Causality in the Saving–Growth Nexus: Empirical Evidence from Five Developed Countries*

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<Abstract>
Utilizing test procedures based on the notion of control causality and test procedure for superexogeneity, we examine the causal relationship between saving rate and economic growth using the annual time-series data for five developed countries. Our results provide empirical evidence that for four out of five countries economic growth control causes saving, but the reverse is not true. Policy implication of our finding is that since economic growth drives saving rates, rather the other way around, priorities should be given to policies to foster economic growth via raising investment growth and improve efficiency of such investment.

Key Words: Control Causality, Superexogeneity, Saving, Growth, Stability

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I. Introduction

While there is a large variation in the saving rate across countries, it is widely recognized that saving rates are positively related to economic growth rates regardless of the development stage. This observation is often backed by the long-run and short-run positive correlations among saving, investment, and growth rates. Given the close association between saving and growth, there is a general agreement as to the importance of saving in the growth process.\(^3\) However, the causal direction between saving and economic growth is far from clear as to whether saving causes growth, or growth causes saving, or that the causality may run both ways.

In resolving the issue of causality, theories of consumption and saving do not offer much help. Specifically, the neoclassical growth model by Solow (1956) and its modifications by Mankiw, Romer, and Weil (1992) suggest a causality running from saving to growth. On the other hand, the Life-Cycle Hypothesis by Modigliani (1970) predicts that a higher growth rate will lead to a higher saving rate, while one version of the permanent income hypothesis with forward-looking consumers by Campbell (1987) predicts that higher income growth may lead to a decline in the saving rate. Nor do results of empirical studies lend much help in resolving the causal

\(^3\) The importance of saving is highlighted by the conference on “Saving Across the World” held at the World Bank in Washington D.C. on September 16–18, 1998.
direction between the saving rate and the growth rate. While the saving–growth nexus has been studied extensively in many empirical studies, not much progress has been made thus far, as Deaton (1999) points out. The causality in the saving–growth nexus is important for a better understanding of how saving, investment, and economic growth are related. It is also important for the design of growth policy. If saving drives growth, then we need to give priorities to those saving incentives, like IRA, Keogh and other instruments designed to promote savings. But if economic growth drives saving, then priorities should be given to those policies to increase investment and to improve efficiency of such investment.

Given the need for better understanding of the relationship between saving and investment, the challenge is to ‘disentangle the dynamic paths of influence’, as Deaton (1999) puts it, between the two variables. As we take up this challenge, it is good to heed Deaton (1999)’s two suggestions for promising directions for future research. One is to apply ‘a range of tools’, including new procedures for causality tests; another is to make use of newly available individual households data, especially from the rapidly growing and high-saving countries in the East Asia.

4) Prominent studies are by Carroll and Weil (1994), Deaton (1999), and Attanasio, Picci, and Scorcu (2000). There are many other studies of saving and the growth for countries in Asia and in the Third World, and individual countries, like Korea, Taiwan, Thailand, Sri Lanka, Pakistan, and India.

5) Deaton and Paxson (2000) report their findings based on individual and household data from Taiwan and Thailand in examining how changes in the economic growth rate will affect the aggregate saving rate by changing the lifetime resources of younger people relative to older people. Their main
It is our purpose to apply a viable testing strategy for causality, based on the notion of control causality and test procedure for superexogeneity, in examining the saving-growth nexus within five individual countries over time. In control causality or superexogeneity, variable A affects variable B in probabilistic sense. Therefore the concept of control causality or superexogeneity is different from causality usually used in economics.

Specifically, we use annual data for the period from 1972 through 2000 for the U.S., U.K., Japan, Germany, and France. In setting up a working hypothesis for the causal direction between economic growth and saving, we first choose to view the saving-growth nexus as growth driving saving. This choice is made in view of more recent empirical evidence by Carroll and Weil (1994) and Deaton and Paxson (2000), providing empirical support to the causality from growth to saving. In the process, we will also examine the reverse causality from saving to growth. Our main finding is that for four out of five countries ‘growth control causes saving’, but not the other way around.

In the next section, we will briefly discuss the notion of control causality and describe the test procedure for superexogeneity. Then we present empirical results of the causality test for each of the five countries. Finally, a summary and major conclusions are presented in the last section.

findings are that changes in the rate of economic growth may have large effect on the aggregate saving rate, while the size and sign of these effects depends on the rate of economic growth and the rate of population growth.
II. Control Causality, Saving and Economic Growth

We begin with a brief discussion of concept of control causality between the saving rate (S) and economic growth (Y). If Y causes S, the data may be generated by the following:

\[ S_t = \beta Y_t + \varepsilon_t, \quad \varepsilon_t \sim N(0, \sigma_\varepsilon^2) \]  

(1)

\[ Y_t = \delta + u_t, \quad u_t \sim N(0, \sigma_u^2) \]  

(2)

where parameters of the saving rate process are \(\beta\) and \(\sigma_\varepsilon^2\), and those of the economic growth process are \(\delta\) and \(\sigma_u^2\).

Simon (1953) identifies the control causality as a property that is invariant to interventions in the data generating process. An intervention is represented by a change in the parameters of the process. If equations (1) and (2) are true, then interventions in the economic growth process, i.e., changes in \(\delta\) and \(\sigma_u^2\), result in instability of \(D(Y)\), \(D(Y \mid S)\), and \(D(S)\), and stability of \(D(S \mid Y)\), where \(D(\cdot \mid \cdot)\) is a conditional distribution and \(D(\cdot)\) is a conditional distribution.

