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SOVEREIGN DEBT IN THE UNITED STATES AND GROWTH EXPECTATIONS

JUAN EQUIZA-GOÑI
Universidad de Navarra

This paper shows empirical evidence and theory consistent with the US government using debt optimally to adjust the federal budget to news about long-term growth. First, using historical forecasts from the Congressional Budget Office (CBO) since 1984, I find that government purchases and deficits are positively correlated with expectations about long-term productivity, real gross domestic product, and tax revenue growth, whereas tax receipts are negatively correlated. A structural vector autoregression estimated with US quarterly data in 1955–2015 identifies permanent and transitory productivity shocks and points to "trend" shocks as the source of these correlations. Second, I present an open economy real business-cycle model with stochastic productivity trend and optimal public purchases and taxes. Calibrating the model to the US economy, the Ramsey planners' allocation yields moments aligned with those observed in the data.

JEL codes: E62, H21, H63, H68

1. INTRODUCTION

This paper studies the reaction of government purchases and taxes to news about long-term output growth, and it derives implications of that relation for the dynamics of sovereign debt and deficits. This analysis is currently of special interest as the financial crisis has led to a downward revision of US long-term growth forecasts. For instance, in 2016, 10-year-ahead forecasts for US real gross domestic product (GDP) growth were at the minimum reached since they started being published by the Survey of Professional Forecasters (SPF) or the Congressional Budget Office (CBO). This paper makes two main contributions: (i) it derives and discusses a new set of stylized facts about long-term growth expectations of productivity, GDP, and tax revenues, and their impact on fiscal policy; (ii) it develops a dynamic macromodel with shocks to long-run (trend) productivity growth and optimal fiscal policy. The paper shows that the model explains the new set of stylized facts.

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The CBO publishes fiscal year projections of federal revenues and outlays. Using the forecasts corresponding to periods 1984–2016, I find that higher growth expectations of fiscal revenue, productivity, and real GDP are positively correlated with federal purchases and deficits (divided by GDP), while negatively correlated with tax receipts. Moreover, I identify permanent and transitory productivity shocks in a structural vector autoregressive (SVAR) model estimated with US quarterly data (1955–2015). I find that government purchases and primary fiscal deficits rise after a permanent or "trend" shock, whereas they fall in response to a transitory one. Estimates of wage income tax rates, however, fall permanently after a "trend" shock, whereas they rise after a transitory shock.

This suggests that the government, searching to smooth taxes and public purchases, borrows if expectations on long-term future revenues are high; or lends when facing gloomier prospects. These features of government behavior have not been discussed in previous research on fiscal policy. Instead, that literature usually assumes fiscal variables to be linked to current real activity through mechanical feedback rules that ignore long-term growth expectations. However, the SVAR analysis presented in this paper shows that fiscal policy differs with the nature of the productivity shock.

These findings motivate the second main contribution of my paper, namely the development of an open economy real business-cycle (RBC) model with stochastic productivity trend and optimal fiscal policy. More specifically, the model assumes that the government is benevolent and solves the well-known Ramsey problem under full commitment. Markets are incomplete as there is only a riskless bond traded among private and public sectors and the rest of the world. Remarkably, this simple model can replicate the above-mentioned stylized facts. It produces a positive correlation of long-term growth expectations with public purchases and deficits (divided by output), while a negative one with taxes. Moreover, the model is consistent with time series properties of other macroeconomic variables.

The model explains the mechanism that makes fiscal policy depend on the type of productivity shocks, as shown in the empirical evidence. On the one hand, the effect on output of a 1% transitory total factor productivity (TFP) shock is temporary. Initially, the government responds by raising taxes and running a primary fiscal surplus. In the long-run, however, the accumulated assets allow the government to lower taxes slightly and enjoy small deficits. In doing so, the government smooths public purchases and distortionary tax rates over time. On the other hand, a 1% permanent TFP shock implies the transition to a new balance growth path where output levels stay permanently higher. In response to this "trend" shock, the government optimally issues debt to finance a frontload of public purchases and a permanent strong reduction of labor-income tax rates. The government is, thus, adjusting public purchases to news about much higher taxable income, and smoothing private consumption by stabilizing distortionary taxation.

Several papers have studied the impact of fluctuations in long-run (trend) growth on asset prices, international financial flows, and investment dynamics; however, no previous paper has studied the effect of "trend" changes in the context of fiscal policy and public finance. This is surprising since long-run growth has a direct impact on tax revenue and potentially on the sustainability of sovereign debt. This paper contributes to the study of the effects of "trend" shocks showing evidence that the US government uses sovereign debt to adjust public purchases and tax rates to news about long-term growth.

The structure of the paper is the following. First, Section 2 reviews previous related work. Then, Section 3 studies empirically the relation between fiscal variables and long-term growth expectations. Section 4 presents the model, and Section 5 explains the calibration. Section 6 compares the model with the new stylized facts. Finally, Section 7 shows some robustness analyses, and Section 8 concludes.

2. REVIEW OF RELATED LITERATURE

This paper shows evidence that US government purchases, taxes, and fiscal deficits respond to changes in long-term GDP growth forecasts and explains this behavior. Conceptually, these forecast variations can be interpreted as news about long-term growth implied by movements in the productivity growth trend. Since the 1990s—a decade of relatively high GDP and TFP growth—productivity trend movements have been found useful in explaining some features of macrodata. For example, Pakko (2002) shows that sharp declines in capital stock growth in the mid-1980s and early-1990s are associated with positive technological growth shocks. Using a New Keynesian model, Gilchrist and Leahy (2002) show that asset prices may rise in response to a persistent increase in the growth rate of technology, and Gilchrist and Saito (2008) derive implications of trend changes for monetary policy. More recently, Hoffmann et al. (2012) show that increasing housing prices in the United States until 2005 can be explained by rational expectations models that allow for productivity trend changes.

Stochastic trend models have been particularly useful in the international macro literature. Aguiar and Gopinath (2007) or Boz et al. (2011) document that some particular features of emerging economies—strongly countercyclical current accounts, consumption volatility that exceeds income volatility, and sudden stops in capital inflows—are mainly caused by perceived shocks to trend growth rather than transitory fluctuations around a stable trend. Similarly, Wada (2014) uses this type of models to analyze cross-country correlations of consumption and output, while Ersal-Kiziler (2016) studies international portfolio flows.

More recently, Hoffmann et al. (2017) and Amdur and Ersal-Kiziler (2014) present slightly different versions of two-country RBC models with stochastic productivity trends. These models produce current account balances like the increasing US deficits of the late-1990s and early-2000s, or their reduction in the years preceding the financial crisis. Since the late 1990s, US long-term GDP growth expectations became more optimistic due to upward movements of the US productivity trend. As suggested by the intertemporal model of the current account—see Obstfeld and Rogoff (1995), higher long-term growth expectations encouraged the US economy as a whole to borrow from the rest of the world—running current account deficits—and to smooth, in this way, private consumption.

However, no previous paper has studied the effect of trend changes in the context of fiscal policy and public finance. This is surprising since long-run GDP growth has a direct effect on long-term government revenue and potentially on the sustainability of sovereign debt. Moreover, as already suggested by Roubini (1988), a benevolent government would search to smooth consumption, not only through international savings and investment, but also smoothing distortionary taxes and generating plausible "twin deficits."[1] My paper fills in this gap providing both theoretical and empirical analyses.

My empirical study includes new stylized facts based on novel data about long-term CBO forecasts. It also identifies permanent and transitory TFP shocks as Sims (2011) or Rebei (2014) did to study the different response of hours. My contribution is to extend this analysis to fiscal variables. Moreover, I provide a model including both types of productivity shocks that characterizes optimal fiscal policy defined as the well-known Ramsey planner's allocation. Thus, my paper is linked to the seminal work of Ambler and Paquet (1996) or Ambler and Cardia (1997) studying optimal government purchases, and Lucas and Stokey (1983) or Chari et al. (1994) analyzing optimal taxation.

However, my closest reference is Marcet and Scott (2009) that investigates the implications of optimal wage-income tax rates for debt and deficits in the United States. In that paper, first, they explain that, with incomplete markets, the government increases debt to smooth taxes after a positive transitory shock to productivity (or negative to spending); and, then, show supportive US evidence for this behavior. My paper extends their analysis to an open economy setup with stochastic productivity trend and endogenous public purchases. The resulting optimal fiscal policy is one that smooths both public purchases and taxation in response to changes in long-term growth. In doing so, both current account and fiscal balances move together, a behavior reminiscent of that described in Roubini (1988).

3. EMPIRICAL EVIDENCE

This section has two main contributions. First, it uses novel data on budget and economic projections from the CBO to report and discuss the correlation between long-term growth expectations and government variables (public purchases, tax revenue, and fiscal balance) as shares of GDP. Then, based on a SVAR model estimated with quarterly US data, I identify transitory and permanent shocks to productivity. Permanent (also called, "trend") shocks generate responses aligned with the reported comovements between fiscal variables and long-run CBO forecasts.

3.1. Correlations with CBO Long-Term Forecasts

The CBO publishes annual reports on the budget and economic outlook since 1975.[2] Each report contains the estimated values for the previous fiscal year,

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a forecast of the outcome for the current year, and projections up to 5 years ahead for the federal budget and general economic variables, like nominal GDP, inflation, or productivity. Moreover, the CBO has reported fiscal year projections of baseline federal revenues and outlays on a National Income and Product Accounts (NIPA) basis since 1984. Consequently, they are suitable for comparison with the data on federal purchases and fiscal balances provided in Table 3 of the NIPA. Since 1996, up to 10-year-ahead projections were added to these reports. For information on the definition of each variable, see Appendix C; and for a detailed explanation of the data from the CBO reports, see the online appendix.

