Optimal fiscal policy and different degrees of access to international capital markets[1]

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Abstract

Empirically, the cyclical pattern of fiscal policy differs between developed and developing countries, with in particular much greater pro-cyclicality and volatility of public investment in developing countries. In this paper I provide a theoretical explanation for the observed differences by analyzing optimal fiscal policy under different degrees of access to world capital markets. If the supply of foreign capital is elastic, as in a developed country, then it is optimal to adjust to an adverse external shock by borrowing from abroad to finance public expenditure and cutting taxes to smooth private consumption. If the supply of foreign capital is inelastic, however, as in a developing country, the optimal adjustment policy is to reduce public investment (by much more than public consumption) and to raise consumption taxes.

Keywords: public investment; public consumption; fiscal policy; procyclicality; natural resources; external shocks

JEL Classifications: E32, E62, F41, H30, H54, Q33, Q43

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1 Introduction

Empirical studies of the cyclical behavior of fiscal variables have consistently found notable differences between developed and developing countries, especially in the pattern of total government expenditure, which tends to be counter-cyclical in the former and pro-cyclical in the latter group of countries (Kaminsky et al. (2005) and the references therein). A first contribution of this paper, using data on G-7 and Latin American countries, is to confirm these earlier results and to sharpen them by distinguishing between public consumption and public investment. I show that both public investment and public consumption are pro-cyclical in countries at all levels of development, but are more strongly so in developing countries[2]. I also show that public investment is more volatile (and more pro-cyclical) than public consumption, and that the volatility of public investment is far greater in developing than in developed countries.

The main contribution of this paper, however, is to provide a theoretical explanation, in the framework of optimal fiscal policy, for these empirical differences. I construct a DSGE model of a small open economy that earns stochastic revenue from exporting natural resources and whose government seeks to maximize the well-being of its citizens in the face of shocks to its resource revenues through its choices concerning four policy instruments: public consumption, public investment, a tax on private consumption, and foreign borrowing. I then show how the optimal policy response to shocks depends on the country's conditions of access to world capital markets, and that differences in capital market access generate differences in policy choices that are consistent with the observed regularities in the cyclical behavior of fiscal policy in developed and developing countries. The model assumes that developed countries have unlimited access to borrowing at a given world interest rate, whereas developing countries face borrowing constraints. These constraints are modeled through a country-specific risk premium that increases with the stock of debt issued. The private sector, which derives income from an endowment of labor and private capital, is assumed not to have access to world capital markets, so that there is a role for the government in smoothing private sector consumption. The benchmark specification of the model assumes that taxes are distortionary, but I unpick the forces that drive policy choices by also analyzing what the optimal solution would be with non-distortionary lump-sum taxes. Public consumption is assumed to provide utility directly to private households. Public capital is treated as an input to the economy's production, and public investment each period adds to the stock of public capital inherited from the previous period.

[2]This is consistent with findings by Ilzetzki and Végh (2008)

Simulations of the benchmark model identify the following effects of differing access to international capital markets on the fiscal policy response to an adverse external shock to government's revenues. In developed countries, it is optimal to borrow heavily from abroad to protect public expenditure and to reduce taxes to protect private consumption, so that both private consumption and public expenditure are more smoothed. In contrast, in developing countries the higher cost of using external finance to smooth shocks makes it optimal for more of the adjustment to be internal - that is, by reducing public expenditure and raising taxes. Most of the adjustment is of public expenditure, since increasing taxes causes large intertemporal distortions and affects the private consumption directly. Most of the public expenditure adjustment, moreover, is of public investment rather than of public consumption. This is because cuts in public consumption affect consumer utility directly and immediately, whilst cuts in public investment affect utility only indirectly, by reducing both the return on private capital and the marginal product of labor, and the effects of public spending cuts on consumer utility are spread over multiple periods of time as capital depreciates over time. There is a simple intuitive interpretation of these differences in policy responses between developed and developing countries[3]. The optimal response to an adverse shock usually includes some sort of borrowing. Developed countries borrow from international capital markets. For developing countries, access to the world capital markets is more costly. They therefore reduce public investment, which is akin to borrowing from the future.

Changes in tax rates usually also play an important role in the optimal policy response to an external shock, and simulations of the model shed light on their nature and determinants. I find that for a lower intertemporal elasticity of substitution, a more elastic labor supply, and a higher degree of persistence of the shock, the optimal dynamic path of tax rates is hump-shaped, when countries face external borrowing constraints, and the optimal cut in the tax rate is larger if the supply of foreign capital is elastic. The intuition for these results is as follows. Lower consumption taxes (or an only moderate increase) today provide a boost to consumers' income and stimulate private investment. Unable to borrow externally, consumers use investment as a means of saving today's increase in income for tomorrow, when tax rates will be higher, and thus smooth their consumption. But how governments implement this tax policy depends on their degree of access to international capital markets. A government with unlimited access to external funds at a given world interest rate is able to stimulate private smoothing by offering tax cuts. If its access to external borrowing is limited, however, the government must initially raise tax rates by less, and increase them

[3] I am indebted to a referee for this point.

again later, generating hump-shaped path of tax rates.

The model sheds light also on the risk-mitigating role of governments in the face of external fluctuations such as terms of trade when the private sector lacks access to insurance markets (a development issue studied earlier by for example Rodrik (1998) and Bates et al. (1991)). I extend the benchmark specification of the model by assuming that the negative resource revenue shock also adversely affects the productivity of the private sector. In this case, the productivity shock directly cuts private sector income and hence dominates the effects of the government resource revenue shock, thereby creating an insurance role for the planner. The degree of insurance that governments can provide, however, is larger in developed countries, because of their unlimited access to international capital markets, than in developing countries. An elastic supply of external funds enables developed countries to cut taxes (by more than in the case of the resource shock alone) and promote private consumption smoothing. By contrast, governments in developing countries cannot afford to borrow externally to finance tax cuts that are big enough to smooth private consumption.

By estimating a partially identified structural VAR, similar to Pieschacón (2012), for one commodity-exporting developing country, Colombia, I compare VAR-based impulse responses with the ones implied by the model. The model successfully predicts the observed magnitudes of responses to shocks and confirms the crucial shock-absorbing role of public investment. The model is less successful in capturing the hump-shaped responses of both public investment and public consumption. Including additional features, such as the time-to-build process of public investment (Leeper et al. (2010) and Leduc and Wilson (2012)), might help to remedy this shortcoming, though it could also alter the optimal path of tax rates. There is thus scope for future research to improve on the present model and to bring it closer to the data, as well as a need for more empirical evidence from developing countries on the roles of public investment and tax rates in fiscal policy.

The paper proceeds as follows. Section 2 presents the main empirical observations regarding the behavior of public investment and government consumption over the business cycle in high income countries and in Latin American developing countries. Section 3 describes and solves the Ramsey problem. Section 4 calibrates the model and presents the impulse responses of the main variables of interest, then discusses the baseline results. It goes on to analyze (a) how optimal policy choices would differ if non-distorting lump-sum taxes were available, and (b) the consequences of an adverse resource revenue shock being associated with a drop in private sector productivity. In Section 5, I examine the sensitivity of the baseline results to variation in the intertemporal elasticity of substitution, the labor supply elasticity, and the degree of persistence of the resource revenue shock. Section 6 concludes.