6) Changes in the parameters of the process are often referred to as a structural break, policy intervention, or regime change. In the control causality literature, the parameter constancy in the conditional equation has been detected by testing the Chow-type stability conditions of the conditional equation during the period of interventions in the process of Y. See Hoover and Sheffrin (1992) and Perez (1998).
marginal distribution.\footnote{7)}

On the other hand, structural changes in the process for the saving rate, i.e. changes in $\beta$ and $\sigma^2_z$, result in instability of $D(S \mid Y)$, $D(Y \mid S)$, and $D(S)$, and stability of $D(Y)$. If $S$ causes $Y$, then the corresponding results in the conditional and marginal distributions and stability conditions are reversed. One-way control causation indicates three unstable and one stable distribution; and mutual control causation means four unstable distributions.\footnote{8)}

The stability conditions are closely related with parameter invariance, and control causality is closely related with superexogeneity (see Engle, Hendry and Richard, 1983; Engle and Hendry, 1993; and Perez, 2000).\footnote{9)} Control causality from $Y$ to $S$ in the sense that “the control of $Y$ renders $S$ controllable” holds if parameter changes in the marginal equation of $Y$ in Equation (2) will not affect the conditional equation for $S$ with respect to $Y$ in Equation (1). This condition requires that the parameters of the conditional equation of $S$ be constant with changes in the parameters of the marginal equation of $Y$.

\footnote{7) The resulting distributions are as follows: $D(S \mid Y) = N(\beta Y, \sigma^2_z)$, $D(Y) = N(\delta, \sigma^2_u)$, $D(Y \mid S) = N\left(\frac{\beta \sigma^2_z S + \delta \sigma^2_u}{\beta^2 \sigma^2_z + \sigma^2_u}, \frac{\sigma^2_z \sigma^2_u}{\beta^2 \sigma^2_z + \sigma^2_u}\right)$, $D(S) = N(\beta \delta, \beta^2 \sigma^2_u + \sigma^2_z)$. For more details, see Mood, Graybill, and Boes (1974), Hoover (1990), and Hoover and Sheffrin (1992) for derivations.}

\footnote{8) Refer to Footnote 5 and Table 1 in Yang and Yi (2002) for the directions of causality and associated stability conditions for both directions of causality.}

\footnote{9) Perez (2000) shows that the complexity of determining control causality is simplified by adopting the concept of superexogeneity proposed by Engle, Hendry and Richard (1983).}
The superexogeneity of $Y$ for the parameters ($\beta$) of the conditional equation for $S$ holds if the inference on $\beta$ is not affected by the way the parameters ($\delta$) of the marginal equation for $Y$ is specified (weak exogeneity of $Y$ for $\beta$) and changes in $\delta$ do not imply changes in $\beta$ (invariance of $\beta$).\textsuperscript{10} These two conditions in the test of the superexogeneity under the stable conditional equation are sufficient to the conditions for the test of control causality. Later we use this sufficiency property to determine the direction of control causality between saving rate and economic growth.

\section*{III. Empirical Methodology}

The conditional and marginal distributions can be interpreted as regression equations, as in Hoover (1990) and Engle and Hendry (1993). Equations (1) and (2) are generalized as follows, following Engle and Hendry (1993).

\begin{align*}
S_t &= \mu_S + \varepsilon_t = \beta Y_t + x_t' \gamma + \varepsilon_t, \quad \varepsilon_t \sim N(0, \sigma_{\varepsilon}^2) \\
Y_t &= \mu_Y + u_t = z_t' \delta + u_t, \quad u_t \sim N(0, \sigma_u^2)
\end{align*}

where $x_t$ is a set of variables included in the information set, and $z_t$ is a set of variables explaining $Y_t$. From the bivariate joint

\textsuperscript{10} In the superexogeneity literature, the parameter constancy has been examined by inserting the residual and squared residual of the marginal equation into the conditional equation and testing their significance during the period of $Y$ intervention. See Engle and Hendry (1993) and Perez (2000).
normal distributions of \( S \) and \( Y \), \( D(S_i | Y_i) \) is given by

\[
D(S_i | Y_i) = N(\mu'_s + \theta_i(Y_i - \mu'_y), \eta_i)
\]  \hspace{1cm} (5)

where
\[
\theta_i = \rho_i \left( \frac{\sigma'_s}{\sigma'_y} \right), \quad \rho_i = \frac{\sigma'_{S,Y}}{\sigma'_s \sigma'_y}, \quad \eta_i = \sigma'_{S,S}(1 - \rho_i^2). \hspace{1cm} (11)
\]

To test the control causality and then superexogeneity, we allow \( \beta' \) to be a variable, \( \beta' \). And to simplify the analysis as usual, we take a linear approximation of \( \beta' \mu'_y \) with respect to \( \mu'_y \) and \( \sigma'_{Y,Y} \) rather than second order approximation,

\[
\beta' \mu'_y = \beta(\mu'_y, \sigma'_{Y,Y}) \mu'_y = \beta_0 \mu'_y + \beta \sigma'_{Y,Y}
\] \hspace{1cm} (6)