Table A.1 reports correlations between economic and fiscal ratios in the US and CBO long-term growth forecasts for productivity (PROD), real GDP (rGDP), and real net tax revenue (nTAX). Net tax revenue is defined as federal tax receipts minus net transfer payments.[3] From 1984 to 1995, the longest horizon of the CBO forecasts that I used for real GDP and real net tax revenue growth is 6 years. Since 1996, the longest horizon available becomes 11 years but I study 10-year-ahead forecasts because this is the standard definition for the long term. Projections for productivity at any horizon start in 1995.

In particular, the correlations presented in Table A.1 correspond to those between the ratio in any year t (for example, 1998) and the annualized expected growth rate from $t - 1$ to $t + 5$ (i.e., from the end of 1997 to the end of 2003) for 6-year-ahead forecasts—and from 1997 to 2007 in the case of 10-year-ahead forecasts. This expectation can be calculated using the economic and budget projections published in the first months of year t (that is, early 1999). In 1992, the SPF started providing also 10-year-ahead forecasts. The correlation between SPF and CBO projections is 0.8 and 0.88 for productivity and real GDP growth, respectively; however, the SPF does not include forecasts on tax revenue. Thus, my paper exploits a longer timespan of 6-year-ahead growth forecasts and totally new information on tax revenue expectations.

The first row in Table A.1 shows the correlation between these forecasts and the ratio of government purchases (G^*) to GDP. The second row shows equivalent correlations for the case of nondefence government purchases (G) divided by GDP. In both cases, the correlation with all forecasts is positive. Nonetheless, I concentrate my study in nondefence government purchases because defence spending can be partly determined by exogenous events, and this paper focuses on endogenous public purchases.[4] Rows 3 to 5 show the correlations of tax revenue (Tax), tax revenue net of transfers (nTax), and the primary fiscal surplus (*pSpl*) divided by GDP, with the long-term growth forecasts. The primary fiscal surplus is defined as federal tax revenue net of transfers minus defence and nondefence federal purchases. All correlations are negative, suggesting that the government reduces taxes and borrows in the presence of brighter long-run prospects.

Finally, the lower part of Table A.1 (rows 6–8) shows the correlations between the ratios of US private consumption (C), private investment (I), and net exports

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(NX) to GDP and the CBO long-term forecasts for productivity and real GDP growth. In line with the predictions of the forward-looking model of the current account—see Obstfeld and Rogoff (1995), Engel and Rogers (2006), or Hoffmann et al. (2017)—net exports are negatively correlated with long-run expectations, precisely because consumption and, mainly, investment are positively correlated.[5] According to this model, households react optimally to news about higher future growth by borrowing from the rest of the world to invest and smooth consumption. This paper contributes to this literature by documenting that US federal fiscal ratios show similar correlations with long-term forecasts. Later, my model explains that a benevolent government would optimally issue debt to lower tax rates and increase public purchases in response to higher long-run growth prospects.

3.2. The Role of "Trend" Shocks

As discussed in Section 2, the literature has studied the implications of the nature of productivity shocks (transitory vs. permanent) for the behavior of economic variables. Clearly, positive "trend" shocks (i.e., those with permanent effects in productivity) can improve long-term growth forecasts. This subsection shows that the estimated responses of fiscal variables to permanent productivity shocks are aligned with the correlations presented in Table A.1.

I follow Sims (2011) to identify shocks with permanent effects in productivity using long-run restrictions in a SVAR model—as in Gali (1999) or, more recently, Rebei (2014). First, the reduced-form VAR represented by the equation below is estimated using US data from 1955Q1 to 2015Q1.

$$X_t = B(L)X_{t-1} + \nu_t, \quad \nu_t = M\epsilon_t \text{ , } \epsilon_t \text{ are structural shocks}$$

$$X_t = \begin{bmatrix} \Delta \ln A_t \\ \ln N_t \\ \Delta \ln Y_t \\ \mathrm{FFR}_t \\ \pi_t \\ \ln G_t/Y_t \\ \mathrm{pSp}_t/Y_t \\ \tau_t \\ \text{other controls} \end{bmatrix} = \begin{bmatrix} \text{tfp growth} \\ \text{hours} \\ \text{real gdp growth} \\ \text{federal funds rate} \\ \text{inflation} \\ \text{government purchases/gdp} \\ \text{primary surplus/gdp} \\ \text{tax on labor income} \\ \text{nTAX, debt, defense G} \end{bmatrix}$$

$B(L)$ is a lag polynomial of order $p = 4$, as it is frequent for quarterly data, and ν_t is a vector of reduced-form innovations with variance-covariance matrix S. I assume that there exists a square matrix M that maps the structural shocks ϵ_t, whose variance-covariance matrix is supposed to be a diagonal matrix D, into the reduced-form innovations ν_t.

We can distinguish three types of variables included in X_t. First, five key variables for the identification: the growth rate of TFP ($\Delta \ln A_t$), the log of hours worked ($\ln N_t$), the growth rate of real GDP ($\Delta \ln Y_t$) and two monetary control

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factors used by Sims (2011): the federal funds rate (FFR_t) and inflation (π_t). Second, our variables of interest: the log of the public purchases ratio ($\ln G_t/Y_t$), the primary fiscal surplus ratio (pSp_t/Y_t), and the tax rate on labor income (τ_t) as estimated by Jones (2002). Finally, the third set of variables that may be included are other fiscal factors used as control variables: the ratio of net federal revenue to GDP (nTAX), the debt to GDP ratio (debt), or defence spending (defence G). For details about the definition of each variable, see Appendix C.

The identification of the shocks is achieved through the choice of $M = L \cdot D^{1/2} \cdot R$. The product $L \cdot D^{1/2}$ is a lower diagonal matrix that imposes the restriction that only the first structural shock can affect TFP growth ($\Delta \ln A_t$) contemporaneously. The Cholesky decomposition (or its variant, the LDL decomposition) guarantees that such matrix exists. R is a rotation matrix that imposes the restriction that the long-run effect of the first structural shock on $\Delta \ln A_t$ must be zero. Thus, R performs a rotation in the space spanned by the first two rows of $L \cdot D^{1/2}$, and therefore the (2,1) element of matrix M (i.e., $M_{2,1}$) is no longer equal to zero. As a result, the first two structural shocks can affect $\Delta \ln A_t$ contemporaneously and, therefore, both are defined as TFP shocks. However, while the long-run effect of the former is null (i.e., it is a transitory shock to the level of productivity), the long-run effect of the latter is not restricted to zero (thus, it may be a shock with permanent effects in the level of productivity).

Figure B.1 shows the estimated SVAR responses of X_t when all three variables of interest are included: $\ln G_t/Y_t$, pSp_t/Y_t, and τ_t[6]. Figure B.2 shows the responses in levels for the natural log of TFP, real GDP, and nondefence government purchases, calculated as cumulative sums of the corresponding responses in Figure B.1. Due to the long-run restriction imposed in the response of $\Delta \ln A_t$ to transitory shocks, the first row of Figure B.2 shows that the response of $\ln A_t$ to a 1% transitory shock dies out, while in response to permanent shocks productivity moves to a new level 1.5% higher. The log of real GDP ($\ln Y_t$) shows a similar behavior, although it takes many periods for the effect of transitory TFP shocks on $\ln Y_t$ to disappear.[7] Inflation and interest rates, as well as hours, increase in response to transitory TFP shocks, while they fall in response to permanent ones.

Importantly, Figure B.1 shows very different reactions of government purchases and primary deficits to TFP shocks of different nature: although they fall in response to transitory perturbations, they increase with permanent shocks. The last row in Figure B.2 illustrates how public purchases ($\ln G_t$) move to a higher level after a permanent shock, whereas they increase only temporarily after a transitory shock. Since the model presented in the next section describes optimal wage income taxation in the presence of a stochastic productivity trend, Figure B.1 also analyzes the response of the empirical proxy to this tax rate (τ_t) calculated according to Jones (2002). Although the tax rate increases in response to transitory shocks, it clearly falls after a permanent productivity shock. These stylized facts are robust to controlling for tax revenue net of transfers, debt, and defence spending.[8]

4. MODEL

The model in this paper is based on the open economy literature featuring transitory and permanent productivity shocks—like Aguiar and Gopinath (2007) or Amdur and Ersal-Kiziler (2014)—and models studying optimal debt and deficits—as Marcet and Scott (2009) or Grechyna (2016). Given that the motivating stylized facts correspond to the United States, the model presents a (large) open economy where both private and public sector can borrow from the rest of the world. Thus, the model includes two countries: home—or the United States—and foreign—or the rest of the world—, variables of the latter denoted with a star $\star$. Each country is inhabited by a large number of identical households that live infinitely and a competitive firm that exploits a production technology. In addition, the home country features a government that raises taxes, issues debt, and decides on its level of public purchases. Both countries can trade a one-period riskless bond. For simplicity, the foreign country has no government, and the paper focuses exclusively on the dynamics implied by the model in the home country.