2 Empirical evidence

This section presents the main empirical observations regarding the behavior of the public sector over the economic cycle in commodity-exporting developing countries. I start by reporting the business cycle properties of fiscal policy in a sample of Latin American developing countries and comparing them with a sample of developed countries. Next, I use a vector autoregression (VAR) to evaluate the effects of commodity prices on the main fiscal variables of interest in one commodity-exporting country, Colombia.

2.1 Stylized facts

In this section I revisit the evidence on the cyclicality of fiscal policy for a sample of high-income countries and Latin American developing countries[4]. I document the business cycle properties of real government expenditure and two of its components: public consumption and public investment. Time-series data on tax rates are unavailable for developing countries, but some indirect evidence suggests that tax rates are pro-cyclical in developing countries (Talvi and Végh (2005))[5]. Table 1 reports the business cycle properties of real government expenditure and its two components of interest. All variables are logged and de-trended with the Hodrick-Prescott (HP) filter. As is clear from the table, there are significant differences in the behavior of total government expenditure between the two groups of countries. In high-income countries, total government expenditure is counter-cyclical, while in developing countries it is pro-cyclical. The two components of public expenditure - public consumption and public investment - tend to be pro-cyclical in both income groups, but they are far more pro-cyclical in developing countries[6]. Public investment is also more

[4]There is a large literature documenting the fact that government expenditure is counter-cyclical in developed countries, but pro-cyclical in developing countries (e.g.,Kaminsky et al. (2005)). Ilzetzki and Végh (2008) document the cyclical properties of several components of government spending, and in particular of public consumption and public investment.

[5]Kaminsky et al. (2005) examine evidence on the pro-cyclicality of tax rates in countries grouped by income levels by using the inflation tax rate as a proxy. They find that inflation tax is pro-cyclical in all four groups under consideration: OECD, middle-high-income, middle-low-income and low-income countries, although the magnitude is the largest for the low-income group and the smallest for OECD countries.

[6]Counter-cyclicality of government spending in high income countries reflects the counter-cyclical nature of transfers (see for more details Ilzetzki and Végh (2008)). This paper aims to explain how governments in developed and developing countries differ in adjusting public expenditure in response to an adverse external shock; however, I neither report the business cycle properties of transfers nor attempt to account for counter-

	Latin America			High income countries		
	$Corr(X,Y)$	$Std(X)$	$\frac{Std(X)}{Std(Y)}$	$Corr(X,Y)$	$Std(X)$	$\frac{Std(X)}{Std(Y)}$
Variables, X:						
Gov't Consumption	0.47	0.09	2.41	0.10	0.02	0.96
Gov't Capital Expend.	0.52	0.23	6.03	0.14	0.12	6.58
Total Gov't Expend.	0.10	0.14	3.37	-0.12	0.04	2.38

Table 1: Business cycle properties of real government spending and its components. Y denotes real GDP. Cyclical components are calculated by first transforming the variables in log and then subtracting the trending component defined by an HP filter. Data for a sample of 8 Latin American countries and G-7, for the period 1972-2006. See Data Appendix for more details. (Sources: IMF, WB, UN)

pro-cyclical than public consumption in both groups of countries. Public investment is the most volatile component of public expenditure in both Latin American developing countries and high-income countries, but the volatility of public investment is far greater in these developing countries than in the developed ones.

The volatility of public investment in developing countries has been noted earlier, for example by Sachs (1990). Commenting on the "lost decade" that followed the debt crisis of the early 1980s, he wrote: "In Latin America, where the foreign credit squeeze was most severe, governments responded to the external shocks with a combination of spending cuts and increased domestic borrowing. In cutting spending, public investment projects were the first to go, public sector real wages the second, and public sector employment a distant third".

2.2 Vector autoregression

In this section, I use VAR analysis to evaluate the effects of commodity price shocks on key fiscal variables of interest: real public investment and real government consumption. I omit tax variables due to data limitations[7]. The VAR model is based upon estimates of the Colombian economy, for which I have also calibrated the theoretical model.

Colombian exports consist mainly of commodities such as coffee, crude oil, gold, and nickel. Between them, coffee and crude oil account for a large share of total exports. The share of coffee exports has declined since the late seventies, recently accounting for about

cyclical fiscal policy in high income countries in the theoretical framework.

[7]Ilzetzki et al. (2011) have also omitted tax variables for the same reason, and argue that it does not bias their results.

5 percent of total exports (top panel of Figure 1). The share of crude oil, however, has increased over the same time period, recently accounting for about 50 percent of total exports. Thus, both crude oil and coffee constitute large sources of income for the Colombian economy.

The empirical methodology follows Pieschacón (2012) and assumes that commodity prices are strictly exogenous to other macroeconomic variables, as would be consistent with the small open economy position of Colombia in commodity markets[8]. Given the scope of the paper, which aims to analyze only the effects of commodity price shocks on domestic variables, full identification of the remaining structural shocks is not necessary. The assumption of the strict exogeneity of commodity prices allows the identification of the structural commodity price shock, whereas all other shocks remain unidentified, and the ordering within the endogenous variables is irrelevant.

Hence, I estimate the following VAR model:

$$\begin{aligned} p_{c,t} &= \mathbf{A}(L)p_{c,t-1} + u_{c,t} \\ \mathbf{x}_t &= \mathbf{H}(L)p_{c,t} + \mathbf{J}(L)\mathbf{x}_{t-1} + \mathbf{u}_{x,t} \end{aligned} \tag{1}$$

where $p_{c,t}$ is the commodity price and $\mathbf{x}_t$ is the vector of domestic variables. Here, $\mathbf{x}_t \equiv (x_{Gt}, g_t, y_t)$[9], where x_{Gt} is real government capital expenditure, g_t is real government consumption, and y_t is real GDP. In Equation (1), $u_{c,t}$ denotes the commodity price shock, and $\mathbf{u}_{x,t}$ denotes the shocks pertaining to the variables in $\mathbf{x}_t$, such that vector $\mathbf{u}_{x,t}$ is uncorrelated with $u_{c,t}$.

The system (1) is estimated at quarterly frequency, with two lags[10]. The data go from 1977 Q1 to 2011 Q2. All variables are in constant prices, and are logged then de-trended through a Hodrick-Prescott filter. Commodity prices are deflated by using the US GDP deflator. The data in x_t were obtained from the National Statistics Department (DANE) in Colombia. Commodity prices, and the US GDP deflator are obtained from the International Financial Statistics released by the IMF.

I have experimented with two alternative specifications of the model (1), depending on the choice of variable $p_{c,t}$ in the model. I have used either the coffee price or the oil price

[8] It can be argued that Colombia, as one of the biggest producers of coffee, is actually a price-taker in the coffee market. Based on Baynesian analysis, Karp and Perloff (1993) conclude that the behavior of Brazil and Colombia is close to what can be classified as price-taking. In addition, to empirically verify the strict exogeneity assumption for commodity prices, I estimate the first equation in (1) by including endogenous variables and showing that domestic variables are statistically insignificant.

[9] The same vector of endogenous variables, with real GDP as an additional control, has been used by Ilzetzki et al. (2011) in their analysis of the real effects of fiscal stimulus.

[10] The lag length in a VAR is determined on the basis of lag-order statistics such as LR, FPE, and AIC.

as variable $p_{c,t}$, and the results are qualitatively similar. I report results based upon the oil price.