Then substituting the conditional mean of \( S_i \), \( \mu'_s = \beta_0 \mu'_y + x_i' \gamma + \beta \sigma'_{Y,Y} \), into Equation (5), a simple manipulation yields the conditional equation for \( S \),

\[
S_i = \beta_0 Y_i + x_i' \gamma + (\theta_i - \beta_0) \hat{u}_i + \beta \hat{u}_i^2 + \epsilon_i
\] \hspace{1cm} (7)

where \( \hat{u}_i = Y_i - \mu'_y \), \( \hat{u}_i^2 = \sigma'_{Y,Y} \). Equation (7) may be used as the regression equation. The weak exogeneity condition requires that \( \theta_i = \beta_0 \), and the invariance condition requires that \( \beta_i = 0 \). In short,

11) See Mood, Graybill, and Boes (1974), pp.162-169.
the test for the superexogeneity of Y for β can be performed by the F-test of exclusion of $\hat{u}_t$ and $\hat{u}^2_t$ in Equation (7).

To consider the case of reverse causality of saving rate control causing economic growth, we may set up the conditional equation for Y and the marginal equation for S similarly.\(^{12}\)

The final step in the empirical implementation of the test in determining whether or not Y control causes S with interventions to Y, the conditional equation (3) and the marginal equation (4) are formally parameterized as follows,

\[
D(S_t \mid Y_t, R_t) = \Delta S_t = \alpha + \sum_i \beta_i \Delta \ln Y_{t-i} + \sum_i \gamma_i \Delta S_{t-i} + dS_{t-1} + eY_{t-1} + \sum_i f_i R_{t-i} + \epsilon_t
\]

(8)

\[
D(Y_t \mid R_t) = \Delta \ln Y_t = a + \sum_i b_i \Delta \ln Y_{t-i} + eY_{t-1} + \sum_i g_i R_{t-i} + u_t
\]

(9)

where R represents the real interest rate, which is a control variable, to account for its effect on saving rate and also to account for the contribution of investment to economic growth. In Equations (8) and (9), variables S and Y are introduced both in the difference and level forms to allow for both short and long run effects, as in the error correction model.

\(^{12}\) Y conditional equation may be expressed as

\[
Y_t = \beta_0 S_t + x_i' \gamma + (\theta_t - \beta_0) \hat{u}_t + \beta_1 \hat{u}^2_t + \epsilon_t,
\]

where $\hat{u}_t = S_t - \mu^i$, $\hat{u}^2_t = \sigma^2_{S.S}$. The test for the control causality from S to Y and superexogeneity of S for Y can be again performed by the F-test of exclusion of $\hat{u}_t$ and $\hat{u}^2_t$ in the above equation.
To test the superexogeneity of $Y$ for the parameters of $D(S_t | Y_t, R_t)$, we insert $\hat{u}_t$ and $\hat{u}_t^2$ into Equation (8) and obtain the following:

$$\Delta S_t = D(S_t | Y_t, R_t) + h\hat{u}_t + k\hat{u}_t^2$$  \hspace{1cm} (10)

where $\hat{u}_t$ and $\hat{u}_t^2$ are derived from the marginal equation after introducing the dummy variables to account for policy interventions. If the null hypothesis of $h=0$ is not rejected, then we conclude that $Y$ is weak exogenous for the parameters of $D(S_t | Y_t, R_t)$. If the null hypothesis of $h=0$ and $k=0$ is not rejected, then $Y$ is superexogenous for the parameters of $D(S_t | Y_t, R_t)$. If the conditional equation (8) is found to be stable and $Y$ is superexogeneous, then $Y$ control causes $S$.  \hspace{1cm} (13)

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13) The reverse causality from $S$ to $Y$ can be similarly examined as follows:

$$D(Y_t | S_t, R_t) = \Delta \ln Y_t = \alpha + \sum_i b_i \Delta S_{t-1} + \sum_i g_i \Delta \ln Y_{t-1} + d \ln Y_{t-1} + eS_{t-1} + \sum_i f_i R_{t-1} + \epsilon$$

$$D(S_t | R_t) = \Delta S_t = a + \sum_i b_i \Delta S_{t-1} + cS_{t-1} + \sum_i g_i R_{t-1} + u_t.$$
IV. Empirical Results

1. Data

For the estimation of conditional equation (8) and the marginal equation (9) with dummy variables, we use annual data for five countries (U.S., U.K., Japan, Germany, and France) during the period of 1972–2000. The data required for the estimation are the saving rate ($S$), the economic growth rate ($\triangle \ln Y$), real interest rate ($R$), and real GDP ($Y$). $S$ is measured by the ratio of saving to nominal GDP. The real interest rate is calculated as the nominal government bond yield of mid-term (3–5 years) minus the current rate of inflation derived from the CPI. All country data are extracted from the International Financial Statistics (IFS) database, which are internationally comparable time-series data.