Firms use the constant returns to scale technology (1) to produce one good Y_t with capital K_{t-1} and hours of efficient labor $\Gamma_t N_t$ (i.e., Γ_t is labor-augmenting productivity)

$$Y_t = Z_t K_{t-1}^{\alpha}\left(\Gamma_t N_t\right)^{1-\alpha}, \tag{1}$$

where $0 < \alpha < 1$ represents labor's share of output. Both Γ_t and Z_t represent productivity processes of different nature. First, $\ln Z_t$ follows the AR(1) process described by (2), where innovations have transitory effects in the level of productivity. Then, Γ_t is the productivity "trend"—defined in (3) as the cumulative product of productivity growth—whose shocks have permanent effects on the level of productivity. Total productivity is equal to $Z_t \Gamma_t^{1-\alpha}$:

$$\ln Z_t = \rho_z \ln Z_{t-1} + \epsilon_t^z \text{ with } \epsilon_t^z \sim \mathcal{N}(0, \sigma_z^2) \text{ and } 0 < \rho_z < 1 \tag{2}$$

$$\Gamma_t = (1 + g_t)\Gamma_{t-1} = \prod_{s=1}^{t}(1 + g_s) \quad \text{where}$$

$$g_t = (1 - \rho_g)g + \rho_g g_{t-1} + \epsilon_t^g \text{ with } \epsilon_t^g \sim \mathcal{N}(0, \sigma_g^2) \text{ and } 0 < \rho_g < 1. \tag{3}$$

The firm operates in a perfectly competitive market and maximizes its profits taking input prices and productivity as given. The usual first-order conditions imply that the marginal productivity of inputs should be equal to their marginal cost, i.e., the rental price of capital r_t^k and wages W_t

$$r_t^k = \alpha Y_t / K_{t-1}, \tag{4}$$

$$W_t = (1 - \alpha) Y_t / N_t. \tag{5}$$

The representative household maximizes the expected value of the sum of instantaneous utilities, discounted by a factor β. Preferences are of the Cobb–Douglas type over private consumption C_t, public purchases G_t, and leisure

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$(1 - N_t)$, with weights ω and κ and $1 - \kappa - \omega$. In the case of the foreign country, I abstract from the public sector because my goal is to model the United States as an open economy; thus, $\kappa^\star = 0$. The inverse of the elasticity of intertemporal substitution is s in both countries. Therefore, the representative household of the home country maximizes

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{\left[C_t{}^{\omega} G_t{}^{\kappa} (1 - N_t)^{1-\kappa-\omega}\right]^{1-s}}{1-s},$$

or equivalently, setting $\nu = \kappa/\omega$, $\theta = (1 - \kappa - \omega)/\omega$ and $(1 - \sigma) = \omega(1 - s)$, maximizes

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{\left[C_t G_t{}^{\nu} (1 - N_t)^{\theta}\right]^{1-\sigma}}{1-\sigma}, \tag{6}$$

subject to the budget constraint:

$$C_t + I_t + p_t A_t = r_t^k K_{t-1} + (1 - \tau_t) W_t N_t + A_{t-1}, \tag{7}$$

where income in period t consists of after-tax wage income, $(1 - \tau_t) W_t N_t$, the return on capital supply to the firm, $r_t^k K_{t-1}$, and real riskless assets brought from last period, A_{t-1}, respectively. Income is used to buy private consumption C_t, investment I_t, and to sell new assets A_t at the home market price p_t. This price is equal to the foreign market price $p_t^\star$ (which agents take as given) and a penalty ζ on country-level external debt[9]:

$$p_t = p_t^\star + \zeta(A_t - D_t). \tag{8}$$

The country-level net position in the assets market is $A_t - D_t$, where $-D_t$ is the net asset position of the government (with D_t being debt) and A_t the one of the household.

Capital depreciates at rate δ and, thus, capital accumulation follows:

$$K_t = (1 - \delta) K_{t-1} - \Phi\left(\frac{K_t}{K_{t-1}}\right) K_{t-1} + I_t, \tag{9}$$

where changes to the capital stock entail a quadratic adjustment cost $\Phi(\cdot)$

$$\Phi\left(\frac{K_t}{K_{t-1}}\right) = \frac{\phi}{2}\left[\frac{K_t}{K_{t-1}} - (1 + g)\right]^2 \text{ or, in short, } = \Phi_{t,t-1}. \tag{10}$$

Solving the utility maximization problem of the household implies that the first-order condition that determines labor supply is

$$(1 - \tau_t) W_t = \theta \frac{C_t}{1 - N_t}, \tag{11}$$

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and two Euler equations (for assets and capital) hold:

$$p_t + \zeta A_t = E_t \mathrm{MRS}_{t,t+1} = E_t \left\{ \beta \frac{C_{t+1}^{-\sigma} G_{t+1}^{\nu(1-\sigma)} (1 - N_{t+1})^{\theta(1-\sigma)}}{C_t^{-\sigma} G_t^{\nu(1-\sigma)} (1 - N_t)^{\theta(1-\sigma)}} \right\}, \tag{12}$$

$$1 + \Phi'\left(\frac{K_t}{K_{t-1}}\right) = E_t \mathrm{MRS}_{t,t+1} \left\{ r_{t+1}^K + 1 - \delta - \left[\Phi\left(\frac{K_{t+1}}{K_t}\right) - \Phi'\left(\frac{K_{t+1}}{K_t}\right) \frac{K_{t+1}}{K_t} \right] \right\}, \tag{13}$$

where $\mathrm{MRS}_{t,t+1}$ is the marginal rate of substitution of consumption between periods t and $t+1$, and $\Phi'\left(\frac{K_t}{K_{t-1}}\right)$ is the derivative $\phi(\frac{K_t}{K_{t-1}} - (1+g))$ or, more briefly, $\Phi'_{t,t-1}$.

The government in the home country is benevolent and searches for the tax rates, bond issuance, and public purchases that would be optimal for the home household and also compatible with the equilibrium conditions of the home economy. In other words, the government chooses τ_t, D_t, and G_t solving the well-known Ramsey program, that takes the first-order conditions of the firm (4) and (5) and the household (11)–(13) as restrictions of the utility maximization problem, in addition to the resource contraint of the home country (14) and its own government budget constraint (15)

$$C_t + I_t + G_t + p_t(A_t - D_t) = Y_t + (A_{t-1} - D_{t-1}), \tag{14}$$

$$G_t + D_{t-1} = \tau_t W_t + p_t D_t. \tag{15}$$

Therefore, the government takes the price of foreign bonds $p_t^\star$ as given, whereas the effect of decisions about G_t, D_t, and τ_t in home prices p_t, W_t, and r_t^K is fixed by the predetermined equilibrium conditions in the home country. Formalizing explicitly the Lagrangian of the social planner's problem, the government chooses sequences $\{G_t, C_t, N_t, K_t, A_t, D_t\}$ maximizing:

$$\begin{aligned}
\mathcal{L} = E_0 \sum_{t=0}^{\infty} \beta^t \Bigg\{ & \frac{\left[C_t G_t{}^{\nu} (1 - N_t)^{\theta}\right]^{1-\sigma}}{1-\sigma} \\
& + M_t \left\{ E_t \mathrm{MRS}_{t,t+1} - \left[p_t^\star + \zeta(A_t - D_t) \right] - \zeta A_t \right\} \\
& + \Psi_t \Bigg\{ E_t \mathrm{MRS}_{t,t+1} \Bigg[\alpha Z_t K_{t-1}^{\alpha-1} (\Gamma_t N_t)^{1-\alpha} + 1 - \delta \\
& - \left\{ \Phi_{t+1,t} - \Phi'_{t+1,t} \frac{K_{t+1}}{K_t} \right\} \Bigg] - \left[1 + \Phi'_{t,t-1} \right] \Bigg\} \\
& + H_t \Bigg\{ (1-\alpha) Z_t K_{t-1}^{\alpha} (\Gamma_t N_t)^{1-\alpha} - \theta C_t N_t (1 - N_t) \\
& + \left[E_t \mathrm{MRS}_{t,t+1} - \zeta A_t \right] D_t - D_{t-1} - G_t \Bigg\}
\end{aligned}$$

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$$+ \Lambda_t \Bigg\{ Z_t K_{t-1}^{\alpha} \big(\Gamma_t N_t\big)^{1-\alpha} + (1-\delta) K_{t-1} - \Phi_{t+1,t} + (A_{t-1} - D_{t-1}) \ldots$$

$$\ldots - \Big[E_t \mathrm{MRS}_{t,t+1} - \zeta A_t \Big] (A_t - D_t) - C_t - K_t - G_t \Bigg\},$$

where M_t and Ψ_t are the Lagrange multipliers of the Euler equations for bonds and capital, while H_t and Λ_t are the multipliers of the government budget constraint and the resource constraint. Notice that in the Lagrangian equations (4), (5), (8), (9), and (11) have already been subtituted in equations (12)–(15), thus plugging in these equations the planner's allocation yields values $\{Y_t, r_t^K, W_t, p_t, I_t, \tau_t^N\}$ such that the equilibrium optimality conditions hold.

Moreover, the rest-of-the-world counterparts of equations (4)–(11) must hold, with $G_t^\star$, $D_t^\star$, and $\tau_t^\star = 0$ because I abstract from the foreign public sector. Thus, the value of all prices and quantities in both countries are those clearing the international bond market

$$(A_t - D_t) + (A_t^\star - 0) = 0, \qquad \textbf{(16)}$$

which, by Walras' law, also clears the market of goods. To find the solution of this model, it is necessary to rewrite all optimality conditions in detrended terms: $x_t = X_t / \Gamma_t$.