Figure (2) gives the impulse responses of the variables of interest to a one-standard-deviation shock to the oil price. The solid-dotted line presents the impulse response and the two solid lines define the 95 percent confidence interval. A one-standard-deviation shock to the oil price corresponds to a 15% increase and causes significant hump-shaped responses of both public investment and public consumption from the third quarter persisting for another five and three quarters respectively. The responses of government consumption is much smaller than that of government investment during that period. I will return to these empirical results when comparing the model results with the data in section 4.2.

3 Model

In this section I outline a neoclassical, small open economy model of a commodity-exporting country. In this model, the economy consists of households, firms and the government. The government receives exogenously given resource revenue, and chooses optimal level of taxation, external borrowing and public expenditure in order to maximize the utility of its citizens. Two versions of the government problem are considered, depending on the type of tax instrument available to the policymaker. I will first consider the solution obtained when taxes are distortionary, and will set up and solve the Ramsey problem for this case. I will later analyze the case where lump-sum taxes/transfers are possible.

3.1 Households

A representative household maximizes:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, g_t, h_t) \tag{2}$$

where

$$u(c_t, g_t, h_t) = \frac{c_t^{1-\kappa} - 1}{1-\kappa} + \theta \frac{g_t^{1-\kappa} - 1}{1-\kappa} - \frac{h_t^{1+\psi}}{1+\psi} \tag{3}$$

In this utility function c_t and g_t represent private and public consumption, and h_t is the number of hours worked by household. The representative household faces the following budget constraint:

$$(1+\tau_t)c_t + x_t \leq w_t h_t + r_t k_t + T_t \tag{4}$$

where x_t is private investment, k_t is private capital, T_t represent transfers from the government, and τ_t is the consumption tax rate. Households derive income by supplying labor and capital to firms at rental rates w_t and r_t. The private capital stock is accumulated according to:

$$k_{t+1} = (1 - \delta)k_t + x_t \tag{5}$$

First order conditions of the household maximization problem imply:

$$w_t = h_t^{\psi} c_t^{\kappa} (1 + \tau_t) \tag{6}$$

$$\frac{c_t^{-\kappa}}{1 + \tau_t} = \beta E_t \frac{c_{t+1}^{-\kappa}}{1 + \tau_{t+1}} \left[1 - \delta + r_{t+1}\right] \tag{7}$$

Taxes introduce a wedge between the marginal rate of substitution and wages, as condition (6) indicates. The higher the tax rate, the lower the labor supply for a given wage rate. Condition (7) is a standard stochastic Euler equation, which determines intertemporal allocation: it equates the intertemporal marginal rate of substitution in consumption after tax to the real rate of return on private capital.

3.2 Firms

Output y_t is produced by identical firms, and then can be used for consumption, investment or government spending. I distinguish between two types of government spending: public investment, x_{Gt}, and government consumption, g_t. Public investment adds to the (undepreciated) stock of public capital, k_{Gt}, inherited from the previous period. Public capital contributes to the economy's output according to the following production function with constant returns to scale in private capital and labor: $y_t = f(k_t, h_t, k_{Gt}) = Ak_t^{\alpha} h_t^{1-\alpha} k_{Gt}^{\gamma}$. The sector is characterized by perfect competition, so that firms make zero profit in equilibrium and optimality conditions imply:

$$r_t = y_k(t) \tag{8}$$

$$w_t = y_h(t) \tag{9}$$

3.3 Government

The government faces the following budget constraint:

$$g_t + T_t + x_{Gt}\left[1 + \varphi(x_{Gt}/k_{Gt})\right] + b_t(1 + r_{Gt}) + \frac{\omega_G}{2}(b_{t+1} - b)^2 = R_t + b_{t+1} + \tau_t c_t \qquad (10)$$

where g_t is public consumption, x_{Gt} is public investment, $x_{Gt}\varphi(x_{Gt}/k_{Gt})$ is the adjustment cost for public investment, T_t are transfers to the private sector, and r_{Gt} is the real interest rate on foreign funds. The fiscal authority issues foreign debt b_t[11], and acquires revenue R_t from commodity exports. The quadratic term on the left-hand side of the government budget constraint, $\omega_G/2(b_{t+1}-b)^2$, represents the portfolio adjustment costs the government faces in international capital markets. Changes in resource revenue can be due to exogenous changes in either the price of the resource or the endowment of the resource, so that resource revenue is determined exogenously according to the following process:

$$\log(R_t) = (1 - \rho_R)\log R + \rho_R \log(R_{t-1}) + \xi_t,\ \ \xi_t \sim i.i.d.(0, \sigma_R^2) \qquad (11)$$

Adjustment costs for public investment, $\varphi(\cdot)$, are defined as the premium paid for each unit of investment goods relative to consumption goods (Abel and Blanchard (1983)). The function φ has the properties: $\varphi(0) = 0, \varphi'(\cdot) > 0, \varphi''(\cdot) > 0$. Adjustment costs can reflect the fact that investment in the public sector may encounter additional costs due to losses in the tax collection process or as a result of political distortions required to reach a consensus on financing projects. In the quantitative analysis, investment adjustment costs are modeled as a simple quadratic function[12]:

$$\varphi(\frac{x_{Gt}}{k_{Gt}}) = \frac{\alpha_\varphi}{2}(\frac{k_{Gt+1}}{k_{Gt}} - (1 - \delta_G))^2,\ \ \alpha_\varphi > 0 \qquad (12)$$

A distinctive feature of the small-open developing economy in this model is that it faces a high and increasing interest premium on external borrowing. So, following the literature (e.g., Turnovsky (1997), van der Ploeg and Venables (2011)), I assume that the interest rate spread is an increasing and convex function of the country's net debt position, that is:

$$r_{Gt} - r^* = \Phi(b_t) \qquad (13)$$

[11] I assume that only the government can borrow internationally. This assumption captures the fact that households in many resource-rich developing countries find it hard to borrow against future income. The presence of a private sector with no access to capital markets means that there is a role for fiscal policy to play in smoothing private sector consumption.

[12] In the Online Appendix I consider an extension to the basic model, by assuming that both private and public capital investment face the same adjustment costs. I show that adding private capital investment adjustment costs to the model does not alter the main findings of the original model.

where, following Schmitt-Grohé and Uribe (2003), the country spread function is defined as $\Phi(b_t) = \psi_b(\exp(b_t - b) - 1)$[13]. Later, in comparing the results between developing and developed countries, I assume that for developed countries $\psi_b = 0$. The law of motion for public capital stock is:

$$k_{Gt+1} = (1 - \delta_G)k_{Gt} + x_{Gt} \tag{14}$$

As mentioned, I analyze two versions of the government's problem depending on the type of tax instrument available to the policymaker. In what follows, I focus on the case $T_t = 0$, and thus describe the Ramsey problem and its results. In Section 4.3, however, I also study the case where lump-sum transfers are possible and consumption taxes are ruled out.

