrium do not lead saving dynamics. For the US there is no statistically significant long-run relationship between the variables over the period studied here.

The second result is that the variables can be connected in Granger-causal chains through different channels, in ‘long run‘ and ‘short run‘ chains, which might differ both regarding direction and sign. As was emphasised above, the terminology is not to be taken in a temporal sense but is meant to separate dynamics associated with adjustments to a long-run stationary relationship from that of other stochastic shocks. Conditional on the presence of long-run chains through the error-correction mechanism there are no statistically significant short-run chains for Sweden. However, both for the US, where no long-run chain was found, and the UK there are indications of short-run chains, even though they are not significant on traditional significance levels; in the US the short-run causality runs in both directions while the UK appears to have a unidirectional chain from saving to output.

Connecting back to the theoretical predictions in section 2 above, it is evident that the results presented here are just as diverse as one would expect from that discussion. The fact that there is a long-run stationary relation between gross saving and output for two of the countries conforms to the most elementary of the predictions from growth theory. From the cointegration tests it is clear that a variable close to the logarithm of the saving rate can be considered a stationary variable for Sweden during this period, but not for the UK. The plot of the saving rates for the countries in figure 4.1 may give some intuition for this result; the Swedish saving rate appears to be fluctuating around a fairly constant level, while the evolution of the saving rate in the UK is dominated by a positive trend during most of the period.

One interpretation in terms of the Ramsey model presented in section 2 is that both results are consistent with transitional dynamics toward steady states, but with different relations between the underlying structural parameters in each country. In this context, the Swedish transition path would correspond to the case where the saving rate is constant, or at least randomly fluctuating around a certain level, implying a steady-state saving rate very close to the intertemporal elasticity of substitution with the Cobb-Douglas parameterisation. The evolution of the UK saving rate on the other hand would be more in line with a situation where the steady-state saving rate is larger than the substitution elasticity, resulting in a positively trended saving-rate transition path.

One possibility is that the steady-state saving rate is higher in the UK than in Sweden which would make a trended transition path more likely for the UK. This explanation is supported by the traditional arguments for differing saving rates across countries; the extension of the social security system, the high female labour supply, and the high degree of ageing of the population in Sweden, all point to a relatively lower Swedish saving rate. However, there must be more to this story since the UK gross saving rate in fact has been below the Swedish during the period, even during the first three decades when, except for the beginning of the 70s, the UK saving rate showed a clear positive trend. Another reason for the different transitional patterns could be that UK households in the aggregate display a relatively lower willingness to substitute consumption intertemporally. The same arguments that supported a higher UK steady-state saving rate could be made to support this explanation. For example, the female participation rate, which has been relatively higher in Sweden, has been found to affect the intertemporal substitution elasticity positively (Blundell et al, 1994).

The fact that there is not much that points to a long-run relation between saving and output in the US is harder to reconcile with traditional growth models.[12] Intuitively, it is difficult to combine a situation with no cointegration between saving and output with dynamics where the variables follow stable transition paths. However, the plot of the saving rate for the US in figure 4.1 might explain this result to some extent. Up to around 1980 the saving rate fluctuated around a fairly stable level - perhaps with a slight negative trend. By 1980 there was a very clear break in the series and from 1980 and on the saving rate dropped dramatically. In view of the fact that unit root and cointegration tests are sensitive to trend breaks, the inability to find a stationary relation between output and saving for the US should not come as a complete surprise. Crude regressions using data up to the 1980s actually suggest a stationary saving rate during the first three decades.

[12] The specification used here might just be too simple, and detecting the true dynamics might be obscured by the rather poor fit of the model. It is for example difficult to find a data congruent model of output and saving for the US when the 1950s are included in regressions on quarterly data. Nonetheless, the fact that a joint model of output and saving does not explain much of the dynamics of the two variables is an interesting result in itself.