5. CALIBRATION

In the preceding section, I built an open economy model featuring transitory and permanent TFP shocks. The motivation was to explain new evidence that fiscal policy in the US depends on the nature of productivity shocks. Thus, in my benchmark calibration, I follow previous work including these features and calibrated to the United States. In particular, I take values from Amdur and Ersal-Kiziler (2014) that calibrate a symmetric two-country model to quarterly data from the United States and the G6. My model includes a government for the United States, whereas they modeled exclusively the private sector; thus, there are some minor differences. In particular, ν—the ratio of US government purchases to private consumption—is calibrated to 0.35, which yields government purchases equal to 20% of output. Table A.2 provides the list of all necessary calibrated values.

Amdur and Ersal-Kiziler (2014) and many models featuring open economies set the coefficient of risk aversion equal to 2. Thus, $s = 2$ is the reference value in my benchmark calibration. Also, these models fix hours worked N equal to one-third in both countries. Then, given $N = 0.33$ and $\nu = 0.35$, the parameter ω must be equal to 0.33 and, thus, $\sigma = 1.33$. Then, I put $(1-\sigma^\star)$ equal to $(1+\nu)(1-\sigma)$ so that bond prices are equal in both countries when external debt is zero. This yields $\sigma^\star = 1.45$ and $p = 0.97$ when the discount rate is $\beta = 0.98$ in both countries as

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well as long-run productivity growth $g = 0.73\%$. Table A.2 also reports that, in this case, $\theta = 1.45$ and $\theta^\star = 1.78$.

In contrast, the literature studying optimal taxation, like Marcet and Scott (2009) and Grechyna (2014), typically uses a coefficient of risk aversion $s = 1$, that is, separable log utility. I also study this case as a first additional calibration. So, given $N = 0.33$, $\nu = 0.35$, and the case of $\sigma = 1$ such that $(1 - \sigma) = \omega(1 - s) = 0$, this yields $\theta = 1.73$ in the United States and $\theta^\star = 1.81$ in the foreign economy.[10]

Furthermore, I consider the specification of $s = 2$ with separable preferences to show clearly the role of private consumption and public purchases being complementary. In this second additional calibration I use preferences (6')

$$\frac{\left[C_t{}^{\omega}(1-N_t)^{1-\omega}\right]^{1-s}}{1-s} + \chi\frac{\left[G_t^{\omega}\right]^{(1-s)}}{(1-s)} \equiv \frac{\left[C_t(1-N_t)^{\theta}\right]^{1-\sigma}}{1-\sigma} + \omega\chi\frac{\left[G_t\right]^{(1-\sigma)}}{(1-\sigma)}. \quad (6')$$

Then, setting again $N = 0.33$ and government purchases as 20% of output, I obtain that ω must be equal to 0.37 and, thus, $\sigma = \sigma^\star = 1.37$. In this case, $\chi = 0.81$, $\theta = 1.70$, and $\theta^\star = 1.79$, shown in Table A.2.

Finally, the rest of parameters are set equal in both countries. The depreciation rate δ is 0.05 and $\alpha = (1 - 0.68)$ as in Marcet and Scott (2009) and Amdur and Ersal-Kiziler (2014). The parameter calibrating the capital adjustment costs ϕ is set to 1.5 and the interest rate premium on external debt ζ to 0.005. Importantly, the two AR(1) processes for productivity have been calibrated following the estimated values in Amdur and Ersal-Kiziler (2014) for the US data. Thus, the persistence of transitory shocks to productivity ρ^z is set to 0.77, while their standard deviation is $\sigma^z = 0.41\%$. In contrast, productivity "trend" shocks have standard deviation $\sigma^g = 0.73\%$ and persistence $\rho^g = 0.61$. In the last section, though, I explore other calibrations for these parameters that give a different relative importance and persistence of the two types of TFP shocks.

6. MODEL RESULTS

This section shows the results of the model in terms of impulse-responses and the moments that it produces based on artificial simulations. The model is able to generate correlations of economic and fiscal variables with long-term expectations consistent with those presented in Section 3. Also, impulse-responses follow, broadly, the main features of those estimated in the SVAR for permanent and transitory productivity shocks.

6.1. Model Impulse-Responses

Figures B.3–B.5 show impulse-responses of several variables in the model to one-standard-deviation shocks to productivity. The left column corresponds to transitory shocks, while the right column plots responses to permanent ones. Given the simplicity of the model, the goal is not to match the responses estimated using the SVAR model, but to explain how the responses differ according to the nature of the shock.

First, Figure B.3 shows the responses of TFP, output Y, and public purchases G; i.e., the variables in the empirical analysis of Figure B.2. First, the graphs at the top show the impact on the level of productivity of shocks of different type. Although the effect of transitory shocks dies away after 20 quarters, permanent shocks gradually move productivity to a new level 2.5% higher. The second row shows the effect on output, which is an amplified and more persistent version of the responses of productivity. This is not surprising, given that RBC models yield similar dynamics for output and productivity where international savings and capital accumulation allows for longer and bigger effects. This amplification is clearly observed in the case of permanent productivity shocks where output moves to an almost 4% higher level.

Although not shown in Figure B.3, the responses of tax revenue look very similar to those of output. This is because, in the model, wage income is a constant share of output, and tax rates do not move much (more on this later). An important take away, though, is that permanent productivity shocks not only make the home country richer as a whole but, in particular, the government also becomes much wealthier. Finally, the last row presents the effects in government purchases. All specifications show that the response of government spending to transitory shocks is smaller but more persistent than the response of tax revenue. In response to permanent shocks, public purchases also move to a close to 4% higher level. Notice, however, that when purchases are complementary to private consumption, the adjustment on impact is much stronger. Broadly, these features were found in Figure B.2: the estimated effect of transitory shocks on $\ln G_t$ using the SVAR is temporary, whereas $\ln G_t$ quickly moves to a higher level after a permanent shock.

Figure B.4 helps the reader in understanding the behavior of the government by showing responses the three variables of interest in the SVAR analysis. In particular, it plots the responses produced by the open economy RBC model for public purchases, the primary fiscal surplus, and the tax rate on labor-income. First, the ratio of public purchases to output, G/Y, is below its steady-state value during 10 quarters in response to transitory shocks, whereas it becomes much larger in the first quarters after a permanent shock. Also this response to a permanent shock is much stronger when C and G are complementary. The response of the primary fiscal balance as a share of output, $\text{pSp}/Y = (T - G)/Y$, is a mirror image of that of purchases. The interpretation, then, becomes much clearer: the government smooths over time the extra affordable purchases caused by a positive productivity shock. When this shock is transitory, the government spends less that its revenue generating fiscal surpluses. If the shock is permanent, the government frontloads public purchases running fiscal deficits. Again, this pattern fits, broadly speaking, the behavior described in Figure B.1.

Notice, though, that the government is solving the planner's problem. As a result, it not only tries to smooth public purchases, but also private consumption. Given that wage income taxes are distortionary, the government chooses to raise

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taxes temporarily after a transitory shock. This reaction favors fiscal surpluses during the first quarters and lowers the household's (after-tax) income available for consumption. In the long-run, though, tax rates can stay at a lower level because the government exploits the accumulated savings. As a result, the long-run (after-tax) income of the household would increase, allowing for higher private consumption. This type of optimal response to transitory shocks is discussed in Marcet and Scott (2009).

The last row in Figure B.4 shows that permanent productivity shocks leads to much lower tax rates forever. Given the persistent effect of the shock in the growth rate of productivity, its impact on wealth is higher in the long-run than during the first quarters; thus, the government lowers the tax rate even more in the first periods. This increases the initial fiscal deficits and leaves more wage income available for consumption of the household. Therefore, the optimal response of the tax rate is favoring private consumption smoothing. There is no opposition between smoothing public purchases and taxes because this is an open economy model and the foreign economy lends the necessary goods.

Finally, Figure B.5 shows the responses of the share on output of sovereign debt, D/Y, and net exports, NX/Y where the latter are defined as $NX = Y - C - I - G$. Given that the federal budget generates surpluses after a transitory shock, the government increases savings—i.e., lowers D/Y—when long-term wealth is lower than short-term revenue. In contrast, the optimal response after a permanent shock is to issue debt as this shock improves short-term prospects but even more long-term ones. The reactions of NX/Y are like those discussed in the literature combining "trend" shocks and open economies: Aguiar and Gopinath (2007), Amdur and Ersal-Kiziler (2014), etc. The home country lends to the foreign economy if the shock is transitory, whereas it borrows from the rest of the world after a permanent shock.[11] The contribution of the model, in this paper, is that it characterizes this behavior as the Ramsey planner allocation in an open economy setup. As mentioned by Roubini (1988), optimal tax-smoothing is consistent with the predictions of the intertemporal model of the current account.[12]

6.2. Simulated Moments

In this subsection, the performance of the model is analyzed in terms of the second moments generally discussed in the business cycle literature and, more importantly, in comparison with the stylized facts described in Section 3.

Table A.3 shows the correlations generated by the model of long-run growth forecasts with fiscal and economic variables. These model-implied moments are, in particular, the linear correlation coefficient between the (nonfiltered) timeseries of forecasts and the shares on output of these variables. Long-term forecasts for productivity, real output, and tax revenue growth are calculated by simulating the model for every period t the trajectory of these variables in the following 40 quarters, i.e., $t + s$ for $s = 1, \ldots, 40$. For example, the expectations on

40-quarters-ahead productivity are calculated by iterating forward the processes (2) and (3) followed by Z_{t+s} and Γ_{t+s} and based on their realized values up to t.