3.4 Characterizing equilibrium

To solve for the optimal fiscal policy, I use the primal approach to optimal taxation and formulate the Ramsey problem as that of a planner who must choose an allocation from amongst those that can be implemented as a competitive equilibrium. The constraints imposed on the Ramsey planner are known as implementability conditions. To construct the Ramsey problem, I need to reorganize some of those constraints to reduce the number of choice variables and to obtain a compact expression for the household budget constraint. In particular, combining (5), (6), (8) and (9) gives:

$$(1 + \tau_t)c_t + k_{t+1} - (1 - \delta)k_t = \frac{1}{1 - \alpha} h_t^{1+\psi} c_t^{\kappa} (1 + \tau_t) \tag{15}$$

Next, by adding (4) and (10), and substituting for w_t and r_t from (8) and (9), I obtain the following per capita resource constraint for the economy:

$$\begin{aligned} & g_t + [k_{Gt+1} - (1 - \delta_G)k_{Gt}] \{1 + \varphi(\frac{x_{Gt}}{k_{Gt}})\} + b_t(1 + r_{Gt}) + c_t + k_{t+1} - (1 - \delta)k_t \\ = \; & y_t + R_t + b_{t+1} - \frac{\omega_G}{2}(b_{t+1} - b)^2 \end{aligned} \tag{16}$$

Equation (16) can now be used in place of the government budget constraint (10) when formulating the problem facing the government.

[13] One of two assumptions - the country spread mechanism ($\psi_b \neq 0$) and portfolio adjustment costs ($\omega_G \neq 0$) - is sufficient to induce stationarity and a unique steady state in the model (see Schmitt-Grohé and Uribe (2003)). The objective of this paper, however, is to analyze the role of financial market frictions, represented by country spread, in the adjustment of an economy to external shocks and to compare the results with those economies in which such frictions are absent. Thus, portfolio adjustment costs are introduced to make the analysis of the case when $\psi_b = 0$ possible using the current solution method.

3.5 Ramsey problem

Ramsey optimal policy consists of maximizing (2) subject to the implementability conditions just derived as (7), (15) and (16), and taking b_{-1}, k_{-1} and $k_{G,-1}$ as given. One way to proceed further is to define a Lagrangian for the dynamic optimization problem, with three multipliers attached to three constraints. One can then find the first-order conditions of such a Lagrangian. It is important to note, however, that the constraint (7) incorporates expected values of future variables. Since the work of Kydland and Prescott (1977), it has been known that such optimal policy problems, under commitment with forward-looking constraints, are nonstationary. This means that the optimal choice at time t is not a time invariant function of the state variables $\{k_t, k_{Gt}, b_t, R_t\}$ at time t. To solve the Ramsey problem, I need to reconstruct the optimization problem in a recursive framework. Marcet and Marimon (1998) show that in such cases a recursive framework can be reformulated, by (a) enlarging the planner's state space with an additional costate variable, and (b) adding a law of motion for the additional costate variable. Following their methodology, I first note that any solution to the original problem facing the government is also a solution to maximizing:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left[u(t) + \mu_t \left(\frac{u_c(t)}{1+\tau_t} - \beta E_t \frac{u_c(t+1)}{1+\tau_{t+1}} (1 - \delta + r_{t+1}) \right) \right]$$

subject to (15), (16) and taking b_{-1}, k_{-1} and $k_{G,-1}$ as given. Using the law of iterated expectations, I can show that the government's objective function is equivalent to the following two equations:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[u(t) + \phi_t \frac{u_c(t)}{1+\tau_t} \right] \tag{17}$$

$$\mu_t = \phi_t + \mu_{t-1}(1 - \delta + r_t); \ \mu_{-1} = 0 \tag{18}$$

where equation (18) summarizes the evolution of the Lagrange multiplier μ_t associated with the forward looking constraint (7). The constraint in (18) embeds the assumption of the commitment of the policy maker to chosen policies as his current decisions are tied to past decisions, with the costate variable μ_{t-1} summarizing past commitments, such that optimal policy is time-consistent.

Thus, any solution to the original Ramsey problem must be a solution to the problem of maximizing (17) subject to (18), (15), and (16). This problem is stationary, as the first-order conditions to this problem are a system of time-invariant functions because of the introduction of the lagged multiplier. The Lagrangian for this problem is given by:

$$\begin{aligned}
L &= E_0 \sum_{t=0}^{\infty} \beta^t \{ u(t) + \phi_t \frac{u_c(t)}{1+\tau_t} \\
&+ \lambda_{p,t} \left[(1+\tau_t) c_t + k_{t+1} - (1-\delta) k_t + \frac{1}{1-\alpha} \frac{u_h(t)}{u_c(t)} (1+\tau_t) h_t \right] \\
&+ \chi_t [g_t + (k_{Gt+1} - (1-\delta_G) k_{Gt}) \{1 + \varphi(\cdot)\} + b_t (1 + r_{Gt}) + c_t \\
&+ k_{t+1} - (1-\delta) k_t - y_t - R_t - b_{t+1} + \frac{\omega_G}{2} (b_{t+1} - b)^2] \\
&+ \Omega_t \left[\mu_t - \phi_t - \mu_{t-1} (1 - \delta + r_t) \right] \}
\end{aligned}$$

In addition to (15), (16) and (18), the first order conditions of the Ramsey problem are given by:

$$\chi_t [1 - \omega_G (b_{t+1} - b)] = E_t \chi_{t+1} \beta \left[1 + r_{Gt+1} + b_{t+1} \Phi'(b_{t+1}) \right] \tag{19}$$

$$\phi_t \frac{c_t^{-\kappa}}{(1+\tau_t)^2} = \lambda_{p,t} \left[c_t - \frac{1}{1-\alpha} h_t^{1+\psi} c_t^{\kappa} \right] \tag{20}$$

$$\Omega_t = E_t \beta \Omega_{t+1} (1 - \delta + r_{t+1}) \tag{21}$$

$$\theta g_t^{-\kappa} + \chi_t = 0 \tag{22}$$

$$0 = \chi_t + c_t^{-\kappa} - \phi_t \frac{\kappa c_t^{-\kappa-1}}{1+\tau_t} + \lambda_{p,t} \left[(1+\tau_t) - \frac{1}{1-\alpha} (1+\tau_t) h_t^{\psi+1} \kappa c_t^{\kappa-1} \right] \tag{23}$$

$$\frac{c_t^{-\kappa}}{1+\tau_t} - \Omega_t = 0 \tag{24}$$

$$\begin{aligned}
&-h_t^{\psi} - \chi_t y_h(t) - \Omega_t \mu_{t-1} r_h(t) - \lambda_{p,t} \frac{1}{1-\alpha} h_t^{\psi} c_t^{\kappa} (1+\tau_t) - \\
&-\lambda_{p,t} \frac{1}{1-\alpha} (1+\tau_t) h_t^{\psi} \psi c_t^{\kappa} = 0
\end{aligned} \tag{25}$$

$$\lambda_{p,t} + \chi_t = \beta E_t \left[\lambda_{p,t+1} (1-\delta) + \chi_{t+1} \{ y_k(t+1) + (1-\delta) \} + \Omega_{t+1} \mu_t r_k(t+1) \right] \tag{26}$$

$$\chi_t \left[1+\varphi(\frac{x_{Gt}}{k_{Gt}})\right] + \chi_t \left[k_{Gt+1}-(1-\delta_G)k_{Gt}\right]\alpha_\varphi \left(\frac{k_{Gt+1}}{k_{Gt}}-(1-\delta_G)\right)\frac{1}{k_{Gt}} -$$
$$-E_t\beta\chi_{t+1}y_{k_G}(t+1) - E_t\beta\Omega_{t+1}\mu_t r_{k_G}(t+1) - \beta E_t\chi_{t+1}(1-\delta_G)\{1+\varphi(\frac{x_{Gt+1}}{k_{Gt+1}})\}$$
$$-\beta E_t\chi_{t+1}\{k_{Gt+2}-(1-\delta_G)k_{Gt+1}\}\alpha_\varphi\left(\frac{k_{Gt+2}}{k_{Gt+1}}-(1-\delta_G)\right)\frac{k_{Gt+2}}{k^2_{Gt+1}} = 0 \quad (27)$$

Equation (21) in conjunction with (24) yields an Euler equation identical to (7). Equation (19) is the counterpart of the Euler equation (21) for foreign bonds. Equation (26) is the pricing equation for private capital, which equates the cost of installing one unit of capital to the discounted value of the return on capital, net of depreciation. Equation (42) is the counterpart of equation (26) for public capital. Equations (22) and (23) jointly determine the intratemporal efficiency condition for private and public consumption. Finally, equation (20) determines the optimal level of taxation, while equation (25) is the optimal condition for the labor supply.

