Consumption Smoothing Channels in Open Economies*

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Abstract

We recognize that intertemporal models of the current account (Frankel and Razin with Yuan 1996, or Baxter and Crucini 1993) imply a theory of consumption smoothing channels, and thus we build an empirical model on the theoretical foundations of Sachs (1982)'s optimizing model in order to analyze the intertemporal smoothing role of saving components (fixed investments, inventories and trade balance). The estimation is conducted in a structural VAR framework, in which the minimal identifying restrictions are consistent with both the "intertemporal approach to the current account" and the empirical consumption smoothing literature. Through the use of impulse response functions following different types of shocks, we find that for the OECD countries the bulk of intertemporal smoothing has been carried out domestically, through gross fixed investments and inventories, but the trade balance has also played a relevant — albeit volatile — smoothing role. We also determine the dynamic role of each component: the trade balance and inventories are mostly used as short-run smoothing tools while fixed investment provides more and more smoothing over time. Since our framework can accommodate various models of the current account, we can address some empirical puzzles, such as the "excess sensitivity of investment" anomaly (Glick and Rogoff, JME 1995) and the "saving-investment puzzle" (Feldstein and Horioka, EJ 1980).

1. Introduction

Modern open economy macroeconomics is based on intertemporal optimization, and in particular on the consumption smoothing condition imposed by the Euler equation. Yet not many empirical models in the field focus on the properties of consumption smoothing. This paper aims to set up a framework that unifies the analysis of different strands of the empirical open economy literature from the viewpoint of consumption smoothing channels. Following the empirical literature on consumption smoothing channels (Sørensen and Yosha 1998, Asdrubali and Kim 2004), on the intertemporal approach to the current account (Glick and Rogoff 1995, Ghosh 1995), and on the international real business cycle (Baxter 1995, Baxter and Crucini 1993, 1995), we impose identifying restrictions on national accounts identities, and analyze smoothing channels jointly through a structural VAR's impulse responses. We show that the identifying restrictions and the variables in the empirical model are consistent with the natural implications of intertemporal open economy models (e.g., Obstfeld and Rogoff 1996, Baxter and Crucini 1995). In fact, our framework recasts the standard intertemporal approach to the current account (e.g., Obstfeld and Rogoff 1995) in terms of consumption smoothing channels, and estimates the smoothing effects not only of the current account (or trade balance), but also of other savings components (such as inventory investments). This allows us to look more deeply into the "excess sensitivity of investment" anomaly, documented by Glick and Rogoff (1995). We can also generalize the main tenets of International RBC-type models á la Baxter and Crucini (1995) and Baxter (1995) by estimating the intertemporal smoothing properties of a bonds-only asset market structure.

Our econometric setup can encompass Feldstein and Horioka (1980)-type issues and assess, for example, whether the dynamic responses of saving, investment, and the trade balance depend on the source or type of structural shock hitting the economy. As Ghosh (1995) pointed out, if capital is mobile then the current account should act as a buffer to smooth consumption in the face of shocks to output, investment and government expenditure. Using this criterion we will look for evidence of capital market barriers.

Besides contributing methodologically to the consumption smoothing literature — intended in the above-mentioned broader sense — through a deeper look into the factors of smoothing and their joint dynamics, this paper's application to the OECD countries improves upon the existing consumption smoothing channels literature by using quarterly data. This allows to assess finer dynamic properties of smoothing channels at business cycle frequency, providing a better connection to business cycle studies; but it also allows us to explore the evolution of intertemporal smoothing channels in the 90s without incurring in the efficiency loss inherent in a yearly estimation.

We find that our "smoothing approach" is quite fruitful, in the sense that all the saving channels we consider play a relevant stabilizing role in response to income shocks: the bulk of intertemporal smoothing has been carried out domestically — through gross fixed investments, inventories, and government expenses — but the trade balance has also played a relevant smoothing role. In addition, we find that the dynamic role of each component is quite different; the trade balance and inventories are mostly used as short-run smoothing tools while fixed investment (and possibly government expenditure) provides more and more smoothing over time. In addition, long run smoothing in the 90s is higher than in the 80s, due to the trade balance effect. Finally, since our framework can accommodate various models of the current account, we document empirically relevant mechanisms underlying the "excess sensitivity of investment" anomaly (Glick and Rogoff, 1995) — which turns out to be linked primariily to the saving behavior — and the "saving-investment puzzle" (Feldstein and Horioka, 1980) — which seems to emerge after a productivity shock, and to disappear when the investment change is exogenous.

The analysis proceeds as follows. Section 2 presents the basic theoretical model on saving components which represents a reference for our econometric specification. Section 3 develops the econometric method for the consumption smoothing channels' decomposition. Section 4 illustrates the data. Section 5 documents the empirical results based on the impulse responses of various smoothing channels to structural shocks of various source. Section 6 concludes with the summary of results.

2. Consumption Smoothing Theory in Open Economy

2.1. Intertemporal Model

2.1.1. The Sachs equation

Consider the small open economy model with perfect capital mobility which constitutes the workhorse of the so called "Intertemporal Approach to the Current

Account."[1] In this economy, risk-free international lending and borrowing is allowed without any restrictions. Then, the permanent income hypothesis suggests that changes in consumption depend on innovations in permanent net private income.[2] That is,

$$\Delta C_t = \Delta E_t \widetilde{Z}_t - \Delta E_t \widetilde{I}_t \tag{2.1}$$

where we have defined private income $Z \doteqdot Y - G$, Y is gross domestic income, C is private consumption, I is gross investment and G government consumption expenditures, while $\Delta E_t \widetilde{X_t}$ is the innovation in the expected permanent value of the variable X_t, that is, $\Delta E_t \widetilde{X_t} \equiv \frac{r}{1+r} \sum_{s=t}^{\infty} \left(\frac{1}{1+r}\right)^{s-t} \Delta E_t X_s$.

Substituting for ΔC_t in the national account identity $\Delta TB_t = \Delta Z_t - \Delta I_t^f - \Delta I_t^s - \Delta C_t$, we obtain a first-differenced version of the Sachs (1982) equation

$$\Delta TB_t = (\Delta Z_t - \Delta E_t \widetilde{Z}_t) - (\Delta I_t^f - \Delta E_t \widetilde{I_t^f}) - (\Delta I_t^s - \Delta E_t \widetilde{I_t^s}) \tag{2.2}$$

where TB is the trade balance and gross investment I_t has been decomposed into gross fixed investment I_t^f and inventories I_t^s.

The intertemporal approach recognizes that the responses of the key national account variables to income shocks depend on the nature of the shocks. While global income shocks should have no effect on the trade balance (Glick and Rogoff 1995), on the contrary if consumption follows permanent income, idiosyncratic income shocks elicit responses that differ depending on the persistence of the shock. The more persistent the temporary income shock, the lower the change in the same direction of the trade balance, coeteris paribus; when the income process follows a random walk, the trade balance does not change, coeteris paribus. When the shock is permanent and future income is expected to rise, coeteris paribus permanent income overshoots current income, current consumption should follow suit and the trade balance should jump in the opposite direction.