These modeled expectations are compared with the ratios of budget components—public purchases G, tax revenue $T = \tau \cdot W$, and the primary surplus pSp—and other economic variables—private consumption C, investment I, and net exports NX—to output Y in terms of contemporaneous correlations. Although G is positively correlated, T and pSp are negatively correlated. Similarly, while C and I are positively correlated, NX are negatively correlated. This is true for all types of preferences considered and they successfully replicate the sign of correlations found in the data. However, it is also true that all correlations are stronger than those observed for CBO forecasts.

Table A.4 shows the statistical moments of Hodrick–Prescott (HP) filtered data from the first quarters of 1955–2015 and equivalent moments generated by the model.[13] Its goal is to report how the model performs in terms of the usual moments studied in the RBC literature. Although not shown in the table, all model specifications yield standard deviations for output around 1.7, which are slightly over that observed in the data during that timespan (1.5). Private consumption is less volatile than output, whereas the opposite is true for investment. Both, net exports and the primary fiscal balance are successfully generated less volatile than output; however, tax revenue and public purchases are clearly less volatile than in the data.

The second and third columns of Table A.4 show the correlation of HP filtered variables with output, and their autocorrelation with observations lagged by one period. In general, the model fits well the moments for C, I, and NX/Y, except for the correlation of the latter with output (which is positive in the model but negative in the data). As in the case of their volatility, the simulations for fiscal variables do not match well the moments of the data, though. This is not surprising, given that the model is designed to fit the long-run behavior of fiscal variables and not their dynamics at business cycle frequency. It is a bit more problematic, however, the fact that the model does not match the negative contemporaneous correlation between HP filtered NX/Y and Y. Aguiar and Gopinath (2007) find that the importance of permanent shocks relative to transitory shocks is key to match this moment. Thus, in the next section, I study the performance of the model using other plausible calibrations of the productivity processes in the literature.

7. ROBUSTNESS ANALYSIS

In the preceding section, the parameter values for the persistence of transitory shocks to productivity ρ_z and their standard deviation σ_z, as well as the persistence of productivity "trend" shocks ρ_g and their standard deviation σ_g, were calibrated to those estimated by Amdur and Ersal-Kiziler (2014) for the United States. However, these authors also explain that this calibration yields a measure of relative importance of "trend" shocks much higher than that estimated by other papers. In particular, the parameters estimated by Amdur and Ersal-Kiziler (2014) for the United States give a variance of the trend relative to the total volatility of productivity of $V = 0.67$, where $0 < V < 1$.[14] Ersal calibrates the US economy with parameters that yield a metric V equal to 0.36. The parameter values estimated for Canada by Aguiar and Gopinath (2007) and Boz et al. (2011) give a measure V equal to 0.23 and 0.22, respectively. Thus, this section studies the robustness of previous results to alternative calibrations that yield lower measures of V.

First, Table A.5 reports the correlations between long-run growth forecasts and the ratios as studied in Table A.3. It focuses in the benchmark calibration where $s = 2$ and G and C are complementary goods, changing the parameters determining the relative importance of permanent and transitory TFP shocks. In the first-upper part, these parameters take the values of Ersal-Kiziler (2016), that is, $\sigma_z = 0.1\%$, $\sigma_g = 0.1\%$, $\rho_z = 0.7$, and $\rho_g = 0.55$. The second-middle part uses those estimated by Aguiar and Gopinath (2007) for Canada: $\sigma_z = 0.63\%$, $\sigma_g = 0.47\%$, $\rho_z = 0.97$, and $\rho_g = 0.29$. The third-bottom part uses those estimated by Boz et al. (2011) for Canada: $\sigma_z = 0.7\%$, $\sigma_g = 0.56\%$, $\rho_z = 0.9$, and $\rho_g = 0.21$. An online appendix provides the results for log preferences and separable preferences over G and C with $s = 2$, i.e., the two alternative calibrations also studied in Section 5.

Regarding the correlations with long-term expectations, their sign is generally the same as in the data; however, the size gets closer to the data as the random walk component or trend becomes relatively smaller (i.e., lower V). Thus, if the relative variance of the trend in the United States were actually closer to that estimated for Canada by previous work, the correlations generated by the model would match very closely those observed for the United States. This might be plausible, since Amdur and Ersal-Kiziler (2014) admit that the relevance of "trend" shocks estimated in their work is surprisingly high. Notice also that the correlation of C/Y with long-term expectations becomes negative. This is not problematic, though, since the empirical correlation of C/Y with some private long-term forecasts was also negative, like the mean forecast for real GDP growth of the SPF.

The online appendix shows that calibrating productivity processes where "trend" shocks play a smaller role is less effective in bringing these correlations closer to the data when agents are indifferent to risk, i.e., $s = 1$. For instance, the correlations of fiscal ratios and tax revenue growth forecasts become weaker. The model-implied correlations when there are separable preferences over G and C and agents are risk averse with $s = 2$. Basically, they also get closer to the data as "trend" shocks become relatively less important, like with the benchmark calibration. However, in this alternative calibration and against the empirical evidence, public purchases G/Y become negatively correlated with long-term expectations. Thus, including the complementarity of G and C is helpful in making the model consistent with the data.

Finally, Table A.6 reports the second moments generated by the model at business cycle frequency. The biggest concerned raised by our benchmark calibration was that it produces a positive correlation between HP-filtered NX/Y and Y. Table A.6 shows that using the parameter values that Aguiar and Gopinath

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(2007) estimates for Canada to calibrate my model turns this correlation negative, as in the data. The parameters used in Boz et al. (2011) yield a similar variance of the random walk component relative to the total volatility of productivity (V), but they fail to generate this correlation because the persistence of "trend" shocks ρ_g is too low. Thus, it is enough to increase this parameter for obtaining moments and correlations as good as those obtained with the values of Aguiar and Gopinath (2007). For instance, using the parameter values estimated in Boz et al. (2011) but setting ρ_g equal to 0.29, yields moments that are also very consistent with the data.

The same analysis can be made from the alternative calibrations with separable preferences over G and C or with indifference to risk. In summary, simulating the model with: (i) private consumption and government purchases being complementary, (ii) agents having the usual degree of risk aversion, and (iii) productivity processes were "trend" shocks play a smaller role, yields timeseries' correlations and business cycle second moments very close to those observed in US data.

8. CONCLUSION

The financial crisis has led to a downward revision of long-term growth forecasts in advanced economies. For instance, in 2016, 10-year-ahead forecasts for US productivity and real GDP growth reached minimum since they started being published. Previous papers have shown the important role that shocks hitting the long-term ("trend") growth rate have had in asset prices and international capital flows. This paper contributes to this literature by being the first in studying the effects of trend changes in the context of fiscal policy and public finance. First, I presented a set of stylized facts using novel data on CBO forecasts for productivity, real GDP, and tax revenue long-term growth. Remarkably, government purchases and fiscal deficits are positively correlated with growth expectations, whereas tax receipts are negatively correlated. Moreover, I identified permanent and transitory TFP shocks estimating a SVAR model with US data. I found that public purchases and deficits increase after a permanent shock, whereas they fall in response to transitory innovations. In contrast, estimates of wage-income tax rates fall permanently after a "trend" shock, whereas they rise after a transitory one. These facts suggest that the government, searching to adjust the budget to news about long-term growth, borrows if it expects higher future wealth, or lends when facing gloomier prospects.

Second, I showed that a simple RBC model successfully reproduces these correlations. The first key element in the model is that productivity is hit by transitory and permanent shocks (the latter modeled as a unit root process). The second essential ingredient is that the government is benevolent and makes decisions on purchases, savings, and distortionary taxes solving the well-known Ramsey problem. The third important feature is that the US is modeled as an open economy. As illustrated by the impulse-responses, the government optimally issues debt to finance a frontload of public purchases and a reduction of tax rates after a "trend" shock, whereas the opposite holds if the shock is transitory. The government is, thus, smoothing public purchases and the wage-income tax rate, so that distortionary tax changes can be minimized.

My work leaves aside interesting questions beyond the scope of the present paper. For example, the political process and its own dynamics is clearly an important factor determining government purchases and its financing. However, I leave aside political economy considerations to focus instead on the role of long-term growth expectations on fiscal policy. Thus, my paper joins recent work emphasizing instead the long-term forward-looking behavior of the government, as in Craig et al. (2016) where a buffer stock model is fitted to data on the Unemployment Insurance US state programs to explain their management by politicians.

SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit https://doi.org/S1365100518000330.

NOTES

1. There is a long literature and debate on the relation between the budget and current account balances; see, for example, Corsetti and Mü (2007) or Kumhof and Laxton (2013).

2. The CBO was created in July 12, 1974; but official operations did not begin until February 24, 1975.

3. To avoid considering growth rates related to negative federal net revenue quantities, like the ones observed during the recent crisis, expected changes in net revenue are divided by current GDP; see the online appendix.

4. Focusing in nondefence spending is very common in the literature studying government purchases: since Ambler and Paquet (1996) until more recent work like Bachmann and Bai (2013). In empirical studies on fiscal policy, defence spending is typically treated as exogenous, for instance Ramey (2011) uses war dates to identify exogenous public spending shocks.

5. The correlation between investment and 10-year-ahead private forecasts on productivity and real GDP growth from the SPF are 0.38 and 0.49, respectively, thus, higher than for CBO forecasts. In contrast, those of private consumption are 0.13 and -0.12: not as clearly positive as for CBO projections. Net exports are strongly negatively correlated with SPF long-run forecasts: -0.79 and -0.63, respectively.