2. Estimation Results

1) United States

Equation (8) and (9) are first estimated for the United States by allowing for four lagged terms for $S$ and $Y$. Then the final equations, based on these initial estimation results, are reconstructed and re-estimated by choosing those significant terms, based on the Hendry and Richard (1982) ‘general to specific’ approach. The results are presented below.
### Conditional Equation for Saving Rate

\[
\Delta S_t = 17.60* + 0.37** \Delta \ln Y_t + 0.02 \Delta \ln Y_{t-1} + 0.08 \Delta S_{t-2} + 0.05 \Delta S_{t-3} - 1.24 \ln Y_{t-1}
\]

(7.82)  (0.05)  (0.06)  (0.09)  (0.11)  (0.79)

\[-0.47**S_{t-1} - 0.11*R_{t-1} - 0.26*R_{t-2} + 0.23*R_{t-3} - 0.17**R_{t-4}\]

(0.09)  (0.05)  (0.10)  (0.10)  (0.04)

\[R^2=0.91, \quad \text{LM(2)}=0.80 \ [0.47]\]

### Marginal Equation for Economic Growth

\[
\Delta \ln Y_t = 12.55 + 0.07 \Delta \ln Y_{t-1} - 1.15 \ln Y_{t-1} + 0.27**R_{t-1} - 4.22**D_1 - 6.11**D_2 - 3.83**D_3
\]

(13.24)  (0.09)  (1.52)  (0.12)  (0.97)  (0.46)  (0.26)

\[R^2=0.60, \quad \text{LM(2)}=0.12 \ [0.89]\]

Note:  **: 1% significance level, *: 5% significance level

( ): heteroskedasticity and serial correlation consistent standard error; [ ]: p-value

In order to test the control causality from economic growth to saving rate, the stability for the conditional equation should be checked first. To obtain the robustness of the tests, we perform three stability tests of CUSUM of squares, recursive residuals, and recursive coefficients, whose results are presented in Figure 1 in the Appendix. Briefly, the path of CUSUM of squares lies within 5% significance lines, and the path of recursive residuals also lies within the two-standard error bands, both of which indicate stability in the parameters for the conditional equation. Additionally, the paths of recursive coefficients for the conditional equation do not display significant variations or show dramatic jumps as more data are added. Therefore, results of these three stability tests imply that there is no structural break for the conditional equation.
In order to judge if there might have been significant structural breaks or policy interventions to the marginal equation for economic growth, we examined the path of economic growth over time. A careful inspection of the path allows us to identify three episodes of major breaks, and we introduce three dummy variables to account for these breaks in the marginal equation: $D_1=1$ if year=1974, $D_2=1$ if year=1982, $D_3=1$ if year=1991. The estimated coefficients for the three dummy variables in the marginal equation for economic growth are significant at 1% level, clearly indicating the three major structural breaks in those years. The Breusch–Godfrey serial correlation LM test shows no serial correlation for the marginal equation.

(1) Test for Superexogeneity

To test the superexogeneity of the economic growth for the parameters of the conditional equation for the saving rate, we estimate Equation (10) for U.S., and the results are presented below.

$$
\Delta S_t = 18.88* + 0.33** \Delta \ln Y_t + 0.03 \Delta \ln Y_{t-1} + 0.11 \Delta S_{t-2} + 0.05 \Delta S_{t-3} - 1.41 \ln Y_{t-1}
$$

\[ (8.76) \quad (0.05) \quad (0.06) \quad (0.13) \quad (0.12) \quad (0.89) \]

$$
- 0.46** S_{t-1} - 0.11 R_{t-1} - 0.24 R_{t-2} + 0.22 R_{t-3} - 0.15** R_{t-4} + 0.10 \hat{\epsilon_t} - 0.00 \hat{\epsilon_t}^2
$$

\[ (0.10) \quad (0.10) \quad (0.20) \quad (0.14) \quad (0.04) \quad (0.07) \quad (0.07) \]

$R^2=0.91, \quad LM(2)=1.78 \ [0.22], \quad Joint \ F = 1.44 \ [0.28]$
We find that estimated coefficients for \( \hat{u}_t \) and \( \hat{u}_t^2 \) are both insignificant at the 5% level; and the \( p \)-value for the joint F-test of excluding \( \hat{u}_t \) and \( \hat{u}_t^2 \) is 0.28. Therefore, the parameters of the conditional equation for the saving rate are found to be stable even with structural breaks in the marginal equation, as discussed earlier, during the estimation period from 1972 to 2000. From the stable conditional equation for the saving rate and the superexogeneity of economic growth, it can be inferred that the economic growth control causes the saving rate.

(2) Test for Reverse Causality

To examine the reverse causality from the saving rate to the economic growth, we estimate the conditional equation for economic growth and the marginal equation for the saving rate, and the results are summarized below.

**Conditional Equation for Economic Growth**

\[
\Delta \ln Y_t = -7.27 + 1.62^{**} \Delta S_t - 0.18 \Delta S_{t-1} - 0.14 \Delta \ln Y_{t-2} + 0.43 \ln Y_{t-1} + 0.42 S_{t-1} + 0.44 R_{t-2} - 0.10 R_{t-3}
\]

\[(25.86) \ (0.26) \ (0.32) \ (0.11) \ (2.41) \ (0.43) \ (0.21) \ (0.16)\]

\[R^2=0.68, \quad LM(2)=1.56 \ [0.24]\]

**Marginal Equation for Saving Rate**

\[
\Delta S_t = 9.00 - 0.15 \Delta S_{t-2} - 0.05 \Delta S_{t-3} - 0.53 S_{t-1} - 0.16 R_{t-1} - 0.20^{**} R_{t-4}
\]

\[(3.16) \ (0.13) \ (0.11) \ (0.19) \ (0.08) \ (0.06)\]

\[R^2=0.54, \quad LM(2)=0.49 \ [0.62]\]