Based on the Sachs specification (2.2), one may infer how income shocks are either amplified or smoothed out by the two types of investments (fixed and inventory investments), before trade balance changes adjust. A temporay income

[1] See Sachs (1982) for an earlier contribution to this literature, and Obstfeld and Rogoff (1996) for detailed textbook level presentation.

[2] The relation holds for a quadratic utility function or a linearized model. See Flavin (1980) and Campbell and Mankiw (1989) for a derivation, and Kimball (2003) for a defense of the certainty equivalence approximation to uncertainty.

shock will not have effect on the trade balance if investment is fully procyclical. Similary, a positive permanent income shock may elicit a trade surplus if investment moves very slowly towards its permanent level. The next step will thus be an explicit treatment of investment behavior.

2.1.2. Modelling investment

While the early empirical literature on the intertemporal approach (e.g. Sheffrin and Woo 1990 and Otto 1992) examined the implications of net private output shocks ($\Delta Z_t - \Delta I_t$) on the current account, we follow recent empirical studies (e.g. Glick and Rogoff 1995) in treating investment as both a source of capital accumulation and output growth, and as endogenous to income shocks (or productivity shocks). In fact, as will be shown in the empirical model of the next section, the smoothing role of investment can be made explicit and measured from how investment endogenously responds to income shocks (or productivity shocks); in addition, the lagged dynamics of output are in turn affected by investment changes.

We therefore model the behavior of investment in its role in the capital accumulation process, and then substitute the resulting expression in the Sach's equation. The standard way of doing that is to specify a version of Tobin's q theory, drawing on the independence of investment decisions from saving decisions in a small open economy.[3]

The model assumes a production function of $Y_t = A_t F(K_t)$ where A_t is the productivity index and K_t is the capital stock. In this small open production economy, investment is subject to installation costs $\frac{zI_s^2}{2K_s}$ and in equilibrium it is determined by the profit-maximizing condition:[4]

$$I_t = \frac{q_t - 1}{g} K_t \tag{2.3}$$

where g is the cost-of-adjustment coefficient and q_t, the shadow price of installed capital, is the firm's market value per unit of capital, defined recursively as:

$$q_t = E_t \frac{1}{(1+r)} \left[A_{t+1} F'(K_{t+1}) + \frac{g}{2} \left(\frac{I_{t+1}}{K_{t+1}} \right)^2 + q_{t+1} \right] \tag{2.4}$$

The variant of Sachs' equation will then obey

[3] This investment modelling follows Frankel and Razin with Yuen (1996).

[4] See Obstfeld and Rogoff (1995).

$$
\begin{aligned}
\Delta TB_t \;=\; & \left\{ [\Delta A_t F(K_t) - \Delta G_t] - \left[\Delta E_t \widetilde{A_t F(K_t)} - \Delta E_t \widetilde{G_t} \right] \right\} - \qquad (2.5) \\
& \left[\Delta \frac{(q_t^f - 1)}{g} K_t - \Delta E_t \frac{\widetilde{(q_t^f - 1)}}{g} K_t \right] - \left[\Delta \frac{(q_t^s - 1)}{z} K_t - \Delta E_t \frac{\widetilde{(q_t^s - 1)}}{z} K_t \right]
\end{aligned}
$$

where output is defined net of installation costs and q_t^f and q_t^s refer to gross fixed investment and to inventory investment, respectively.

2.1.3. Dynamics

The dynamics implied by (2.1), (2.5), and (2.4) depend on the nature of productivity shocks. An unanticipated persistent or permanent positive shock to A_t induces an immediate increase in Y_t followed by a rise in expected profits, hence in q_t and I_t; the income increase will be persistent or permanent, respectively, although income changes will be further affected by the investment rise later. Consumption will change one-to-one with respect to innovations in expected permanent net private output, $\Delta E_t \widetilde{Z}_t - \Delta E_t \widetilde{I}_t$. The change in the trade balance will be perfectly complementary to that in consumption, depending only on the temporary component of the current net private output change.[5] The more persistent the productivity shocks, the larger the permanent component and the smaller the temporary component of net private output. Therefore, the more persistent the productivity shocks, the larger the consumption response, and the more negative the initial trade balance response.[6]

In this variant of equation (2.2), investment responds to a persistent productivity shock (since both q^f and q^s depend on the productivity process), but it in turn affects output through the capital accumulation process. Note that investment changes affect capital stock, thus output, at least one period after its installation (time-to-build), and further installation costs will delay the capital adjustment process. Hence, after an unexpected permanent positive productivity shock, investment does not jump up immediately to the optimal level then fall to the steady state next period; rather, it approaches the steady state only slowly.

[5] A purely temporary (one-period) shock to A_{t+1}, instead, only exerts its effects on output, not on investment. As a consequence, the trade balance must necessarily rise, while consumption stays put.

[6] Note that the temporary component may move opposite to the current output changes when the permanent component changes more than the current output.

Since consumption is still supposed to follow expected net private permanent income, the current account deficit will last more than one period, and decrease as saving and investment both converge to the steady state.

The complexity of these dynamic responses defies simple analyses, such as the seminal work by Glick and Rogoff (1995), which determines I and TB (actually, the current account) jointly. Their procedure, while capturing the accumulation role of investment, cannot accommodate its smoothing dynamics. The chain of responses from private output to investment to the trade balance or consumption can be analyzed naturally through a VAR where the impact on the economy of the (productivity) shock to ΔY_t is measured through the absorption of fixed and inventory investment, and of the trade balance; its final impact on consumption is then assessed.

The theory above implies the ordering of each smoothing variable; productivity shocks affect both output and investment but feedback from investment to output would be delayed due to time-to-build (and installation costs); investment does not depend on either consumption decisions or trade balance changes; but the trade balance does depend on investment decisions. Thus, a structural VAR model able to analyze the dynamic behavior of investment and trade balance, seen as consumption smoothing channels, would order $\Delta Z_t, \Delta I_t^f, \Delta I_t^s$,and ΔTB_t, and derive also the consumption response. In the next section, where we lay out the structural VAR model, we will show that the consumption response can be obtained implicitly by making use of a simple accounting restriction. In addition, we will show that our econometric model is exhaustive, in the sense that it is equivalent to an empirical smoothing model based on an accounting identity; thus, a change in one variable, say ΔZ_t, must be necessarily reflected in changes in the other variables of the identity, and only them.

2.2. Real Business Cycle Model

To make the test comparable with that of the intertemporal approach, we will adopt the main features of a so called small open economy model, in the line of the International Real Business Cycle literature represented, for example, by Mendoza (1991), Baxter (1995), Kollmann (1996). Indeed, it often assumes a bonds-only economy, and a constant world interest rate. In so doing, there is not a substantial difference with the intertemporal approach, if one restricts attention to a production function without labor input and capital adjustment costs.

A detailed test of such a model, however, can only be performed on the simulation results of the calibrated model. We will compare the impulse responses from our model, especially to income shocks that may be interpreted as (permanent) productivity shocks, to baseline real business cycle models such as Baxter (1997) and Baxter and Crucini (1995).