3.6 Completeness of the tax system

An important issue in models of optimal taxation is whether or not a utilized set of tax instruments is *complete*. Following Chari and Kehoe (1998), a tax system is defined to be incomplete, if for at least one pair of goods, the government has *no* tax instruments that drive a wedge between the marginal rate of substitution and the marginal rate of transformation of the same goods. When this is not the case, a tax system is said to be complete. In this section I establish that the tax system is complete in the present model, which is an important finding for two reasons. First, as shown by Chari and Kehoe (1998), Correia (1996), Aruoba and Chugh (2010) and many others, an incomplete tax system requires that new constraints reflecting this incompleteness to be added to the Ramsey problem. Second, incomplete tax systems can lead to"non-standard" policy prescriptions because some instruments end up substituting for the ability to create certain wedges that cannot be created in a decentralized economy.[14] I demonstrate below that incompleteness is not an issue for the model of this paper, and thus the Ramsey problem presented in the previous section is valid and the results of the paper are not due to policy instruments serving as imperfect proxies for other, unavailable instruments.

[14] Correia (1996), Jones et al. (1997), provide examples in which an incomplete tax system results in non-zero capital-income taxation. See also discussion in Aruoba and Chugh (2010).

I follow Chari and Kehoe (1998) in arguing below that optimal taxation is best understood in terms of the optimal wedges between marginal rates of substitution (MRS) and the corresponding marginal rates of transformation (MRT).

There are two independent MRS/MRT pairs in the model, which are summarized in the following two conditions:

$$MRS_{c,h} \equiv \frac{u_h(t)}{u_c(t)}; \quad MRT_{c,h} \equiv -y_h(t) = -w_t \tag{28}$$

$$MRS_{c_t,c_{t+1}} \equiv \frac{\beta u_c(t+1)}{u_c(t)}; \;\; MRT_{c_t,c_{t+1}} \equiv \frac{1}{y_k(t+1)+1-\delta} \tag{29}$$

Each MRS and MRT above has the standard interpretation: MRS is a ratio of marginal utilities, while MRT is a ratio of the marginal products of an appropriate production possibilities frontier. The static MRT is the standard marginal rate of transformation between consumption and work (or between consumption and leisure with the opposite sign). The intertemporal MRT can be interpreted by using the economy-wide intertemporal budget constraint as follows. If consumption today is reduced by one unit, then the economy gains one additional unit of capital k_{t+1} (holding output of all other goods constant), which increases c_{t+1} via next period production. Thus, a unit reduction in c_t leads to a gain of $y_k(t+1)+1-\delta$.

The conditions that characterize the allocation in the absence of distortionary taxes (and in the presence of lump-sum taxes) include the conditions that can be stated in terms of the MRS and the corresponding MRT defined above:

$$\frac{MRS_{c,h}}{MRT_{c,h}} = 1, \quad E_t \frac{MRS_{c_t,c_{t+1}}}{MRT_{c_t,c_{t+1}}} = 1 \tag{30}$$

Thus, there are two "zero wedge" conditions that characterize such allocation in the model: one for each of two independent margins of adjustment in the model. Next, I explicitly express the private sector equilibrium conditions in terms of MRS/MRT pairs, as well as the first-order conditions of the Ramsey problem. Using (6) and (7), and the definitions of the MRS and MRT above, in the decentralized economy the following holds:

$$\frac{MRS_{c,h}}{MRT_{c,h}} = 1+\tau_t, \quad E_t \frac{1+\tau_t}{1+\tau_{t+1}} \frac{MRS_{c_t,c_{t+1}}}{MRT_{c_t,c_{t+1}}} = 1 \tag{31}$$

Finally, I also express (some) of the first-order conditions of the Ramsey planner (25), using (23), and (21), using (24) in terms of the two MRS/MRT pairs:

$$\frac{MRS_{c,h}}{MRT_{c,h}} = 1+\left(\frac{u_c(1-\alpha)}{\lambda_{p,t}(1+\tau_t)}-\alpha+\frac{c_t(1-\alpha)u_{cc}}{u_c}-h_t\frac{u_{h,h}}{u_c}\right)+ \\ +\frac{1-\alpha}{\lambda_{p,t}(1+\tau_t)y_h}\left[u_h-\Omega_t\mu_{t-1}r_h(t)\right] \tag{32}$$

$$E_t\frac{1+\tau_t}{1+\tau_{t+1}}\frac{MRS_{c_t,c_{t+1}}}{MRT_{c_t,c_{t+1}}}=1 \tag{33}$$

By comparing (31) with (32)-(33), I can prove that the government has tax instrument for each wedge between the MRS and the MRT, which proves the completeness of the tax system in the model.

4 Optimal fiscal policy: results

In this section, I present the main results of the quantitative analysis of optimal fiscal policy responses to an adverse external shock.

4.1 Parametrization

The model calibration involves selecting parameter values that are, as closely as possible, consistent with the main features of a representative developing, commodity-rich economy: Colombia. I assign values to the structural parameters using a combination of calibration and econometric estimation techniques. I calibrate the parameter values using values that are common in similar business-cycle studies. The baseline parameter choices of the model are summarized in Table 2, while Table 3 reports macroeconomic ratios implied by the theoretical model as well as the corresponding values for the Colombian data[15].

The steady-state private and public capital depreciation rates are set at 0.06 and 0.03 respectively (van der Ploeg and Venables (2011) set both depreciation rates equal to 0.05). The value of α_φ is chosen to yield a steady-state value of $\varphi(\cdot)$=0.01. This implies that public capital adjustment costs are equal to 1% of public investment.

The steady-state value of external debt as a share of GDP is assumed to be 0.1 (as in Riascos and Végh (2003)). The world interest rate is set at 3%, which makes the value of subjective discount factor, β, of 0.97. The steady state value of oil income, R, was set

[15] The following sources have been used in calculating macroeconomic ratios. Public and private consumption, GDP and gross capital formation are taken from IMF (IFS) annual data, 1972-2009; public investment data is from the web site of Ministry of the Exchequer, annual data, 1995-2009. The average tax rate in an economy is calculated as a ratio of the tax revenues to GDP.