6. The results do not change by estimating three SVARs including only one variable of interest on each.

7. The online appendix shows that this problem is attenuated using data up to 2009—as in Sims (2011)—and it is no longer present if you take data before 2007. The results of the SVAR analysis for fiscal variables in this paper also hold in those subsamples.

8. Because the SVAR described in Figures B.1 and B.2 already captures the dynamic link between fiscal variables, I show the robustness of X_t responses in the online appendix, where all three extra controls were added.

9. Interest rate premia are used in the open economy literature to make the net asset position of the country stationary in the linearized model; see Schmitt-Grohe and Uribe (2003).

10. Recall that the tax rate is 0 in equation (11) corresponding to the rest-of-the-world.

11. See early work in international economics—Baxter and Crucini (1995), Kollmann (1998), etc.—for a discussion on the implications of incomplete markets and the persistence of technological shocks in current account dynamics.

12. Responses for private sector variables like the ratios consumption C/Y and investment I/Y, or the level of private consumption C are shown in the online appendix.

13. Model generated moments are the average of those obtained by creating 100,000 artificial simulations of the same size as our sample.

14. According to the model in this paper, total productivity is equal to $Z_t \Gamma_t^{1-\alpha}$. The growth rate of productivity has then volatility equal to $[2\sigma_z^2/(1+\rho_z)] + [(1-\alpha)^2\sigma_g^2/(1-\rho_g^2)]$, as explained in Boz et al. (2011). Thus, a measure of the importance of permanent shocks relative to transitory shocks in total productivity that account for their persistence parameters is

$$V = \frac{(1-\alpha)^2\sigma_g^2/(1-\rho_g^2)}{[2\sigma_z^2/(1+\rho_z)] + [(1-\alpha)^2\sigma_g^2/(1-\rho_g^2)]} \quad \text{where} \quad 0 < V < 1,$$

that is, the variance of the random walk component relative to the total volatility of productivity.

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APPENDIX A: TABLES

TABLE A.1. Correlations with CBO long-run growth forecasts for 1984–2016

			rGDP		nTAX	
Share of GDP		PROD 10y	6y	10y	6y	10y
1	G^*	0.25	0.33	0.31	0.37	0.73
2	G	0.25	0.35	0.21	0.70	0.67
3	Tax	−0.34	−0.45	−0.48	−0.57	−0.73
4	nTax	−0.28	−0.25	−0.22	−0.64	−0.65
5	*pSpl*	−0.28	−0.35	−0.18	−0.71	−0.66
6	C	0.44	−0.01	0.17		
7	I	0.06	0.20	0.13		
8	NX	−0.85	−0.59	−0.79		

Note: The correlation between the average of private forecasts in the Survey of Professional Forecasters (SPF) and CBO forecasts for PROD and rGDP is 0.8 and 0.88, respectively. Correlations of averaged SPF forecasts and the shares of C, I, and NX on GDP are 0.13 and −0.12, 0.38 and 0.49, and −0.79 and −0.63.

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TABLE A.2. Calibration for the United States

Parameter values			
Benchmark calibration			
s	2	$s^\star$	2
σ	1.33	$\sigma^\star$	1.45
θ	1.70	$\theta^\star$	1.78
$\nu = G/C$	0.35	$\nu^\star$	0
D/Y	0	$A^\star$	0
β	0.98	δ	0.05
α	0.32	ϕ	1.5
ζ	0.005	g	0.73%
ρ^z	0.77	ρ^g	0.61
σ^z	0.41%	σ^g	0.73%
Logarithmic preferences			
s	1	$s^\star$	1
σ	1	$\sigma^\star$	1
θ	1.73	$\theta^\star$	1.81
Separable preferences on $C\&G$			
s	2	$s^\star$	2
σ	1.37	$\sigma^\star$	1.37
θ	1.70	$\theta^\star$	1.79

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TABLE A.3. Correlations with long-run growth forecasts

		PROD		rGDP		nTAX	
Share of GDP		Data	Model	Data	Model	Data	Model
a				$s = 1$			
a1	C	0.44	0.69	0.17	0.68		
a2	I	0.06	0.71	0.13	0.71		
a3	NX	−0.85	−0.90	−0.79	−0.89		
a4	$pSpl$	−0.28	−0.81	−0.18	−0.80	−0.66	−0.83
a5	G	−0.25	0.71	0.21	0.70	0.67	0.74
a6	T	−0.34	−0.86	−0.48	−0.85	−0.73	−0.87
b				$s = 2$			
b1	C	0.44	0.73	0.17	0.72		
b2	I	0.06	0.63	0.13	0.63		
b3	NX	−0.85	−0.91	−0.79	−0.91		
b4	$pSpl$	−0.28	−0.88	−0.18	−0.88	−0.66	−0.89
b5	G	−0.25	0.87	0.21	0.87	0.67	0.88
b6	T	−0.34	−0.87	−0.48	−0.87	−0.73	−0.87
c				$s = 2$ G separable			
c1	C	0.44	0.76	0.17	0.75		
c2	I	0.06	0.68	0.13	0.68		
c3	NX	−0.85	−0.91	−0.79	−0.90		
c4	$pSpl$	−0.28	−0.84	−0.18	−0.83	−0.66	−0.86
c5	G	−0.25	0.76	0.21	0.74	0.67	0.78
c6	T	−0.34	−0.87	−0.48	−0.87	−0.73	−0.87

Note: The empirical correlation between the average of private forecasts in the Survey of Professional Forecasters (SPF) and CBO forecasts for PROD and rGDP is 0.8 and 0.88, respectively. Correlations of averaged SPF forecasts and the shares of C, I, and NX on GDP are: 0.13 and −0.12, 0.38 and 0.49, and −0.79 and −0.63.

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TABLE A.4. Moments for HP filtered simulations

		sd_X/sd_Y		$corr(X, Y)$		$corr(Yt, Y_{t-1})$	
Y = output variable X		data	model	data	model	data	model
a				$s = 1$			
a1	C	0.54	0.78	0.82	0.80	0.89	0.77
a2	I	3.95	2.24	0.93	0.81	0.85	0.81
a3	NX/Y	0.27	0.64	−0.44	0.15	0.77	0.57
a4	pSp/Y	0.76	0.17	0.65	0.41	0.83	0.53
a5	G	3.41	0.80	0.08	0.80	0.48	0.77
a6	T	2.70	1.04	0.52	0.95	0.81	0.83
b				$s = 2$			
b1	C	0.54	0.84	0.82	0.85	0.89	0.80
b2	I	3.95	2.09	0.93	0.88	0.85	0.81
b3	NX/Y	0.27	0.67	−0.44	0.06	0.77	0.60
b4	pSp/Y	0.76	0.29	0.65	0.20	0.83	0.56
b5	G	3.41	1.30	0.08	0.52	0.48	0.64
b6	T	2.70	1.03	0.52	0.95	0.81	0.84
c				$s = 2$ G separable			
c1	C	0.54	0.86	0.82	0.82	0.89	0.78
c2	I	3.95	2.16	0.93	0.84	0.85	0.81
c3	NX/Y	0.27	0.63	−0.44	0.09	0.77	0.58
c4	pSp/Y	0.76	0.19	0.65	0.32	0.83	0.53
c5	G	3.41	0.86	0.08	0.77	0.48	0.75
c6	T	2.70	1.04	0.52	0.93	0.81	0.82

Note: All model specifications yield standard deviations for output around 1.7, which are slightly over that observed in the data during that timespan (1.5).

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TABLE A.5. Correlations with long-run growth forecasts ($s = 2$)

Share of GDP		PROD		rGDP		nTAX	
		data	model	data	model	data	model
			(a) Ersal-Kiziler (2016)				
a1	*C*	0.44	0.55	0.17	0.50		
a2	*I*	0.06	0.54	0.13	0.55		
a3	*NX*	−0.85	−0.89	−0.79	−0.85		
a4	*pSpl*	−0.28	−0.85	−0.18	−0.81	−0.66	−0.89
a5	*G*	0.25	0.84	0.21	0.79	0.67	0.88
a6	*T*	−0.34	−0.84	−0.48	−0.80	−0.73	−0.86
			(b) Aguiar and Gopinath (2007)				
b1	*C*	0.44	−0.19	0.17	−0.23		
b2	*I*	0.06	0.43	0.13	0.42		
b3	*NX*	−0.85	−0.44	−0.79	−0.39		
b4	*pSpl*	−0.28	−0.29	−0.18	−0.22	−0.66	−0.34
b5	*G*	0.25	0.25	0.21	0.18	0.67	0.30
b6	*T*	−0.34	−0.38	−0.48	−0.32	−0.73	−0.42
			(c) Boz et al. (2011)				
c1	*C*	0.44	0.10	0.17	0.04		
c2	*I*	0.06	0.34	0.13	0.38		
c3	*NX*	−0.85	−0.74	−0.79	−0.71		
c4	*pSpl*	−0.28	−0.45	−0.18	−0.39	−0.66	−0.51
c5	*G*	0.25	0.44	0.21	0.38	0.67	0.52
c6	*T*	−0.34	−0.44	−0.48	−0.39	−0.73	−0.48

Note: The empirical correlation between the average of private forecasts in the Survey of Professional Forecasters (SPF) and CBO forecasts for PROD and rGDP is 0.8 and 0.88, respectively. Correlations of averaged SPF forecasts and the shares of C, I, and NX on GDP are: 0.13 and −0.12, 0.38 and 0.49, and −0.79 and −0.63. Ersal-Kiziler (2016) uses $\sigma_z = 0.1\%$, $\sigma_g = 0.1\%$, $\rho_z = 0.7$, and $\rho_g = 0.55$, which yields $V = 0.36$. Aguiar and Gopinath (2007) uses $\sigma_z = 0.63\%$, $\sigma_g = 0.47\%$, $\rho_z = 0.97$, and $\rho_g = 0.29$, which yields $V = 0.22$. Boz et al. (2011) uses $\sigma_z = 0.7\%$, $\sigma_g = 0.56\%$, $\rho_z = 0.9$, and $\rho_g = 0.21$, which yields $V = 0.23$.