2.3. The Feldstein-Horioka Puzzle

One of the most famous puzzles in international economics is the empirical result — pioneered by Feldstein and Horioka (1980) and confirmed in many other papers — that saving and investment are highly correlated in cross sections of industrialized countries, and recently also in time series. Although this correlation appears to have decreased over time, it still appears as evidence against intertemporal models based on the cushioning role of the current account in open economies. In addition, the scarce changes recorded in current accounts could signal a very low international mobility of capital. Many possible explanations have been provided for the puzzle. One of the most popular ones relies on the endogeneity of both savings and investment, which suggests that a common cause, such as a persistent productivity shock, may induce a change in both variables in the same direction (e.g., Mendoza, 1991, Baxter and Crucini, 1993, and Glick and Rogoff, 1995). Our model can perform a test of such an explanation, because it analyzes the responses of all the relevant variables to various structural shocks in industrialized countries.

3. Econometric Model

The literature on consumption smoothing channels suggests that a feasible implementation in terms of consumption smoothing of an equation like (2.2) could be represented by a static SUR system measuring the degree of consumption smoothing of income changes taking place through investment, government consumption and trade balance changes (see e.g., Sørensen and Yosha, 1998 and Mélitz and Zumer, 1999). Alternatively, as shown in Asdrubali and Kim (2004), a natural implementation of consumption smoothing measures after a shock triggering nontrivial dynamics is represented by impulse response functions of a recursive VAR, featuring all the relevant variables. In this section, we lay out the econometric model of such a VAR, pointing out its advantages with respect to static systems such as SURs. The model is also aimed at showing that our VAR specification — being based on an accounting identity — contains all the variables relevant to smooth income shocks before they affect consumption. Also note that the ordering of variables in the VAR models based on the literature on consumption smoothing channels in the presence of income changes naturally fit the ordering that is supposed to be adopted in the intertemporal approach in the presence of productivity shocks.

Considering country-specific variables — that is, variables expressed in deviation from their aggregate — and defining private income $Z \doteqdot Y - G$, domestic savings can be defined as

$$S \equiv Z - C. \tag{3.1}$$

In an open economy, gross domestic saving S satisfies

$$S \doteqdot I^f + I^s + TB \tag{3.2}$$

wherethe trade balance, is again defined as the difference between exports (EX) and imports (IM).

We can plug (3.2) into (3.1) at time t, and manipulate it by taking first differences and dividing through by ΔZ_t, to obtain:

$$\frac{\Delta I_t^f}{\Delta Z_t} + \frac{\Delta I_t^s}{\Delta Z_t} + \frac{\Delta TB_t}{\Delta Z_t} + \frac{\Delta C_t}{\Delta Z_t} = 1 \tag{3.3}$$

or, with obvious definitions:

$$\beta_F^l + \beta_S^l + \beta_{TB}^l + \beta_C^l = 1 \tag{3.4}$$

The marginal propensities on the LHS can be interpreted as the (country-specific) responses of fixed and inventory investment, net exports and consumption to a change in (country-specific) private output. The interest of (3.3) lies in the exact decomposition of responses to output changes: the change in Z_t that is not reflected in consumption must be absorbed by the saving components, which can be connected to the theoretical model discussed in the previous section.

Recalling that we measure variables in deviation from aggregate, the fractions could be estimated as the slope coefficients in the regressions

$$\Delta I_t^f = \beta_F \Delta Y_t + \varepsilon^i \tag{3.5}$$

$$\Delta I_t^s = \beta_S \Delta Y_t + u^i \tag{3.6}$$

$$\Delta TB_t = \beta_{TB}\Delta Y_t + \nu^i \tag{3.7}$$

$$\Delta C_t = \beta_C \Delta Y_t + \eta^i \tag{3.8}$$

A specification like this, even when estimated through a SUR system (as in Sørensen and Yosha, 1998), suffers from at least three shortcomings: a) it does not control for the endogeneity of income; b) it cannot distinguish between different kinds of shocks; and c) it completely ignores dynamics. To implement a metric for intertemporal smoothing, we devised a method of estimating the β coefficients more precisely than with unrelated static simple regressions. To that purpose, we adopt the following structural VAR model.[7]

$$\begin{bmatrix} a_{11}^0 & 0 & 0 & 0 \\ a_{21}^0 & a_{22}^0 & 0 & 0 \\ a_{31}^0 & a_{32}^0 & a_{33}^0 & 0 \\ a_{41}^0 & a_{42}^0 & a_{43}^0 & a_{44}^0 \end{bmatrix} \begin{bmatrix} \Delta Z_t \\ \Delta I_t^f \\ \Delta I_t^s \\ \Delta TB_t \end{bmatrix} = \sum_{l=1}^{p} A^l \begin{bmatrix} \Delta Z_{t-1} \\ \Delta I_{t-1}^f \\ \Delta I_{t-1}^s \\ \Delta TB_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{Z,t}^i \\ \varepsilon_{F,t}^i \\ \varepsilon_{S,t}^i \\ \varepsilon_{TB,t}^i \end{bmatrix} \tag{3.9}$$

where A^l is a 4×4 matrix, $\varepsilon_{Z,t}^i$ is a shock to private GDP, $\varepsilon_{F,t}^i$ is a shock to gross fixed investment, $\varepsilon_{S,t}^i$ is a shock to inventories, and $\varepsilon_{TB,t}^i$ is a shock to the trade balance. Note that the structural VAR has a recursive structure: ΔZ_t is assumed to be contemporaneously exogenous to the other three variables, ΔI_t^f is contemporaneously exogenous to ΔI_t^s and ΔTB_t, and ΔI_t^s is contemporaneously exogenous only to ΔTB_t..[8] This follows the accounting logic of national accounts which has been adopted in the literature on channels of risksharing, for example Sørensen and Yosha (1998), Mélitz and Zumer (1999) and Asdrubali and Kim (2004), but is also consistent with the intertemporal model that we discussed in the previous section. Further, note that the consumption dynamics can be obtained by using the national income identity, that is, $\Delta C_t = \Delta Z_t - \Delta I_t^f - \Delta I_t^s - \Delta TB_t$.

By expressing equation (3.9) in a moving average form, we obtain

[7]The preliminary data analysis favors a unit root in each variable (except for inventory investment), but rejects a unit root in the first difference of each variable. In addition, the preliminary data analysis favors no cointegration among variables. Therefore, we construct a VAR model in the differenced form of each variable. Refer to Appendix for the unit root and cointegration tests results.

[8]For recursive VARs, see Sims (1980).

$$\begin{bmatrix} \Delta Z_t \\ \Delta I_t^f \\ \Delta I_t^s \\ \Delta TB_t \end{bmatrix} = \sum_{l=0}^{\infty} B^l \begin{bmatrix} \varepsilon_{Z,t}^i \\ \varepsilon_{F,t}^i \\ \varepsilon_{S,t}^i \\ \varepsilon_{TB,t}^i \end{bmatrix} \tag{3.10}$$

where B^l is a 4×4 matrix and B^0 is a lower triangular matrix. The moving average representation (or impulse responses) shows how each variable responds to a shock over time, for example, B_{jk}^l (which is the j-th row and k-th column of B^l) shows the effect of the k-th shock in the system on the j-th variable in the system in the l-th period after the shock. From the impulse responses to shocks to private output, $\varepsilon_{Z,t}^i$, we can infer the intertemporal smoothing role of savings components. Note that we can apply the decomposition of equation (3.3) to the responses to shocks to private income since such shocks would generate exogenous changes in private income in our VAR model; the VAR structure ensures that impact changes in private income are actually due only to income shocks, rather than, say, lagged investment changes.