Parameter	Value	Definition
α_φ	22.2	public investment adjustment costs parameter
δ	0.06	private capital depreciation rate
δ_G	0.03	public capital depreciation rate
β	1/1.03=0.97	subjective discount factor
r^*	0.03	risk-free interest rate
ψ_b	0.0007	country spread parameter
$1/\kappa$	0.75	intertemporal elasticity of substitution
$1/\psi$	1	elasticity of labor supply
θ	0.16	weight of public consumption in utility
α	0.4	share of private capital in production of goods
γ	0.25	share of public capital in production
b/GDP	0.1	external debt
R/GDP	0.20	commodity export income
ρ_R	0.5	the degree of persistence of resource shock
ω_G	0.0002	portfolio adjustment costs

Table 2: Baseline parameter values

at 20% of GDP, where GDP is defined as $GDP_t = R_t + y_t$. Following van der Ploeg and Venables (2011), I set the private and public capital shares in the domestic output, α and γ, equal to 0.4 and 0.25 respectively. The inverse of the labor supply elasticity ψ is set equal to 1 (as in Devereux et al. (2006), Demirel (2010)). For the baseline calibration, the value of the parameter κ is chosen to make the elasticity of intertemporal substitution is equal to 0.75 (as in van der Ploeg and Venables (2011)). The value of the parameter θ is chosen such that the model's steady-state ratio of government expenditure to private consumption, g/c, is 0.25. The benchmark value of the responsiveness of the country spread ψ_b is set at 0.0007 as in Schmitt-Grohé and Uribe (2003).

The value of ρ_R has been set at 0.5 guided by the following considerations. Colombian exports are not dominated by a single commodity, but in reality are made up of exports of crude oil, coffee, nickel and gold. Thus, when estimating ρ_R for Colombia, it might be appropriate to estimate the degree of persistence of the terms of trade, given that the parameter ρ_R can be interpreted as the degree of persistence of either the commodity price or the terms of trade of the resource dependent economy[16]. The estimate of the degree of

[16]Since resource revenue is denominated in the units of consumption goods and can be represented as

	$\frac{c}{GDP}$	$\frac{g}{GDP}$	τ	$\frac{x}{GDP}$	$\frac{x_G}{GDP}$
RBC model	0.61	0.15	0.14	0.21	0.09
Data (Colombia)	0.67	0.14	0.10	0.15	0.05

Table 3: Structure of the theoretical economy and the data

autocorrelation in the growth rate of the terms of trade for Colombia suggests that a value of 0.3 would be appropriate[17]. On the other hand, as is well known, the serial correlation of most commodity prices is much higher, and can often be above 0.7[18]. The set up of the theoretical model, however implies that commodity price shocks can be interpreted as terms of trade shocks. As such, the best way to proceed when calibrating the value of ρ_R is to assign the parameter a value somewhere between 0.3 and 0.7 and to perform sensitivity analysis using other values of ρ_R.

4.2 Discussion of baseline results

4.2.1 Analysis of dynamic responses

Figure 3 shows the impulse responses of the key variables to a 1% decrease in resource revenue and compares them between a typical developed and a typical developing country, the difference between the two country types being just in their conditions of access to the world capital market. The dash-dotted line presents the developed-country case, when $\psi_b = 0$, and the continuous line presents the developing-country case, when $\psi_b = 0.0007$. All variables are expressed in terms of percentage deviations from the steady state, except for tax rates and the return on capital (r_t), for which the responses are expressed as absolute deviations from their steady-state values. If a shock reduces resource revenue, one option for the government would be to smooth over the difference in revenue by borrowing abroad. The cost of external borrowing, however, is dependent upon the degree to which the economy

$R = p_c O$, where p_c is the world commodity price and O is resource endowment, then p_c represent the price of the commodity relative to the price of consumption goods, which are traded. Thus, p_c can be considered the terms of trade of the economy.

[17]To estimate the degree of the persistence of terms of trade shocks, I consider the following equation: $\Delta p_{c,t} = \rho_R \Delta p_{c,t-1} + \epsilon_t$, where $\Delta p_{c,t}$ is the growth rate of the terms of trade. Data sources are as follows. Terms of trade are constructed as a ratio of unit value of exports and unit value of imports. Indices for export and import prices are from IFS (IMF), quarterly data for 1970-2004 period.

[18]First-order autocorrelation for twelve out of thirteen primary commodities over the period 1900-1987 considered in Cafiero et al. (2011) are above 0.7, while one other is 0.62. Some other studies (e.g, Hamilton (2009)) cannot reject the the hypothesis that oil prices have a unit root.

in question is integrated into international capital markets. In the developed-country case, when $\psi_b = 0$, a small economy can borrow unlimited amounts at the global interest rate. In the developing-country case, by contrast, the economy in question faces an increasing interest rate premium on borrowing (i.e. $\psi_b \neq 0$). It is therefore clear that the situation of a developed country permits a greater degree of consumption smoothing than for a developing country. However, even for a developed country, complete smoothing is not possible because of portfolio adjustment costs. The future re-establishment of the original level of resource income, and convergence towards the initial steady-state, imply that it is optimal for an economy to minimize portfolio adjustment costs, even at the expense of some loss of consumption smoothing.

In both the developed-country and the developing-country cases, adjustment to the shock involves a combination of lower government spending (on both consumption and investment) and greater borrowing abroad. However, the reduction in government spending is far greater in the developing-country case, when $\psi_b \neq 0$, while the amount of external borrowing is far greater in the developed-country case, when $\psi_b = 0$. The difference is even more striking with respect to tax rates, which rise in the case of increasingly costly access to international capital markets, and fall in the case of completely elastic access to these markets. These optimal adjustments of the tax rate and of public expenditure can be understood by recalling that the Ramsey problem is about creating optimal distortions, or wedges, between a variety of MRSs and their corresponding MRTs. As can be seen in (33), fiscal policy tries to keep the tax rate constant over time, so that it does not impose any intertemporal distortion (equating the MRS and its corresponding MRT, as in (30). In the present model, however, the ability of the government to avoid imposing intertemporal distortions on private consumption depends on the country's degree of financial integration with the rest of the world.

The unlimited availability of external funds at a fixed global interest rate in developing countries allows planners to use external resources to finance public expenditure and to cut taxes so as to boost private sector income and induce maximal smoothing of private consumption. In contrast, in developing countries, the higher cost of using external finance to smooth shocks makes it optimal for more of the adjustment to be internal, that is, achieved by reducing public expenditure and by raising taxes. These cuts in public expenditure are predominantly cuts in public investment, rather than in public consumption, for the following reason. Cuts in public consumption affect consumer utility directly and immediately, whereas cuts in public investment affect utility indirectly and the effects on consumer utility of a smaller public investment are spread over multiple time periods. In developing countries, it is therefore optimal for shocks to be accommodated by changes in public investment to a much greater degree than in developed countries, which also explains why public investment is more volatile in developing countries.

In the developed-country case, consumption follows a 'hump-shaped' path, which can be explained as follows. Two conflicting forces are at work. Firstly, an expected increase in the tax rate induces a shift in consumption away from the future and towards the present. Secondly, an expected decline in the return on private capital encourages the postponement of consumption to the future, by greater investment in private capital in the present. Depending upon which of these two forces dominates, the adjustment of consumption following a temporary deterioration in the terms of trade can be broken into two distinct phases. During the first phase, the tax rate effect dominates the rate of return effect, so that consumption follows a path similar to that of the tax rate, and thus exhibits negative growth. During the second phase, the tax rate effect disappears as the tax rate reaches its long-run level - meaning that the consumption path is governed by the rate of return effect - so consumption experiences positive growth towards its long-run equilibrium level.

Finally, it is noteworthy that in both cases the return on private capital (r_t) remains above its long-run level during most of the adjustment towards equilibrium. As the expected real interest rate is above its long-run value, there is an intertemporal substitution effect of the interest rate that induces workers to give up some leisure and work more during the adjustment period towards the steady state.