Examining the estimation results for the conditional equation for
economic growth, we note that the short-run effect of a higher saving rate on the growth rate is positive and significant. For the marginal equation of the saving rate, we note that the interest rate effect on saving is also negative and significant. The Breusch–Godfrey serial correlation LM test shows no serial correlation in the both equations. Next, we also perform the three stability tests of CUSUM of squares, recursive residuals, and recursive coefficients for the conditional equation for economic growth. [Figure 2 in the Appendix]. Examination of the path of CUSUM of squares shows that the path went outside of the 5% significance line in 1989 and stayed outside until 1997 when the path moves back within the line. The path of recursive residuals shows that it briefly went outside the two standard-error bands in 1991 and 1999. Finally, the paths of recursive coefficients display large changes in estimated parameters over time, as data are added. The magnitude of changes in the estimated coefficients over time is much larger than in the case for the test of causality from growth to saving earlier. The results of these three stability tests show that there are structural breaks for the conditional equation for economic growth. Since the parameters of the economic growth equation are not stable, it suggests that the saving rate does not control cause the economic growth. Therefore, we conclude that for the United States the economic growth control causes the saving rate, but the reverse is not true.
2) United Kingdom

Since the presentation and discussion of estimation results for the remaining four countries are similar to those of the United States, it is best to be brief. We will highlight only the important results, and focus on the differences, if any. The estimation results of Equations (8) and (9) for the U.K. are presented below.

**Conditional Equation for Saving Rate**
\[
\Delta S_t = 47.33** + 0.26** \Delta \ln Y_t + 0.43** \Delta \ln Y_{t-2} - 0.05 \ \Delta S_{t-2} + 0.22* \Delta S_{t-4} - 5.29** \ln Y_{t-1} \\
(14.65) \quad (0.09) \quad (0.13) \quad (0.16) \quad (0.10) \quad (1.76)
\]
\[-0.82**S_{t-1} - 0.13**R_{t-2} - 0.10*R_{t-3} \\
(0.21) \quad (0.03) \quad (0.04)
\]
\[R^2=0.71, \quad LM(2)=0.41 \ [0.68]\]

**Marginal Equation for Economic Growth**
\[
\Delta \ln Y_t = 11.44 + 0.57** \Delta \ln Y_{t-1} - 0.34* \Delta \ln Y_{t-2} - 0.20 \Delta \ln Y_{t-4} - 1.46 \ln Y_{t-1} \\
(9.59) \quad (0.10) \quad (0.12) \quad (0.13) \quad (1.54)
\]
\[+ 0.03 \ R_{t-1} + 0.13* \ R_{t-4} - 3.63**D_1 - 2.94** \ D_2 \\
(0.07) \quad (0.06) \quad (0.43) \quad (0.34)
\]
\[R^2=0.82, \quad LM(2)=1.38 \ [0.29]\]

To test the control causality from economic growth to the saving rate, the stability for the conditional equation is first checked. As in Figure 2a–2c, the path of CUSUM of squares lies within 5% significance lines; and the path of recursive residuals lies within the two-standard error bands; the path of recursive coefficients appear stable as well. The results of all three stability tests clearly indicate
stability in the parameters for the conditional equation. Next, we identified two structural breaks on the basis of visual inspection of the path of economic growth over time, and introduce two dummy variables in the marginal equation: D1=1 if year=1980, D2=1 if year=1991. The estimated coefficients for the dummy variables are significant, indicating the two major structural breaks in the marginal equation for economic growth. The Breusch–Godfrey serial correlation LM test shows no serial correlation.

(1) Test for Superexogeneity

To test the superexogeneity of economic growth for the parameters of the conditional equation for the saving rate, we estimate and test the significance of \( \hat{u}_t \) and \( \hat{u}^2_t \) in the Equation (10) for U.K. as follows:

\[
\Delta S_t = 45.21^* + 0.32^{**} \Delta \ln Y_t + 0.44^* \Delta \ln Y_{t-2} - 0.06 \Delta S_{t-2} + 0.28^* \Delta S_{t-4} - 5.02^* \ln Y_{t-1} - 0.81^* S_{t-1} - 0.12^{**} R_{t-2} - 0.12^* R_{t-3} - 0.22 \hat{u}_t + 0.00 \hat{u}^2_t
\]

\[
(19.13) \quad (0.07) \quad (0.21) \quad (0.16) \quad (0.11) \quad (2.24) \quad (0.29) \quad (0.03) \quad (0.05) \quad (0.20) \quad (0.29)
\]

\[R^2=0.73, \quad \text{LM(2)}=0.95 \quad \text{[0.42]}, \quad \text{Joint F} = 3.19 \quad \text{[0.07]}\]

The estimated coefficients of \( \hat{u}_t \) and \( \hat{u}^2_t \) are both insignificant at the 5% level and the p-value for the joint F-test of excluding \( \hat{u}_t \) and \( \hat{u}^2_t \) is 0.07, indicating that the parameters of the conditional
equation are stable at 5% significance level. From the stable conditional equation for saving rate and the superexogeneity of economic growth, it can be also inferred that the economic growth *control causes* the saving.