Of course, the drop of the US saving rate, both on the national level and the household level, in the 1980s has been the focus of numerous studies, but so far there has been no agreement on one particular cause behind this phenomenon. This pronounced break naturally raises the question of regime shifts, and a number of reasons for such a shift in the 1980s, e.g. financial market developments, social security and health care extensions, changing demographic structure, have been offered as explanations for the development of the US saving behaviour. A deeper analysis of these matters has not been made here but could be taken into account explicitly by estimation of Markov-switching VARs for example. This would, however, add further complexity to the causality analysis since specific regimes and switches between specific regimes might be associated with different causal relations.[13]

Admittedly, the discussion of the estimated cointegrated relations above is a rather intuitive interpretation. The estimated model is not rigorously tied to any particular underlying theory. Other interpretations of these results are of course possible.[14] Still, even though the close connection between saving and output is confirmed for two of the countries, the results also show that the claim that saving is the driving force in this relationship clearly is too strong. The notion may fit the Swedish results where the causality mainly runs from saving to output, but it does not apply to the UK or US experience. For the UK deviations from the long-term relationship will induce changes in both saving and output in order to re-establish the equilibrium.

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[13] For an applied analysis of Granger-causality in MS-VARs see for example Jacobson, Lindh and Warne (1998) where focus is on saving, growth, and financial-market expansions in the US.

[14] As for example in the literature focused on testing neo-classical growth models with stochastic technological progress (e.g. Neusser, 1991 - see discussion above).

Some clues to the propagation mechanisms behind these causal chains should be given by the sign of the estimated coefficients. The long-run relation between saving and output is included with a positive sign in the output equations for both UK and Sweden, so increases in saving relative to output the previous period lead increases in output this period. This is consistent with the ”mechanical” link through capital accumulation, i.e. the mechanism in focus of the neo-classical growth models. Positive disequilibria, possibly resulting from higher saving, will result in increased output. For the UK there is a mutual dependence where causality also runs from output to saving. Since the error-correction mechanism is significant in the output equation, positive adjustments to the ECM lead negative changes of gross saving. So, increased output the previous period (relative to saving) will bring saving and output below the stationary combination, which in turn will increase saving. Hence, relative increases in output lead increased saving, a result that is in line with the traditional life-cycle model of saving.

Even though the long-run causal chain is consistent with the mechanical capital accumulation story behind growth, the short-run causality from saving to output for the UK and the US shows the reversed sign; increases of saving precede output decreases. So here there is some support for previous results that, to the extent that saving leads growth, it is with a negative sign. A possible interpretation of this result is that of a traditional Keynesian aggregate-demand effect; a positive shock to saving will reduce aggregate demand and therefore temporarily dampen production increases.

Experiments with estimations of alternative specifications have been made to check the robustness of the results above. These regressions have been of two types: estimations with a pure investment variable and estimations with quarterly data instead of annual. Results from these estimations are summarised in the appendix. On the whole, the results are consistent across estimations with different variables, but differs somewhat depending on frequency of the data. With annual data, there is a cointegrating combination of output and fixed investment for the UK and Sweden which is close to the relationship for saving found above.

The long-run causal patterns between investment and GDP are also the same as for saving, with the exception that UK error-correction dynamics is included in the investment equation with a positive sign, indicating that increased output relative to investment will lead investment decreases. However, as opposed to the case with gross saving, there are statistically significant short-run causal chains, and for the UK there is a positive link from output to investment via the short-run causal chain which is more in line with predictions from accelerator-type models of investment. In the UK there is also a short-run link in the other direction from investment to output, while Sweden has a unidirectional chain from investment to output. The finding of no long-run relationship between a capital-accumulation measure and output for the US is a surprisingly robust result. Virtually all experiments with different variable definitions, dummy sets, and data frequencies fail to detect a cointegrating relationship.

Results from estimations with quarterly data for the UK are similar for saving and investment, but is somewhat different from the results with annual data; the cointegrating relationship between output and saving/investment is similar, but the results from the long-run Granger causality tests are not. The long-run causal chain in both cases is unidirectional from output to gross saving or fixed investment, while the chain is bi-directional with annual data. This suggests that the effect from saving/investment on output is a process that takes longer time to be effective than the link in the other direction. There is a short-term link from saving to output, but no statistically significant link in either direction for investment.

For Sweden the results with quarterly data are very different from the annual results; none of the tests find evidence of a cointegrating relationship between saving/investment and output. However, as mentioned above, the time span of the quarterly data for Sweden (1970:1 - 1998:3) is short and could be inadequate to detect long-run features. There is for example some evidence from unit-root tests that both gross saving and fixed investment can be considered I(0) series for this particular time period. Furthermore, since the quarterly data for Sweden are seasonally unadjusted, dealing with integrated components of the seasonal processes add additional considerations to the cointegration tests[15].