The relative responses of ΔI_t^f, ΔI_t^s, ΔTB_t and ΔC_t to ΔZ_t would show how saving components stabilize income in response to shocks to output. For each time horizon l, we apply the decomposition in the following way:

$$1 = \beta_F^l + \beta_S^l + \beta_{TB}^l + \beta_C^l \tag{3.11}$$

where $\beta_F^l \equiv -\frac{\sum_{i=0}^l B_{12}^l}{\sum_{i=0}^l B_{11}^l}$, $\beta_S^l \equiv -\frac{\sum_{i=0}^l B_{13}^l}{\sum_{i=0}^l B_{11}^l}$, $\beta_{TB}^l \equiv -\frac{\sum_{i=0}^l B_{14}^l}{\sum_{i=0}^l B_{11}^l}$, $\beta_C^l \equiv -\frac{\sum_{i=0}^l \left(B_{11}^l - B_{12}^l - B_{13}^l - B_{14}^l\right)}{\sum_{i=0}^l B_{11}^l}$. β_F^l, β_S^l, β_{TB}^l, and β_C^l can be interpreted as the fraction of private income changes absorbed by gross fixed investment, inventories, trade balance and consumption respectively, l-th period after the shock to income. Hence our model introduces the dynamics of shock propagation which — as our results will show — is quite relevant in assessing theoretical predictions. In addition, our model also allows to study the responses to shocks different from output disturbances, and analyze therefore the causal interrelations that simple theoretical models with only productivity shocks do not fully address.

3.1. Past Empirical Studies

The econometric model we have set up, and particularly the VAR specification in (3.9) with its variables' ordering, generalizes and deepens several models, both in the smoothing channel and in the intertemporal current account literature. As for the former, our framework draws inspiration from Asdrubali and Kim (2004), who assess the overall degree of intertemporal smoothing among US states and OECD countries; the models in Sørensen and Yosha (1998) and Mélitz and Zumer (1999) are instead an unconditional static version of (3.5), (3.6), (3.7), and (3.8), where all lagged and non-Y coefficients are set to zero. As for the intertemporal approach to the current account, Glick and Rogoff (1995) is a specification with fewer lags and fewer variables, which does not consider the interactions among various components of saving and output, while Sheffrin and Woo (1990), Otto (1992), and Ghosh (1995) concentrate only on the unconditional current account behavior, in the sense that they do not separate various structural shocks. In contrast, we analyze the dynamic behavior of various components of saving to various types of shocks, by accounting for dynamic interactions among various components of saving and income.

4. The Data

Our estimations are performed on a dataset generated mostly from OECD data. The series, including 19 OECD members,[9] come mostly from OECD's Quarterly National Accounts, plus (average) quarterly exchange rates from "Main Economic Indicators" and (disaggregated) purchasing power parities and population series from "Economic Outlook."

The dataset contains Quarterly National Accounts data, and for each country it includes the longest and most complete series. In addition, a few missing data are filled in by (appropriately rescaled) observations drawn from other accounting formats within the QNA series of the country; the rest of missing observations come from other sources, as follows:

- Canada
  - Unchained CPI 1961:I–2000:IV is current total consumption divided by constant (1992) total consumption: this data series is used.
- Norway

[9] Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, and United States.

  - CPI 1960:I–2001:III is taken from "Main Economic Indicators": it is used before 1990.

- West Germany
  - Change in stocks 1995:I–2001:I is computed as difference between GDP and the other expenditure components of GDP
  - CPI 1962:I–1997:I is taken from "Main Economic Indicators"
  - Original data and CPI from national source (1995-2000) are used.

- Italy
  - Change in stocks 1998:IV–2001:I is computed as difference between GDP and the other expenditure components of GDP

- Portugal
  - Change in stocks 1999:I–2000:IV, S3 is computed as difference between GDP and the other expenditure components of GDP (in turn rescaled from S1 format)

- Austria
  - Change in stocks 1996:I–2001:I, S3 is computed as difference between GDP and the other expenditure components of GDP

- Sweden
  - statistical discrepancy 1999:I–2001:I, S2 is computed as difference between GDP and the other expenditure components of GDP

In order to create a benchmark reference year for real variables, CPIs have all been rebased in 1990.

5. Results

Figure 1 reports impulse responses with two standard error bands (at 95% probability) over eight quarters in the structural VAR system. Each column shows the impulse responses of all interested variables to each structural shock. The name of each structural shock is noted at the top of each column while the names of the responding variables are noted at the far left of each row. "Z," "If," "Is," "TB," and "C" represent ΔZ_t, ΔI_t^f, ΔI_t^s, ΔTB_t, and ΔC_t, respectively. Therefore, they depict the changes in private income, gross fixed investment, inventories, the trade balance, and consumption.

5.1. Responses to income shocks

We start by examining the effects of income shocks (in the first column in Figure 1). To discuss the exact numbers, we report the responses in Table 1 where we normalize the size of the shocks so that the sum of total (cumulative) changes in income over time — that is, the long run response of the income level — is 100. We also report standard errors in parentheses. In Table 2, we report cumulative impulse responses in order to examine the cumulative role of each smoothing channel over time. Finally, Table 3 reports cumulative impulse responses, but the responses of Z up to the point of horizon is normalized to 100, in order to discuss the percentage of income smoothed by each component up to each horizon (discussed in Section 2).

First, from the impulse responses of ΔZ_t, we can infer the nature of the income shocks. (The difference in) income shows a positive response on impact, a near zero response in the next period and a positive response for a few years thereafter. The impact increase in income is 64.0% of the long run income increase, reaches 95.2% in two years and 99.5% in three years. Hence, quarterly private output in our sample is integrated, and shows a positive autocorrelation in first differences. This result is hardly surprising for our sample; for example, Campbell and Mankiw (1989) found high persistence in the quarterly real GDP series of the G7 countries.

The first smoothing channel is Gross Fixed investment (I^f)..... It smoothes income shocks substantially and persistently. On impact, it smoothes 24.9% of impact changes in income (15.9% of long run changes in income). In the long run, 43.1% of the long run change in income. Given the procyclical nature of fixed investment expenditures, this strong smoothing effect is not surprising. In fact, the overall behavior of gross fixed investment appears consistent with the prediction of an intertemporal model, in the presence of a permanent productivity shock, when the productivity difference has a positive autocorrelation.[10]

Inventory investment has never been analyzed as a consumption smoothing channel in past studies, although the literature agrees on the buffering nature of capital stock changes on the part of firms in response to fluctuations in demand. Its short run smoothing capacity is in fact substantial: 21.7% of the impact income change (13.9% of the LR income change) is absorbed on impact. However, such buffering action becomes volatile in later years, and in the long run, "only" 13.1% of the long run income changes is smoothed by inventory changes. The dynamic smoothing behaviors of gross fixed investment and inventory investment are well-contrasted. Inventory changes provide strong smoothing in the short run but not in the long run, while gross fixed investment provides more and more smoothing over time. These results may be obtained because inventory investments are a natural tool for short-run adjustment while a long run perspective directs fixed investment decisions.