(2) Test for Reverse Causality

To examine the possibility of reverse causality from the saving rate to the economic growth, we also estimate the conditional equation for economic growth and the marginal equation for the saving rate.\(^\text{15}\) Based on these estimation results, we conduct three stability tests (Figures 2d–2f in Appendix). First, we find that the path of CUSUM of squares went outside the upper significance line at 5% in 1985, came within the line in 1998 and went outside again and stayed outside 5% significance line until 1993, clearly indicating instability in the conditional equation. The two other stability tests show no such instability, as evidenced by the recursive residuals staying inside the two standard-error bands and the path of recursive coefficients displaying only minor changes as data is added. So the results of three stability tests are somewhat mixed, but it is safe and reasonable to conclude that the parameters of the economic growth equation are not stable, as long as at least one of the three tests, in this case the CUSUM of squares test, shows any evidence of instability. We therefore conclude that the saving rate does not *control cause* economic growth. In conclusion, empirical

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\(^{15}\) For United Kingdom, Japan, Germany, France, these results are not reported here for the space consideration and available upon request.
evidence show that for U.K. the economic growth control causes the saving rate, but the reverse is not true.

3) Japan

The estimation results of equation (8) and (9) for Japan are presented below.

**Conditional Equation for Saving Rate**

\[ \Delta S_t = -10.52 + 0.24** \Delta \ln Y_t + 0.29** \Delta \ln Y_{t-1} + 0.20 \Delta S_{t-3} + 0.20 \Delta S_{t-4} \\
+ 1.75* \ln Y_{t-1} - 0.43** S_{t-1} - 0.06R_{t-4} \]

R\(^2\)=0.79, \quad LM(2)=0.60 \ [0.56]

**Marginal Equation for Economic Growth**

\[ \Delta \ln Y_t = 45.79** + 0.43** \Delta \ln Y_{t-1} - 3.45* \ln Y_{t-1} + 0.01 R_{t-1} - 7.84** D_1 \\
+ 2.82** D_2 - 3.88** D_3 \]

R\(^2\)=0.83, \quad LM(2)=0.53 \ [0.60]

Examining the results of stability tests, (Figure 5 in the Appendix), we find that the path of CUSUM of squares lies within the 5% significance lines; and that the path of recursive residuals also lies within the two-standard error bands. In addition, the path of recursive coefficients looks stable as well. All of these results clearly indicate that parameters of the conditional equation are
stable. For the estimation of the marginal equation for economic growth, we first identified by visual inspection three major structural breaks in the path of economic growth rates over time. To account for them, we introduced three dummy variables in the marginal equation: \( D_1 = 1 \) if year=1974, \( D_2 = 1 \) if year=1988, \( D_3 = 1 \) if year=1998. The estimated coefficients for the dummy variables are highly significant at 1% level. The Breusch–Godfrey serial correlation LM test shows no serial correlation.

(1) Test for Superexogeneity

To test the superexogeneity of the economic growth for the parameters of the conditional equation for the saving rate, we estimate and test the significance of \( \hat{u}_t \) and \( \hat{u}_t^2 \) in the equation (10) for Japan as follows:

\[
\Delta S_t = -7.46 + 0.18^{**} \Delta \ln Y_t + 0.32^{**} \Delta \ln Y_{t-1} + 0.21 \Delta S_{t-3} + 0.22 \Delta S_{t-4} \\
(6.82) \ (0.06) \ (0.09) \ (0.18) \ (0.13)
\]

\[
+ 1.51^* \ln Y_{t-1} - 0.43^{**} S_{t-1} - 0.06 R_{t-4} + 0.11 \hat{u}_t - 0.02 \hat{u}_t^2 \\
(0.60) \ (0.08) \ (0.07) \ (0.09) \ (0.05)
\]

\[ R^2=0.80, \quad \text{LM}(2)=0.38 [0.69] \quad \text{Joint F } =0.77 [0.48] \]

The estimated coefficients of \( \hat{u}_t \) and \( \hat{u}_t^2 \) are both insignificant at the 5% level and the \( p \)-value for the joint F-test of excluding \( \hat{u}_t \) and \( \hat{u}_t^2 \) is 0.48, implying that the parameters of the conditional equation are stable (with the introduction of structural breaks in
the marginal equation directly into the conditional equation). From the stable conditional equation for the saving rate and the superexogeneity of economic growth, it can be inferred that economic growth control causes the saving rate for Japan too.

(2) Test for Reverse Causality

To examine the reverse causality from the saving rate to economic growth, we estimate the conditional equation for economic growth and the marginal equation for the saving rate. The Breusch–Godfrey serial correlation LM test shows no serial correlation. Applying the same three stability tests reveal that the path of CUSUM of squares in Figure 3d lies within the 5% significance lines, while the path of the recursive residuals in Figure 3e shows large fluctuations and went outside the two standard-error lower band in 1998. Visual inspection of recursive coefficients shows fairly large changes in parameters in earlier period as data are added. On balance, we find that parameters of the conditional equation for the economic growth are not stable. These results lead us to conclude that saving does not control cause economic growth. Therefore, we conclude that for Japan economic growth control causes the saving rate, but the reverse is not true.