Another way of interpreting the main results of this paper is to consider accumulating debt in the model as decumulating of the stock of foreign assets in a Sovereign Wealth Fund (SWF). The paper's analysis then suggests that a resource-rich developed country should absorb the shock by running down the assets of its SWF. In contrast, the optimal response in a resource-rich developing country (which presumably does not set up a SWF at all or has a small sized SWF) involves depleting the stock of domestic assets - public capital. A similar conclusion is made by van der Ploeg and Venables (2011), though I use a stochastic rather than a deterministic framework. This becomes an important distinction, as it allows me to analyze the business cycle properties of fiscal variables. It further allows testing the consistency of the implications of the model with the empirical regularities, which I discuss in the next section.

4.2.2 The model versus the data

In this section, I compare the simulation results of the theoretical model with the empirical results reported in Section 2. I start by the comparing the business cycle properties implied by the model with the ones reported in Table 1. The case where $\psi_b = 0$ corresponds to empirical evidence from the sample of developed countries, while the case where $\psi_b \neq 0$ corresponds to empirical evidence from the sample of Latin American developing countries. The discussion of the baseline results above suggests that the model is successful in reproducing the observed pro-cyclicality and volatility of public investment and public consumption in both developing and developed countries. Also consistently with the data, public investment is more volatile than public consumption, and it is more volatile in developing than in developed countries.

With respect to matching the VAR-based impulse responses, the model results are mixed. On the one hand, the model does a very good job of matching the empirical responses in terms of size. The response of government consumption to the shock is much smaller than that of public investment in both the data and the model. Thus, the model accurately captures the shock-absorbing property of public investment in developing countries. On the other hand, the model does not capture the hump shapes of the VAR impulse responses. While this prediction of the data is not explained by the model, the results, in general, provide encouragement for an approach that makes an explicit distinction between public investment and government consumption. This is the first paper, to the best of my knowledge, that takes such an approach and applies it to developing countries within a stochastic general equilibrium framework. Future research may possibly need to consider other features suggested by the literature that could help to match the empirical evidence better. For instance, time-to-build process from public investment to public capital (Leeper et al. (2010) and Leduc and Wilson (2012)) and the distinction between credit-constrained and credit-unconstrained consumers might be considered. As noted before, in the empirical VAR the responses of both public investment and public consumption are significant for about three to five quarters only. Thus, future research also needs to provide more empirical evidence on public consumption and public investment behavior in the presence of shocks in a larger group of commodity-producing countries[19].

4.3 Policy with lump-sum taxes/transfers

In this section I consider how the problem facing the government would alter if lump-sum taxes and transfers were available, rather than consumption taxes. Lump-sum taxes are rarely a practical possibility, but analyzing their hypothetical effects sheds light on the role that the distortionary consumption tax plays in determining the results of the model.

[19] Pieschacón (2012) has analyzed the responses of various endogenous variables, including government expenditure to oil price shocks in both Mexico and Norway, but she has not distinguished between different components of public expenditure such as public consumption and public investment

With a lump-sum tax but no consumption tax, the optimal allocations can be obtained by maximizing (2) subject to the resource constraint (16). The effect of a temporary reduction in resource revenue is illustrated in 4: The solid line represents the developing-country case with an external risk premium ($\psi_b \neq 0$), and the dashed line depicts the developed-country case in which there are no borrowing constraints ($\psi_b = 0$). The possibility of lump-sum transfers enables the government to control the level of private consumption directly, in a non-distortionary manner. Thus, taxes no longer cause any distortions. When $\psi_b = 0$, there is also no distortion associated with external borrowing so that the government, as in the baseline case, borrows heavily in order to smooth both private and public consumption. To induce more smoothing of private sector income and thus consumption through investment in private capital, transfers increase, too.

When $\psi_b \neq 0$, however, smoothing options are as before limited. The government adjusts to the shock by raising (lump-sum) taxes, cutting public consumption and increasing public investment. In the benchmark specification with consumption taxes, the government avoided large tax rate changes to reduce distortions and instead used public investment as the main instrument to absorb the shock. But with lump-sum taxes, which are non-distortionary, public investment ceases to be the main instrument to absorb the shock. Instead, public investment and transfers are used together to alter the level of income in the private sector, and both are linked by the budget constraint, and thus by the level of external debt. Fiscal policy attempts to use those instruments to boost private income. When the level of external debt is high, the planner can increase consumer income directly via transfers. Debt, however, is a predetermined variable and it accumulates successively as planners provide stimulus. Thus, when the level of the external debt is low, and thus the transfers are low, or equivalently income is taxed, then the planner uses the second instrument, public investment, to boost income of consumers. More public infrastructure raises the return on private capital and increases the marginal product of labor as well as the wage rate directly.

4.4 Associated productivity shocks

The analysis thus far has focused on optimal responses to exogenous changes in government resource revenues. This is a benchmark in studies of the optimal management of resource revenues in developing countries. But it is also of interest to analyze cases in which shocks to fiscal revenue coincide with changes in private sector productivity. To get a sense of the value of the correlation between changes in commodity prices and changes in productivity, I use the residual measure of TFP constructed from the following production function [20]:

$$Y_t = A_t K_t^{\alpha} (h_t L_t)^{1-\alpha} \tag{34}$$

Here Y_t is the value added when prices are constant, K_t is a measure of the total real capital stock constructed using the perpetual inventory method, h_t is a measure of human capital, and L_t is aggregate employment[21]. Empirical evidence from several commodity-exporting Latin American countries suggests that the value of correlation is in the range of 0.32 to 0.4.

To model the correlation between commodity price shocks and productivity shocks, I assume that the same resource revenue shock affects private sector productivity, whose behavior is modeled as:

$$\log(A_t) = \rho_a \log(A_{t-1}) + \rho\xi_t,\ \xi_t \sim i.i.d.(0, \sigma_R^2) \tag{35}$$

Here, ρ is the correlation between productivity and the government's resource revenue. I set ρ equal to 0.3. There is also a new parameter in this formulation of the model, ρ_a, which I set equal to 0.42, as in Schmitt-Grohé and Uribe (2003).

Figures 5 and 6 depict the responses to an adverse resource revenue shock coupled to a productivity shock for the developing-country ($\psi_b \neq 0$) and developed-country ($\psi_b = 0$) cases respectively. It is clear that all the variables react more strongly when both these shocks hit the economy, since both shocks are adverse and both of them move variables in the same directions. The productivity shock has a more severe effect than the resource revenue shock. The reason is that both shocks have adverse effects on the return on private capital, but while the productivity shock has a direct effect, the resource revenue shock acts indirectly through the stock of public capital: $y = (Ak_t^{\gamma})k_t^{\alpha} h_t^{1-\alpha}$.

The mechanisms through which the two shocks affect the economy are also different. A resource revenue shock lowers government income, whereas a productivity shock directly cuts the income of the private sector. Since it cannot borrow externally, the private sector has only limited ability to smooth the impact of the shock. A government with unlimited access to external borrowing could provide insurance in response to a productivity shock by cutting taxes to smooth the income of consumers. However, the governments of developing

[20] This measure of productivity is constructed in Kuralbayeva and Stefanski (2011), so interested readers are referred to the original source for more details.

[21] Obviously this measure of productivity does not control for differences between stocks of private and public capital in an economy. This measure, however, does give some approximation for the possible correlation between productivity and terms of trade (exogenous changes in commodity prices) in resource-exporting countries.

countries lack (unconstrained) external funds sufficient to implement tax cuts to ensure that consumption is smooth.