The last component of saving we analyze is the trade balance. Its smoothing role in the short run is the largest but that in the long run is the smallest among the three channels; 26.5% of the impact income change (17.0% of the LR income change) is smoothed on impact while only 9.0% of the long run income changes is buffered in the long run. Indeed, the trade balance response exhibits a high volatility, alternating positive and negative changes. Like inventory investment, the trade balance is mainly used as a short run smoothing tool, rather than a long run smoothing tool. This strong short-run smoothing role of the trade balance is consistent with the general idea behind the intertemporal approach to the current account: the current account or trade balance is a tool to smooth short-run or temporary fluctuations in income. However, the detailed dynamic behavior of the trade balance represents a problem for intertemporal theories of the current account. Intertemporal theory predicts that the trade balance should fall when private income net of investment ($\Delta Z_t - \Delta I_t$) is expected to increase. In our results, the impact change in private income net of investment is 34.2% (of the long run income change), and the long run increase reaches 43.8% (of the long run income change). Yet, the trade balance increases on impact, instead of falling. More generally, if income shocks are interpreted as unanticipated permanent productivity shocks — consistently with our results —

[10] The long run dynamics of gross fixed investment is more puzzling: instead of falling back to its original steady-state, gross fixed investment follows the dynamics of income in reaching a new long-run level. Possible explanations of this behavior include high depreciation rates coupled with time to build.

the trade balance should optimally go into a persistent deficit, in the expectation of future output level increases. However, the trade balance only goes into deficit a few quarters later in our results.

The last row of the first column shows that on impact, only 26.9% of the current income change (or 17.2% of the long run income change) is unsmoothed, and is therefore borne by consumption changes. In the long run, 34.8% of the long run income change is not smoothed. The size of the impact consumption change is too small to be consistent with the details of the prediction of intertemporal theory. Intertemporal theory instead would predict that on impact consumption should rise by more than private income net of investment changes; more precisely, by more than 53.4% of the impact income change ($\Delta Z_t - \Delta I_t = 100.0 - 24.9 - 21.7 = 53.4$), and by more than 34.2% of the long run income change ($\Delta Z_t - \Delta I_t = 64.0 - 15.9 - 13.9 = 34.2$) because private income net of investments further increases.

Intertemporal models predict that, in the presence of permanent productivity shocks, trade balance changes (in absolute term) should be larger than investment changes (in absolute term) because saving and investment would move in opposite directions. In our results, instead, the size of investment responses are far larger than that of trade balance responses. This pattern confirms the "investment–trade-balance" puzzle (total investment changes are larger than trade balance changes in the presence of permanent productivity shocks, contrary to theoretical prediction) documented by several analyses, like Sachs (1981), Baxter and Crucini (1993) and Glick and Rogoff (1995). It has never been clarified, however, which behaves perversely between saving and investment. For example, Hoffmann (2001) labelled the result "the excess sensitivity of investment" puzzle, while Glick and Rogoff (1995) suggest that it is the trade balance response to be altered.

As we analyze saving responses, in addition to trade balance and investment, we can infer how the perverse effect of the "investment–trade-balance" puzzle does not lie on the investment side, but rather on the saving side. In Glick and Rogoff (1995) and in our model, investment and saving move in the same direction (and thus the trade balance changes less than investment). The dynamics show that, at least on impact, investment responses are consistent with the prediction of the theory but saving responses are not, a result linked to the problematic consumption behavior described above. Hence our results show empirically how the "investment-trade-balance" puzzle or the "excess sensitivity of investment" puzzle is just the flip side of Deaton's paradox of excess smoothness of consumption.

The puzzle remains also when analyzing the shock propagation from the point of view of real business cycle models, as described in section 3.2. The small open production economy models in Baxter and Crucini (1995) and Baxter (1995), for instance, predict that the impact (idiosyncratic) consumption response to an integrated productivity shock should be larger than the impact (idiosyncratic) output response (p. 838 in Baxter and Crucini, 1995, and p. 1823, 1827, 1831 in Baxter, 1995).

Finally, in response to income shocks, both investment and saving increase on impact (saving responses can be inferred by subtracting consumption changes from income changes); this generates a positive correlation between investment and saving, which may lie at the basis of the Feldstein and Horioka (1980) puzzle, as suggested by some studies such as Mendoza (1991) and Baxter and Crucini (1993).

5.2. Responses to shocks to smoothing channels

We now examine the impulse responses of shocks to each smoothing channel (in the second, third, fourth and fifth columns in Figure 1). In response to gross fixed investment shocks, output and inventories oscillate around their steady states, and the trade balance worsens, counterbalancing the fixed investment shock, so that consumption remains basically unchanged.

Next, shocks to inventories are also mostly offset by the trade balance, and thus decrease consumption only slightly on impact. In the next period, inventories exhibit a reduction, which is partly offset by a decrease in output, so that consumption slightly increases.

A shock to the trade balance decreases consumption substantially. Such a shock can be interpreted as a consumption or preference disturbance relative to abroad, since a trade balance shock given income and investment is equivalent to a shock to consumption given income and investment. The substantial increase in output that we observe after such shocks is interesting; many past studies on consumption smoothing treat output as exogenous and assume that consumption shocks do not affect output, but this result clearly shows that — at least in quarterly data — output is endogenous to consumption shocks.

Finally, we are able to discuss the Feldstein-Horioka puzzle, according to which empirically investment is financed mostly by domestic saving, contrary to the implications of models of small open economies under perfect capital mobility. Interesting in this regard are the responses to investment shocks. In response to gross fixed investment rises, the trade balance decreases sharply, implying that exogenous fixed capital accumulation is almost fully financed by international borrowing, not by domestic saving. This large role played by external investment financing is consistent with a vast empirical literature that, starting from Sachs (1981) up to Nason and Rogers (2002), associates investment booms to current account deficits. A similar observation (although domestic saving increases a bit in this case) can be made for inventory changes. On the other hand, we do find a positive correlation between investment and saving following income shocks. Our VAR model illustrates vividly how the Feldstein-Horioka puzzle can coexhist with the association between investment booms and trade deficits: when investment booms are endogenous to income, the increase in savings carries the bulk of financing, as suggested by Mendoza (1991) and Baxter and Crucini (1993); whereas when investment booms are exogenous, income and savings do not rise contemporaneously, and financing comes from abroad through a current account deficit. The coexhistence of these seemingly inconsistent correlations can explain the results found in papers such as Tesar (1991) — where the unconditional correlation between investment and the current account is negligible.