4) Germany

The estimation results of equation (8) and (9) for Germany are presented below.
Conditional Equation for Saving Rate

\[ \Delta S_t = 16.12 + 0.07 \Delta \ln Y_t - 0.12 \Delta \ln Y_{t-3} - 0.08 \Delta \ln Y_{t-4} - 0.20 \Delta S_{t-4} \]

\[ - 1.03 \ln Y_{t-1} - 0.43 S_{t-1} + 0.07 R_{t-2} + 0.53 ** R_{t-3} \]

\[ R^2 = 0.62, \quad \text{LM}(2) = 0.96 [0.41] \]

Marginal Equation for Economic Growth

\[ \Delta \ln Y_t = 46.15 ** - 0.18 \Delta \ln Y_{t-3} - 5.66 ** \ln Y_{t-1} + 0.22 R_{t-3} + 0.32 R_{t-4} \]

\[ - 7.02 ** D_1 - 9.55 ** D_2 + 5.45 ** D_3 \]

\[ R^2 = 0.81, \quad \text{LM}(2) = 1.12 [0.35] \]

In examining the stability for the conditional equation (Figures 4a-4c in Appendix) we find that the path of CUSUM of squares lies within 5% significance lines; and the path of recursive residuals lies within the two-standard error bands, both of which indicate the stability of conditional equation. An examination of the of recursive coefficients shows some variations in the early years, but they remain relatively stable in the remaining years.

For the marginal equation for economic growth, we also identified three major breaks in the path of economic growth and introduced the three dummy variables in the marginal equation: \( D_1 = 1 \) if year=1979, \( D_2 = 1 \) if year=1985, \( D_3 = 1 \) if year=1990. The estimated coefficients for the dummy variables are significant. The Breusch-Godfrey serial correlation LM test shows no serial correlation.
(1) Test for Superexogeneity

To test the superexogeneity of the economic growth for the parameters of the conditional equation for the saving rate, we estimate and test the significance of $\hat{u}_t$ and $\hat{u}_t^2$ in the equation (10) as follows:

$$\Delta S_t = 20.38^* + 0.13\Delta \ln Y_t - 0.13^*\Delta \ln Y_{t-3} - 0.07 \Delta \ln Y_{t-4} - 0.30^*\Delta S_{t-4}$$

$$(7.03) \quad (0.10) \quad (0.05) \quad (0.05) \quad (0.11)$$

$$- 1.36^*\ln Y_{t-1} - 0.51S_{t-1} + 0.12R_{t-2} + 0.55^*R_{t-3} - 0.12\hat{u}_t - 0.13\hat{u}_t^2$$

$$(0.59) \quad (0.18) \quad (0.12) \quad (0.07) \quad (0.15) \quad (0.06)$$

$R^2=0.74, \quad LM(2)=2.24 \ [0.15], \quad \text{Joint F} = 3.07 \ [0.08]$ 

The estimated coefficients of $\hat{u}_t$ and $\hat{u}_t^2$ are both insignificant at the 5% level and the $p$-value for the joint F-test of excluding $\hat{u}_t$ and $\hat{u}_t^2$ is 0.08. This implies that parameters of the conditional equation are stable at 5% significance level. From the stable conditional equation for the saving rate and the superexogeneity of economic growth, it can be inferred that the economic growth control causes the saving rate.

(2) Test for Reverse Causality

To examine the reverse causality from the saving rate to the economic growth, we estimate the conditional equation for economic growth and the marginal equation for the saving rate. The
Breusch–Godfrey serial correlation LM test in these estimations shows serial correlation in the conditional equation, while we find no such evidence for the marginal equation. From applying the same three stability tests, whose results are presented as Figures 4d–4f in Appendix, we find that the path of CUSUM of squares went outside of the 5% significance upper line in about 1989 and stayed briefly outside before it moves back within the line in 1992. The path of recursive residuals stays within the two standard-error bands, and the recursive coefficients over time show fairly large variations in early years but seem to stabilize over time. Since the parameters for the equation for economic growth are not stable, as indicated by the CUSUM squares test, we may conclude that the saving rate does not control cause economic growth, but the reverse is not true.

5) France

The estimation results of equation (8) and (9) for France, presented below, are similar to those for the four other countries.

Conditional Equation for Saving Rate
\[
\Delta S_t = 3.51 + 0.64^{**} \Delta \ln Y_t + 0.18 \Delta \ln Y_{t-2} - 0.27 \Delta S_{t-1} - 0.57^{*} \Delta S_{t-2} \\
- 0.57 \ln Y_{t-1} - 0.08 S_{t-1} + 0.32^* R_{t-2}
\]

\[
(7.02) \quad (0.06) \quad (0.15) \quad (0.16) \quad (0.24)
\]

\[
R^2=0.82, \quad \text{LM}(2)=0.91 \ [0.42]
\]
Marginal Equation for Economic Growth

\[ \Delta \ln Y_t = 26.66 + 0.43^{**} \Delta \ln Y_{t-1} - 0.45^* \Delta \ln Y_{t-4} - 2.78 \ln Y_{t-1} \]

\[ + 0.28 R_{t-3} + 0.33 R_{t-4} \]

\[ (28.77) \hspace{1cm} (0.13) \hspace{1cm} (0.19) \hspace{1cm} (3.29) \hspace{1cm} (0.20) \hspace{1cm} (0.22) \]

\[ R^2 = 0.45, \quad LM(2) = 0.92 \quad [0.42] \]

The results of the three stability tests for the conditional equation for France (Figures 5a–5c in Appendix) shows that the path of CUSUM of squares lies outside 5% significance line during the 1994–1998 period, and the path of recursive residuals also went outside the two-standard error bands in 1999. Furthermore, a visual inspection of recursive coefficients over time also confirms the instability of parameters evident in the first two stability tests. Considering the results of the three stability tests together, we find that parameters for the conditional equation for the saving rate are unstable. Given the evidence of parameter instability for the conditional equation, we no longer need to specify and estimate the marginal equation for economic growth.