TABLE A.6. Correlations with long-run growth forecasts ($s = 2$)

		sd_X/sd_Y		$corr(X, Y)$		$corr(Yt, Y_{t-1})$	
Y = output variable X		data	model	*data*	*model*	data	model
(a) Ersal-Kiziler (2016)							
a1	C	0.54	0.78	0.82	0.91	0.89	0.78
a2	I	3.95	2.33	0.93	0.90	0.85	0.75
a3	NX/Y	0.27	0.52	−0.44	−0.08	0.77	0.57
a4	pSp$/Y$	0.76	0.21	0.65	0.19	0.83	0.54
a5	G	3.41	1.11	0.08	0.70	0.48	0.64
a6	T	2.70	1.01	0.52	0.97	0.81	0.83
(b) Aguiar and Gopinath (2007)							
b1	C	0.54	0.74	0.82	0.98	0.89	0.76
b2	I	3.95	2.48	0.93	0.93	0.85	0.69
b3	NX/Y	0.27	0.32	−0.44	−0.34	0.77	0.57
b4	pSp$/Y$	0.76	0.10	0.65	0.19	0.83	0.55
b5	G	3.41	0.96	0.08	0.92	0.48	0.65
b6	T	2.70	0.98	0.52	0.99	0.81	0.79
(c) Boz et al. (2011)							
c1	C	0.54	0.62	0.82	0.94	0.89	0.75
c2	I	3.95	2.45	0.93	0.95	0.85	0.67
c3	NX/Y	0.27	0.26	−0.44	0.05	0.77	0.62
c4	pSp$/Y$	0.76	0.14	0.65	0.64	0.83	0.69
c5	G	3.41	0.74	0.08	0.85	0.48	0.64
c6	T	2.70	1.08	0.52	0.99	0.81	0.74

Note: All model specifications yield standard deviations for output around 1.7, which are slightly over that observed in the data during that timespan (1.5). Ersal-Kiziler (2016) uses $\sigma_z = 0.1\%$, $\sigma_g = 0.1\%$, $\rho_z = 0.7$, and $\rho_g = 0.55$, which yields $V = 0.36$. Aguiar and Gopinath (2007) uses $\sigma_z = 0.63\%$, $\sigma_g = 0.47\%$, $\rho_z = 0.97$, and $\rho_g = 0.29$, which yields $V = 0.22$. Boz et al. (2011) uses $\sigma_z = 0.7\%$, $\sigma_g = 0.56\%$, $\rho_z = 0.9$, and $\rho_g = 0.21$, which yields $V = 0.23$.

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APPENDIX B: FIGURES

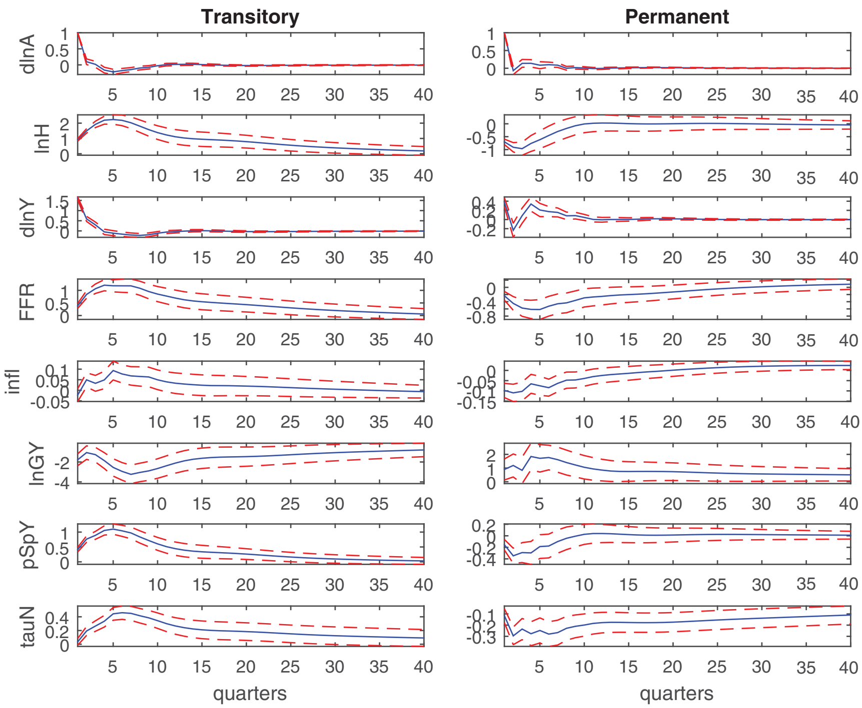

FIGURE B.1. SVAR responses: Growth rates and ratios. Variables included are $d\ln A$, i.e., $\Delta \ln A_t$ or the growth rate of TFP; $\ln H$, i.e., $\ln N_t$ or the log of hours worked; $d\ln Y$, i.e., $\Delta \ln Y_t$ or the growth rate of output; FFR or the federal funds rate; pi, i.e., π_t or inflation; $\ln GY$, i.e., $\ln G_t/Y_t$ or public purchases to GDP; pSpY, i.e., pSp_t/Y_t or the primary fiscal surplus to GDP; and tau$N$, i.e., τ_t or the tax rate on labor income. One-standard-deviation confidence bands are reported.

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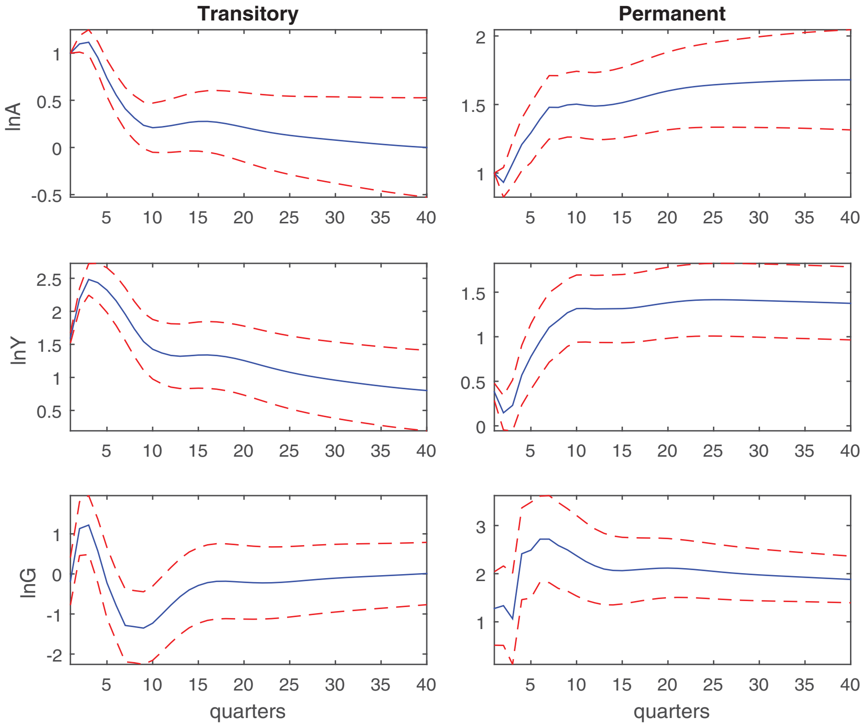

FIGURE B.2. SVAR responses in levels. Responses of $\ln A$ and $\ln Y$ are the cumulative sum of the impulse-responses of the growth rates $\Delta \ln A_t$ and $\Delta \ln Y_t$; while the response of $\ln G$ is the one of the $\ln\, G_t/Y_t$ plus that of $\ln Y$. One-standard-deviation confidence bands are reported.

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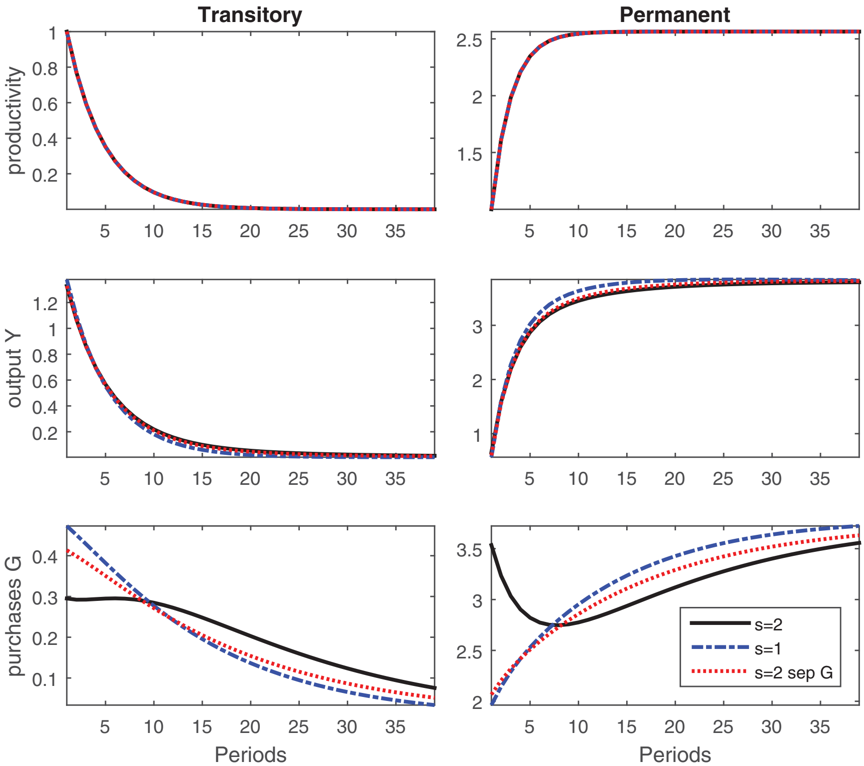

FIGURE B.3. Responses of productivity $Z_t \Gamma_t^{1-\alpha}$, output Y_t and public purchases G_t to permanent and transitory shocks to productivity. In solid and black the benchmark specification with $s = 2$, in blue and dotted-dashed for $s = 1$, while in red and dotted for $s = 2$ with separable preferences over $C\&G$.