6. Extended Analysis

6.1. Government Smoothing

We extend our framework to further consider the smoothing role of the government. The basic model is modified by considering total output and government spending seperately. Equations (**??**) and (**??**) can then combine into:

$$Y \equiv I^f + I^s + G + TB + C \tag{6.1}$$

Then, following similar steps as in section 2, output (Y) shocks can be regarded as smoothed by various components of saving, as well as government spending. The extended VAR model includes the variables in the following order: $\{\Delta \mathrm{Y}_t, \Delta \mathrm{I}_t^f, \Delta \mathrm{I}_t^s, \Delta \mathrm{G}_t, \Delta \mathrm{TB}_t\}$.[11] Figure 2 illustrates the results.

A small positive role of government smoothing is found: on impact, government spending smooths 8.2% of impact income changes (5.3% of LR income

[11] We ordered investments before government spending but trade balance after government spending. In this way, we assume that government spending smoothes income after investment decisions are made, but before the trade balance is determined. As already pointed out, the ordering among investment, government spending, and trade balance does not matter for discussing the smoothing role of each channel under income shocks.

changes) and in the long run, 8.1% of LR income changes. Note that the effect in the long run is larger than in the short run, because the smoothing role of government increases over time. The size and the pattern of smoothing by other channels and the nature of income shocks do not change much, compared to the basic model.

The responses to shocks to smoothing channels are also similar to the basic model. Interestingly, government spending shocks are mostly offset by the trade balance, leaving consumption virtually unchanged; this result is consistent with the implications of the trade balance and fiscal budget movements under perfect capital mobility (the twin deficits).

6.2. Sub-Period Estimations

In order to analyze the dynamics of intertemporal smoothing over time, we perform subperiod estimations for the periods 1982:II-1990:IV and 1991:I-2000:IV. Past studies often analyzed consumption smoothing channels only up to 1990. The few papers that went beyond 1990 happened to use annual data, and had to stretch back also to previous periods in order to avoid the efficiency loss inherent in a yearly estimation. By using quarterly data, instead, we can provide results for separate subperiods, including the 1990s.[12]

The results are displayed in Tables 4 and 5, and show that long run smoothing properties differ markedly. In general terms, long run smoothing is higher in the 90s than in the 80s. Although long run investment smoothing is higher in the 80s, the opposite dynamics of net exports outbalances this effect: in the 80s the trade balance, after a surplus on impact, responds to the shock in net private income change with persistent deficits; in the 90s, instead, the trade balance response records a persistent surplus. A possible explanation of these results hinges on the different nature of productivity shocks in the 90s. The reprise of productivity growth in the US after 20 years, led essentially by ICT technology progress; the regime shock brought about by the German reunification; the persistent deflationary shocks hitting Japan throughout the decade... These new kinds of asymmetric shocks might have affected the ability of economic agents of correctly distinguishing temporary from permanent changes. As a consequence, their saving behavior has been more consistent with responses to mean-reverting productivity processes.

[12] The year 1990 is a natural separating date, due to the issue of German reunification.

7. Conclusions

We have examined the way shocks of different nature propagate and are absorbed through various smoothing channels in OECD economies. A structural VAR appeared as the natural econometric methodology to address that issue, since VARs focus precisely on shock identification and propagation, and the minimal identifying restrictions for the VAR models can be drawn from the intertemporal open economy model and also from the empirical consumption smoothing literature. Remarkably, in the period 1982–2000, about 73% of income shocks are cushioned on impact, by the trade balance (27%), inventories (25%) and gross fixed investments (22%). In the long run, the smoothing effect of gross fixed investments becomes preponderant (43%) relative to inventories and the trade balance (both scarcely significant around 10%). Thus, while investments are typically modelled as engines of capital accumulation and growth, they obviously play also a relevant intertemporal smoothing role, which has been largely neglected by the empirical literature although implied by the theoretical literature on intertemporal open economy models. The dynamic responses of each component are also informative: the trade balance and inventories are mostly used as short-run smoothing tools while fixed investment provides more and more smoothing over time. The 90s, however, have seen a more important long run smoothing effect of the trade balance.

Our model allows to analyze also the effects of investment changes orthogonal to income changes. Shocks to gross fixed investment and inventories are mostly offset by a change in the trade balance, suggesting that investment changes, far from drawing on domestic savings, tend to be financed through international borrowing.

Our results are generally consistent with the implications of the intertemporal approach to the current account: following an unexpected increase in productivity change, investment increases and consumption rises, as predicted by the theory. However, our impulse responses also reveal well-known puzzles. Following such an unanticipated permanent income shock (and the consequent increase in private income net of investment over time), the trade balance increases initially instead of falling, and by an amount smaller than the investment change (the "excess sensitivity of investment" puzzle). We document how the problem — which should be more appropriately labelled the "excess trade balance smoothing" puzzle — does not revolve around investment (whose behavior is consistent with the theory) but rather lies in the lagged consumption reaction to net income changes; in other words, it is an expression of the Deaton's paradox of excess smoothness of consumption of an unanticipated permanent income shock.

Our analysis of trade balance shocks confirms previous evidence on the role of preference (consumption) shocks in the estimation of smoothing (Stockman and Tesar, 1995 and Asdrubali and Kim 2004). The impact of such exogenous shocks on private income on one hand lends support to a non-negligible role of demand changes in the determination of equilibrium income; on the other hand, it endorses the appropriateness of the adoption of an econometric methodology, like structural VARs, which can control for endogenous feedbacks of variables.

A. Panel Unit Root and Cointegration Tests

To examine whether the panel VAR system is consistent with the statistical properties of the data, we perform panel unit root and cointegration tests. We employ the panel unit root tests suggested by Levin, Lin and Chu (2002) and Im, Pesaran, and Shin (2003) and the panel cointegration test suggested by Pedroni (1999), which allows for heterogeneous intercepts and trends across individual members. Detailed results are reported in Tables A1 and A2.

For our sample, the panel unit root tests for each variable ("level" of Z, I^f, I^s, and TB) suggest that the null hypothesis of the unit root is not rejected except for I^s, while the panel unit root tests for the difference of Z, I^f, and TB show that the null hypothesis of the unit root is rejected in all cases. The panel cointegration tests of all possible combinations of "levels" of Z, I^f, and TB suggest that the null hypothesis of no cointegration is not rejected in most cases. Therefore, the VAR system discussed in this paper is consistent with the statistical properties of our OECD data sample.[13]

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	Z	TB	I^s	I^f
LLC rho-stat.	1.01	-1.32	-24.79**	-0.13
LLC t-rho-stat.	0.68	0.82	-8.19**	0.84
LLC adf-stat.	0.31	1.35	-3.41**	0.48
IPS adf-stat.	-0.60	-0.60	-7.48**	-1.50

Table A.1: Unit Root Tests of Levin, Lin and Chu (2002) and Im, Pesaran and Shin (2003). "*" and "**" indicate that the null hypothesis of unit root is rejected at 5% and 1% significance level, respectively.

	ΔZ	ΔTB	ΔI^f
LLC rho-stat.	-92.70**	-120.14**	-92.61**
LLC t-rho-stat.	-26.84**	-40.32**	-27.17**
LLC adf-stat.	-20.41**	-24.95**	-20.88**
IPS adf-stat.	-25.12**	-32.40**	-25.84**

Table A.2: Unit Root Test of Levin, Lin and Chu (2002) and Im, Pesaran and Shin (2003). "*" and "**" indicate that the null hypothesis of unit root is rejected at 5% and 1% significance level, respectively.