To examine the possibility of reverse causality, we first estimate the conditional equation for economic growth and the marginal equation for the saving rate. The results of the same three stability tests for France (Figures 6a–6c in Appendix) show that parameters of the conditional equation of economic growth for France are also unstable. Since parameters of both conditional equations for the saving rate and economic growth are unstable, we are forced to conclude that the direction of causality is not certain for France.
We simply do not have any clear evidence on the causal direction in the relationship between saving rate and economic growth.

V. Summary and Conclusions

We have applied in this paper a viable testing strategy for causality, based on the notion of control causality and test procedure for superexogeneity, in examining the causal direction in the saving–growth nexus. We used annual data from five developed economies (U.S., U.K., Japan, Germany, and France) for the period from 1972 through 2000. In carrying out our estimation, we chose as a working hypothesis to view the saving–growth nexus as growth driving saving. We also examined the reverse causality. Our empirical results show that for the first four countries economic growth control causes the saving rate, but the reverse is not true. For France, however, it was not possible to determine which way the causality runs, because both the conditional equations for economic growth and for the saving rate were found to be unstable. Overall, the thrust of our empirical findings lends support to a more recent view that economic growth causes the saving rate presented by Bosworth (1993), Carroll and Weil (1994), and Deaton and Paxson (2000). Considering that the five countries chosen for our study are all advanced industrialized countries, it seems reasonable to conclude then that economic growth appears to 'control causes' saving in mature economies at late stages of economic development. It would be interesting to know whether or
not our finding of causality running from economic growth to saving would also hold for the less-developed countries with poorly developed financial sector and where lack of saving may serve as a major constraint on economic growth. Our findings also provide supporting evidence to a view offered by Bosworth (1993) that lower rates of income growth are primarily responsible for reduced rates of private saving in developed countries. Finally, since our findings indicate that economic growth causes saving, it makes more sense to give priorities to those policies designed to enhance the potential GDP, rather than to those policies designed to raise saving rate, such as IRA and Keogh and other saving enhancing policies. Growth-enhancing policies may include those designed to bring about technical advance and to foster social institutions that mold technical advance, as well as those policies to increase investment and improve efficiency of such investment.
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Appendix

<Figure 1> Stability Tests of Conditional Equation for Saving : U.S.

a. CUSUM of Squares: $\Delta S_t$

b. Recursive Residuals: $\Delta S_t$

*  ------ : 5% Significance
*  ------: ± 2 Standard Error

<Figure 2> Stability Tests of Conditional Equation for Economic Growth : U.S.

a. CUSUM of Squares: $\Delta \ln Y_t$

b. Recursive Residuals: $\Delta \ln Y_t$

*  ------ : 5% Significance
*  ------: ± 2 Standard Error
Figure 3. Stability Tests of Conditional Equation for Saving: U.K.

- a. CUSUM of Squares: $\Delta S_i$
- b. Recursive Residuals: $\Delta S_i$

* *- - - - - - - - - - - - : 5% Significance  
* *- - - - - - - - - - - - : ± 2 Standard Error

Figure 4. Stability Tests of Conditional Equation for Economic Growth: U.K.

- a. CUSUM of Squares: $\Delta \ln Y_i$
- b. Recursive Residuals: $\Delta \ln Y_i$

* *- - - - - - - - - - - - : 5% Significance  
* *- - - - - - - - - - - - : ± 2 Standard Error
<Figure 5> Stability Tests of Conditional Equation for Saving: Japan
a. CUSUM of Squares: $\Delta S_t$

b. Recursive Residuals: $\Delta S_t$

* ----- : 5% Significance
* ------: ± 2 Standard Error

<Figure 6> Stability Tests of Conditional Equation for Economic Growth: Japan
a. CUSUM of Squares: $\Delta \ln Y_t$

b. Recursive Residuals: $\Delta \ln Y_t$

* ----- : 5% Significance
* ------: ± 2 Standard Error
<Figure 7> Stability Tests of Conditional Equation for Saving: Germany

a. CUSUM of Squares: $\Delta S_t$

b. Recursive Residuals: $\Delta S_t$

* ----- : 5% Significance

* ----- : ±2 Standard Error

<Figure 8> Stability Tests of Conditional Equation for Economic Growth: Germany

a. CUSUM of Squares: $\Delta \ln Y_t$

b. Recursive Residuals: $\Delta \ln Y_t$

* ----- : 5% Significance

* ----- : ±2 Standard Error
<Figure 9> Stability Tests of Conditional Equation for Saving: France
a. CUSUM of Squares: $\Delta S_t$

* ------ : 5% Significance

* ------ : ± 2 Standard Error

<Figure 10> Stability Tests of Conditional Equation for Economic Growth: France
a. CUSUM of Squares: $\Delta \ln Y_t$

* ------ : 5% Significance

* ------ : ± 2 Standard Error