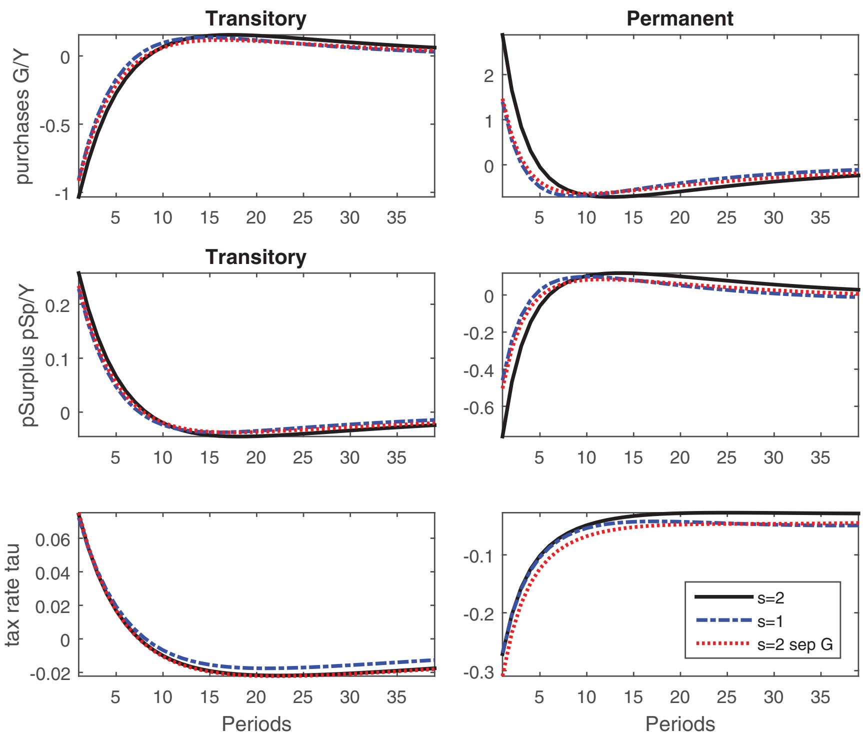

FIGURE B.4. Responses of public purchases G_t/Y_t and primary fiscal surplus pSp_t/Y_t as shares of output, and the wage-income tax rate τ_t to permanent and transitory shocks to productivity. In solid and black the benchmark specification with $s = 2$, in blue and dotted-dashed for $s = 1$, while in red and dotted for $s = 2$ with separable preferences over $C\&G$.

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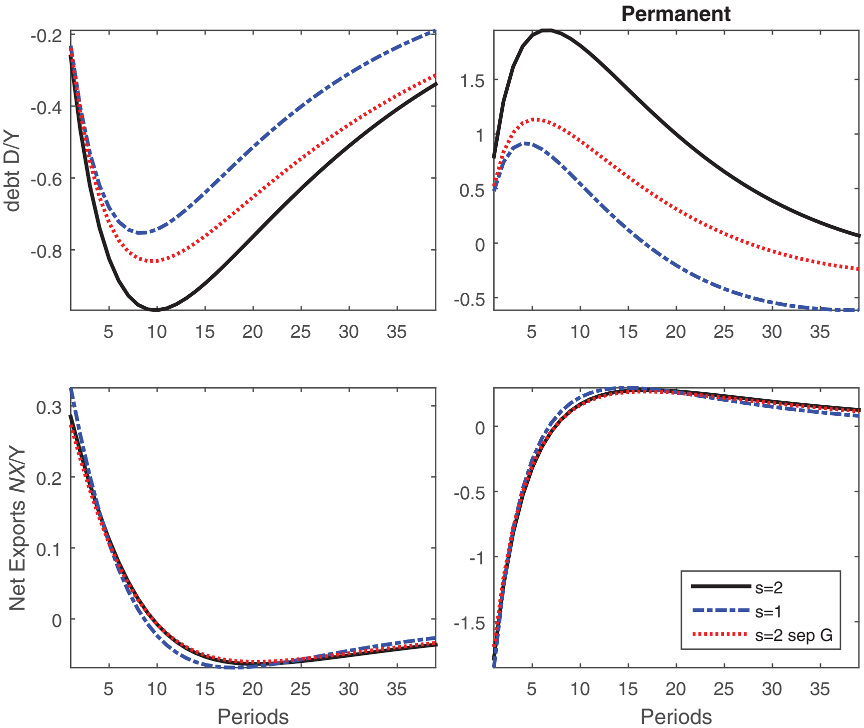

FIGURE B.5. Responses of the shares of sovereign debt D_t/Y_t and net exports NX_t/Y_t on output to permanent and transitory shocks to productivity. In solid and black the benchmark specification with $s = 2$, in blue and dotted-dashed for $s = 1$, while in red and dotted for $s = 2$ with separable preferences over $C\&G$.

APPENDIX C: DATA DEFINITIONS

VARIABLES USED IN CORRELATIONS

Output (GDP or Y): Table 1.1.5 line 1

Consumption (C): Private consumption of nondurable goods (Table 1.1.5, line 5) + services (line 6)

Investment (I): Gross private domestic investment (Table 1.1.5, line 7) + private consumption of durable goods (line 4)

Net exports (*NX*): Net exports of goods and services (Table 1.1.5, line 14)

Federal (nondefence) consumption of fixed capital = Federal consumption of fixed capital (Table 3.2, line 47) − defence consumption of fixed capital (Table 3.10.5, line 27)

Federal (nondefence) purchases (G) = federal nondefence consumption expenditures (Table 3.9.5, line 26) + federal nondefence gross investment (line 27) − federal (nondefence) consumption of fixed capital

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Federal purchases ($G^{\star}$) = Federal (nondefence) purchases + national defense expenditures (Table 3.9.5, line 17) − defence consumption of fixed capital (Table 3.10.5, line 27)

Federal transfers: Current transfer payments (Table 3.2, line 25) − current transfer receipts (line 18) + subsidies (line 35) − current surplus of government enterprises (line 22) + capital transfer payments (line 45) − capital transfer receipts (line 41)

Federal tax receipts (TAX): Current Receipts (Table 3.2, line 1) − current transfer receipts (line 18) − current surplus of government enterprises (line 22)

Federal net tax revenue (nTAX): Federal tax receipts (TAX) − federal transfers

Primary federal fiscal surplus (pSp) = Federal net tax revenue (nTAX) − federal purchases ($G^{\star}$)

OTHER VARIABLES USED IN SVAR ESTIMATION

TFP growth ($\Delta \ln A_t$): $dtfp$ from Fernald (2014)

per capita real GDP growth ($\Delta \ln Y_t$) = (log differences of)
Real Gross Value of Nonfarm Business Sector (Table 1.3.6, line 3)
− Civilian Noninstitutional Population (CNP16OV, St. Louis Fed)

Federal funds rate (FFR): Effective (FEDFUNDS, St. Louis Fed)

Inflation (π_t): (log differences of) the Price Index for GDP (Table 1.1.4, line 1)

log of per capita hours ($\ln N_t$) = (log differences of) Nonfarm business sector hours worked (PRS85006033, BLS: Major Sector Productivity and Costs database) − Civilian Noninstitutional Population (CNP16OV, St. Louis Fed)

Federal debt ($debt_t$): Federal Debt: Total Public Debt (GFDEBTN, St. Louis Fed)

Average personal income tax rate: $\tau_p = \frac{\mathrm{IT}}{W+\mathrm{PRI}/2+\mathrm{CI}}$, as defined in Jones (2002)
where, *capital income*, $\mathrm{CI} = \mathrm{PRI}/2 + \mathrm{RI} + \mathrm{CP} + \mathrm{NI}$
and IT = Personal current taxes (Table 3.2, line 3)
W = Wages (Table 1.12, line 3)
PRI = Proprietor's income(Table 1.12, line 9)
RI = Rental income (Table 1.12, line 12)
CP = Corporate profits (Table 1.12, line 13)
NI = Net interest (Table 1.12, line 18)

Labor income tax rate: $\tau = \frac{\tau_p \left(W+\mathrm{PRI}/2 \right) + \mathrm{CSI}}{\mathrm{EC}+\mathrm{PRI}/2}$, as defined in Jones (2002)
where CSI = Contributions to government social insurance (Table 3.2, line 11)
EC = Total compensation of employees (Table 1.12, line 2)

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