	Z, TB	Z, I^f	TB, I^f	Z, TB, I^f
Panel V-stat	-2.74**	-2.74**	1.11	-2.35**
Panel rho-stat	0.44	2.41	-0.27	0.95
Panel pp-stat	-0.60	2.28	-0.41	0.62
Panel adf-stat	0.18	2.79	1.14	2.74
Group rho-stat	0.59	1.67	-1.75*	-1.59
Group pp-stat	-0.99	0.90	-1.39	-2.51**
Group adf-stat	-0.04	1.77	0.32	0.76

Table A.3: Panel cointegration test of Pedroni (1999). "*" and "**" indicate that the null hypothesis of no cointegration is rejected at 5% and 1% significance level, respectively.

step	ΔZ_t	ΔI_t^f	ΔI_t^s	ΔTB_t	ΔC_t
0	64.0(1.2)	15.9(1.1)	13.9(1.3)	17.0(1.5)	17.2(1.0)
1	1.3(1.8)	3.5(1.2)	-3.2(1.5)	-0.8(1.6)	1.8(1.2)
2	6.3(1.7)	5.7(1.1)	3.7(1.4)	-5.0(1.5)	1.8(1.2)
3	9.5(1.7)	5.2(1.2)	-2.4(1.4)	2.1(1.6)	4.7(1.2)
4	4.4(1.8)	4.7(1.2)	-3.2(1.5)	0.1(1.6)	2.9(1.2)
8	1.4(0.5)	0.9(0.3)	-0.1(0.3)	-0.1(0.3)	0.7(0.3)
16	0.2(0.1)	0.1(0.1)	0.0(0.0)	0.0(0.0)	0.1(0.0)
24	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
32	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)

Table 1: Impulse responses to private income shocks (first differences)

step	Z_t	I_t^f	I_t^s	TB_t	C_t
0	64.0(1.2)	15.9(1.1)	13.9(1.3)	17.0(1.5)	17.2(1.0)
1	65.3(2.2)	19.4(1.4)	10.7(1.4)	16.2(2.1)	19.0(1.4)
2	71.6(2.9)	25.1(1.7)	14.4(1.5)	11.2(2.7)	20.8(1.6)
3	81.2(3.5)	30.3(1.9)	12.0(1.5)	13.3(3.3)	25.5(1.9)
4	85.6(4.2)	34.9(2.3)	8.8(1.7)	13.4(3.7)	28.5(2.3)
8	95.4(6.3)	40.1(3.2)	12.8(1.7)	10.0(4.8)	32.5(3.1)
16	99.5(7.7)	42.8(4.0)	13.0(1.8)	9.1(5.4)	34.5(3.8)
24	99.9(8.0)	43.1(4.1)	13.1(1.9)	9.0(5.5)	34.7(3.9)
32	100.0(8.0)	43.1(4.2)	13.1(1.9)	9.0(5.5)	34.8(3.9)

Table 2: Impulse responses to private income shocks - levels (percent of cumulative Z)

step	Z_t	I_t^f	I_t^s	TB_t	C_t
0	100.0	24.9(1.7)	21.7(2.1)	26.5(2.3)	26.9(1.6)
1	100.0	29.7(2.1)	16.4(2.2)	24.8(3.3)	29.1(2.1)
2	100.0	35.0(2.3)	20.2(2.1)	15.7(3.8)	29.1(2.2)
3	100.0	37.3(2.3)	14.8(1.9)	16.4(4.0)	31.5(2.3)
4	100.0	40.8(2.6)	10.3(2.0)	15.6(4.3)	33.3(2.6)
8	100.0	42.0(3.3)	13.4(1.8)	10.5(5.1)	34.0(3.3)
16	100.0	43.0(4.0)	13.1(1.9)	9.2(5.5)	34.7(3.8)
24	100.0	43.1(4.1)	13.1(1.9)	9.0(5.5)	34.8(3.9)
32	100.0	43.1(4.2)	13.1(1.9)	9.0(5.5)	34.8(3.9)

Table 3: Impulse responses to private income shocks - levels (percent of Z)

step	Z_t	I_t^f	I_t^s	TB_t	C_t
0	71.5(2.1)	16.3(1.9)	15.7(2.0)	21.8(2.5)	17.8(1.5)
1	72.5(3.8)	19.7(2.5)	15.1(2.4)	18.3(3.4)	19.5(1.9)
2	77.5(5.2)	31.9(3.1)	19.9(2.7)	-0.7(4.3)	26.4(2.5)
3	83.9(6.7)	37.4(3.7)	16.9(3.1)	-4.9(4.8)	34.6(3.1)
4	85.4(7.7)	41.6(4.4)	11.5(3.1)	-5.5(5.0)	37.9(3.8)
8	95.9(10.7)	47.7(6.1)	17.9(3.2)	-12.5(5.4)	42.7(5.7)
16	99.5(13.4)	50.2(7.8)	17.9(3.6)	-13.9(6.2)	45.2(7.3)
24	99.9(14.0)	50.6(8.1)	18.0(3.7)	-14.2(6.3)	45.5(7.7)
32	100.0(14.1)	50.6(8.2)	18.0(3.7)	-14.2(6.4)	45.6(7.8)

Table 4: 1982:II-1990:IV, Impulse responses to private income shocks - levels (percent of cumulative Z)

step	Z_t	I_t^f	I_t^s	TB_t	C_t
0	65.9(1.7)	19.1(1.5)	10.9(1.9)	15.4(2.1)	20.6(1.8)
1	67.2(3.2)	22.3(2.0)	8.7(2.1)	14.0(3.5)	22.2(2.2)
2	73.7(4.3)	24.2(2.6)	9.7(2.4)	18.9(4.8)	20.9(2.5)
3	84.7(5.2)	31.7(3.1)	8.2(2.4)	20.7(6.2)	24.0(2.8)
4	87.2(6.3)	32.8(3.6)	5.5(2.5)	23.3(7.1)	25.6(3.2)
8	96.7(9.2)	35.3(4.9)	8.1(2.3)	27.0(10.5)	26.3(4.1)
16	99.7(11.1)	35.9(5.6)	8.3(2.4)	29.3(12.8)	26.2(4.8)
24	100.0(11.4)	35.9(5.8)	8.3(2.4)	29.6(13.1)	26.2(4.8)
32	100.0(11.4)	35.9(5.8)	8.3(2.4)	29.6(13.2)	26.1(4.9)

Table 5: 1991:I-2000:IV, Impulse responses to private income shocks - levels (percent of cumulative Z)