[15] More specifically, since seasonal unit roots might distort tests of cointegration between the non-seasonally integrated parts of the variables it is important to identify the seasonal processes. Here, tests of cointegration ”at the zero frequency” between variables are made after seasonal differencing to remove any seasonal unit roots present according to HEGY-tests (Hylleberg et al, 1992). As it turns out seasonal roots might not be a problem,

In sum, the results confirm the findings in previous studies to some extent; there is more to the saving/growth relationship than the ‘capital fundamentalist‘ view. On the other hand, a case can be made for the argument that fluctuations of the saving rate, or another measure of the long-run relationship between saving and output, precede positive growth. However, as mentioned above, the point of the analysis here is that the causal chains are more complex than this, and that the temporal dependence between output and gross saving will depend on country characteristics and what type of dynamics one is studying.

Furthermore, focus really should not be on the saving *rate* - particularly if the purpose is to interpret these causal chains in terms of policy recommendations. From a theoretical view the relation between the saving rate and the growth rate is ambiguous, and from an empirical view, since it is a combination of two non-stationary variables, the saving rate is at best a long-run combination toward which output and saving tend to gravitate. To establish whether incentives to increase saving really are growth promoting one should concentrate on determining the causal chains linking total saving and output. As we have seen, there is indeed evidence of such a positive link, but also of feed-back links.

Finally, from the estimations above it is clear that reliance on the mechanical link between capital accumulation and growth as the major source of growth dynamics does not appear promising; a large part of the changes in gross saving and GDP are left to explain when we model these two variables bivariately. However, the goal here is not to explain saving or GDP growth, but rather to investigate a temporal relationship between these variables. A more realistic specification left for future research would include other potentially important variables to test whether the information content of gross saving contained in GDP, and vice versa, is stemming from a third underlying variable. The results from the exercise above simply show the need for more careful theoretical and empirical modelling of the determination of the saving rate and the dynamics of the saving/output relationship over time and across countries, where country heterogeneity might be due to differences in demographic structure, trade patterns, institutional or financial market features.

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at least for fixed investment and output, since tests indicate different roots for these variables. The GDP series includes an annual seasonal root, fixed investment a half-annual root, while the tests for gross saving indicate seasonal unit roots at all frequencies.

Appendix

Summary of results of cointegration tests and tests of long and short-run Granger non-causality with annual and quarterly data, and for gross saving and fixed investment.

	USA		UK		Sweden	
	saving	investment	saving	investment	saving	investment
Annual						
ECM			$s_t - 4y_t + 0.07t$	$i_t - 4.5y_t + 0.08t$	$s_t - y_t - 0.004t$	$i_t - 2y_t + 0.03t$
GC l-r			$s \xrightarrow{+} y$ $s \xleftarrow[+]{} y$	$i \xrightarrow{+} y$ $i \xleftarrow[-]{} y$	$s \xrightarrow{+} y$	$i \xrightarrow{+} y$
GC s-r	$s \xrightarrow{?-} y$ $s \xleftarrow[?+]{} y$		$s \xrightarrow{?-} y$	$i \xrightarrow{-} y$ $i \xleftarrow[+]{} y$		$i \xrightarrow{-} y$
Quart.						
ECM			$s_t - 3y_t + 0.01t$	$i_t - 3.5y_t + 0.01t$		
GC l-r			$s \xleftarrow[+]{} y$	$i \xleftarrow[+]{} y$		
GC s-r	$s \xrightarrow{+} y$	$i \xrightarrow{+} y$	$s \xrightarrow{-} y$		nc	nc

Notes: the upper part of the table contains results from estimations with annual data, and the lower part results with quarterly data. ECM is the estimated restricted cointegrated relationship, GC l-r is the estimated long-run Granger causal chain between the variables, and GC s-r the estimated short-run chain. The sign above or below the 'arrow of causality' indicates the sign of the causal chain. However, note the difficulty in interpreting this sign. The effect from saving on output, for example, refers to the effect from a positive deviation from equilibrium, i.e. either a relative increase or relative decrease of saving compared to output. The effect from output on saving, on the other hand, refers to a negative disequilibrium, i.e. either a relative increase or relative decrease of output compared to saving. A blank field means that no statistically significant (on the 5%-level) relationship was found. The abbreviation nc means that a test was not calculated. Note the uncertainty (indicated by a ?) of some of the estimated relations for the US and the UK. These estimated short-run causal chains were not significant on traditional levels, but bordered on significance on the 10%-level. More detailed output of the estimations and tests are available on request.

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