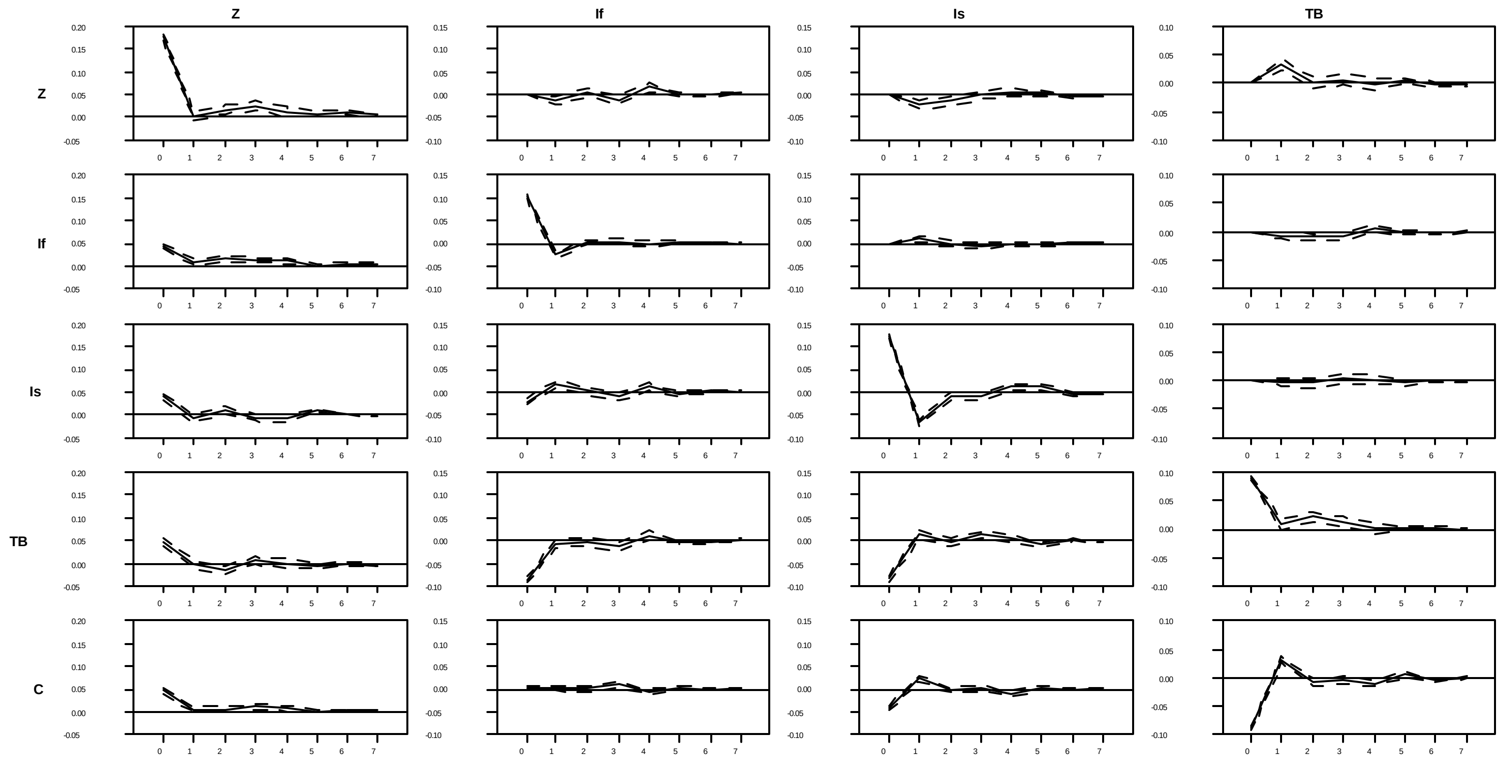

Figure 1. Impulse Responses: Basic Model

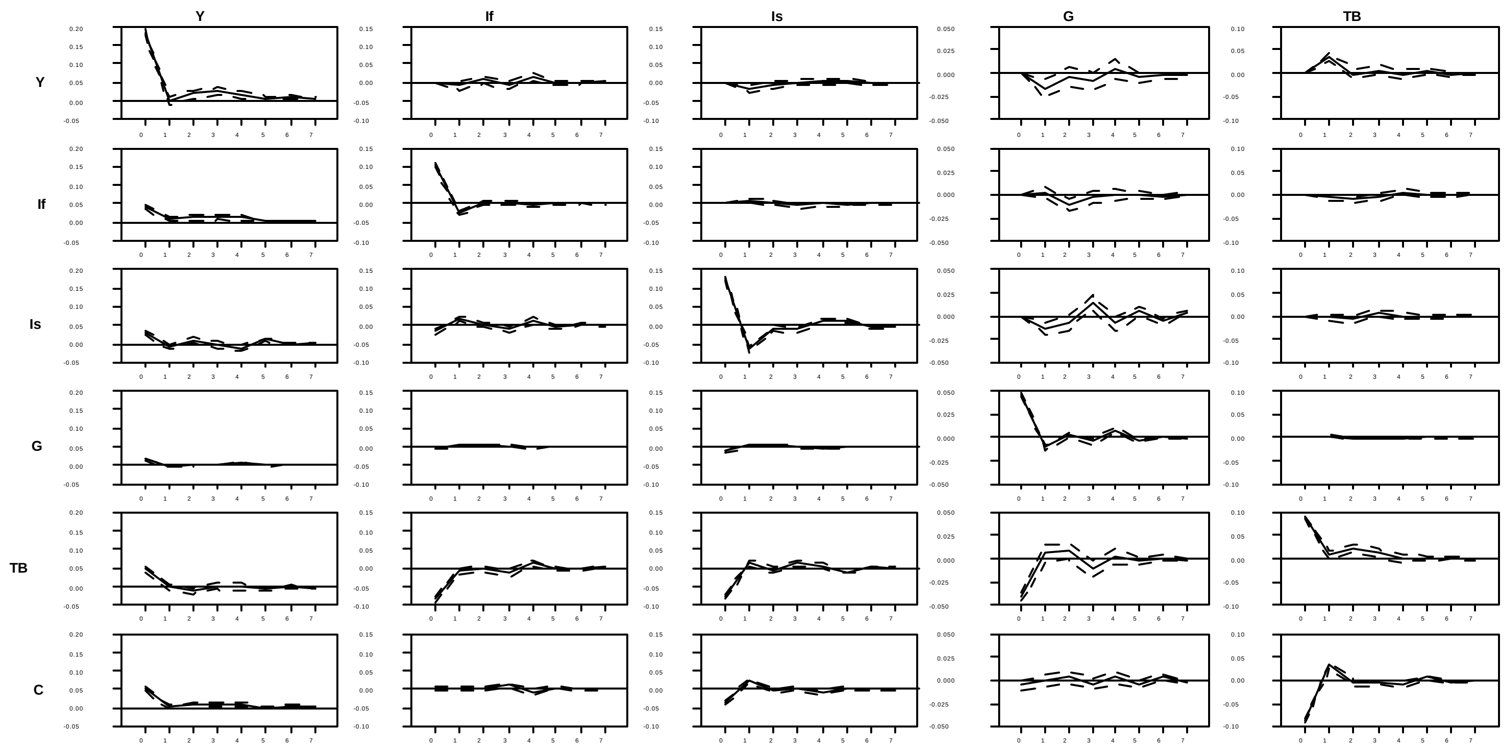

Figure 2. Impulse Responses: Extended Model with Government Smoothing