This point relates to earlier work on the role that governments can play in mitigating the risks of international trade, such as terms-of-trade fluctuations. Rodrik (1998) examines government expenditure reactions to adverse shocks. He finds that government spending has an important insurance function: in developed countries mainly through social security and welfare spending, and in developing countries mainly through public employment and other public-works programs. Similarly, Bates et al. (1991) demonstrate how the provision of internal means of insurance by governments, such as programs of transfer payments, can mitigate the risks from international markets and hence promote openness. They argue that governments in developed countries are able to maintain more open trade policies because they have access to larger revenues from non-trade sources and can thus finance more extensive social insurance programs. Thus, governments in both developed and developing countries, seeking to maximize social welfare, implement policies to reduce external risks, but they are constrained by the policy instruments at their disposal. The current paper has likewise highlighted that the scope of insurance provided by governments tends to be larger in developed countries than in developing countries because the former have a wider range of financial instruments at their disposal to cope with external shocks.

5 Sensitivity analysis

In the previous section, I concluded that a model with different degrees of access to international capital markets governed by the parameter ψ_b can explain the observed empirical differences in the cyclical behavior of fiscal policy in developing countries and developed countries. This is because different degrees of access to international capital markets affect the ability of the government to smooth shocks and thus influence the choices of the Ramsey planner. Three further elements of the model crucially affect the optimal distortions in the Ramsey allocation: As can be seen from equations (6) and (7), both the intertemporal elasticity of substitution (governed by the parameter $1/\kappa$) and the elasticity of labor supply $(1/\psi)$ affect optimal fiscal responses. The sensitivity of the results to these parameters is examined below. Similarly, the results depend on the degree of persistence of the shock, ρ_R, assumed above to be 0.5. However some authors find higher persistence in the prices of certain commodities, which for oil cannot be distinguished from a random walk. Hence higher values of ρ_R are also considered below.

As will be shown in more detail in the following three subsections, variation in values of these parameters (κ, ψ and ρ_R) sheds further light on the model's baseline results. It does not affect the mechanism through which the adjustment to the shock takes place: public external debt when $\psi_b = 0$ and public investment when $\psi_b \neq 0$ remain the main instruments. However, changes in the values of these structural parameters alter the dynamic pattern of taxes when $\psi_b \neq 0$ and the magnitude of taxes when $\psi_b = 0$. For a lower value of the IES, a higher elasticity of labor supply and a higher degree of persistence of the shock, the dynamic path of tax rates becomes hump-shaped when $\psi_b \neq 0$ and tax cuts are greater when $\psi_b = 0$.

5.1 Intertemporal elasticity of substitution

In the model, the intertemproal elasticity of substitution (IES) represented by the parameter $1/\kappa$ is set at 0.75 in the baseline case. While this value is consistent with other macroeconomic models, there is debate about its true value. I hence consider the value $\kappa = 2$, which is the upper bound in a range of estimates by Gourinchas and Parker (2002). Figures 7 and 8 compare the simulation results for these two values of κ in the developing country ($\psi_b \neq 0$) and developed country ($\psi_b = 0$) cases respectively. For a planner considering an adjustment in response to an adverse resource revenue shock, a low value of the IES signals that individuals are more concerned about the timing of consumption, and are therefore eager to smooth it.

If the government must rely on domestic sources to absorb the shock ($\psi_b \neq 0$), a lower IES will therefore lead it to cut public expenditure (consumption and investment) by more, and to increase taxes by less than in the baseline specifications. It also makes the path of taxes hump-shaped. This is because smaller tax increases today leave consumers with more disposable income and hence opportunity to smooth consumption through investment.

On the other hand, when the shock is absorbed primarily via external borrowing ($\psi_b = 0$), the dynamic response patterns of the tax rate and private consumption remain similar to the ones in the baseline case: The government cuts tax rates and the reaction of consumption remains hump-shaped. The planner however initiates a larger tax cuts which is accommodated by larger increase in external debt. Larger tax cuts, being a response of the planner to a lower value of the IES, are undertaken to induce consumption smoothing by the private sector. In response, private investment increases by more today to provide more income from capital and thus higher consumption tomorrow when taxes are higher.

5.2 Elasticity of labor supply

The elasticity of labor supply is $1/\psi$ in the model, and the baseline assumption of $\psi = 1$ therefore implies an elasticity of 1. In line with a range of elasticities reported by Rogerson and Wallenious (2009), I consider the effects of two alternative values of this parameter on the baseline results: $\psi = 0.5$ and $\psi = 0.33$. Figures 9 and 10 show the impulse response functions for these three different values of ψ for each value of ψ_b.

When the labor elasticity is low, consumption taxes are less distortionary in the sense that individuals' labor supply changes only a little in response to distortions (ceteris paribus), as can be seen from the the log-linearized labor supply equation:

$$\log \frac{h_t}{h} + \frac{\kappa}{\psi} \log \frac{c_t}{c} = \frac{1}{\psi} \log \frac{w_t}{w} - \frac{1}{\psi}(\tau_t - \tau) \tag{36}$$

When the labor elasticity is higher, it is optimal for workers to face smaller tax distortions. Intuitively, the less workers decrease their labor supply, the smaller the inefficiency caused by taxation. This becomes especially relevant when the government faces external borrowing constraints and will have to respond to revenue shortfalls by raising taxes or lowering expenditure. In this case, the best the planner can do is avoid high tax increases initially, so that the tax rate follows a hump-shaped pattern in subsequent periods. Financing this tax policy will inevitably entail larger cuts in public expenditure and larger external debt than in the baseline case.

To summarize, the elasticity of labor supply governs the reaction of workers to changes in the tax rates. In order to minimize distortions, the planner should avoid using large tax increases to finance revenue shortfalls when labor supply is very elastic. In the case of $\psi_b = 0$ this can be readily achieved through external borrowing, whereas limited access to external funds creates a trade-off between tax distortions and cutting public expenditure, resulting in a hump-shaped pattern of the tax rate.

5.3 Autocorrelation coefficient

The shock's persistence is governed by the parameter ρ_R, whose value in the baseline specification is 0.5. I conduct a sensitivity analysis on this parameter value, by considering two alternative values: $\rho_R = 0.7$ and $\rho_R = 0.9$. Figures 11 and 12 show dynamic responses under these different assumptions for the degree of persistence of the resource revenue shock. Persistent external shocks translate directly into persistent fluctuations. A comparison with the baseline case reveals that the response of private consumption becomes hump-shaped when $\psi_b \neq 0$ and when the shock is more persistent. The higher value of ρ_R does not, however, alter the shock-absorbing role of public investment, as it is still cut by more than public consumption. When $\psi_b = 0$, the patterns of adjustments of both private consumption and tax rates remain as in the baseline specification. The intuition for these results is as follows.

To find an optimal allocation, the Ramsey planner needs to take account of the fact that the original level of resource revenue will be re-established in the future. A higher value of ρ_R, however, means that the shortfall in resource revenues will last longer and will thus induce the planner to shift consumption from the future to the present and promote more consumption smoothing. With a more persistent shock, the planner will also find it more desirable to respond using tax changes, as taxes have immediate effects and directly facilitate income smoothing.

Stimulating income smoothing through tax policy, as shown above, works much better when access to external funds is unlimited. In this case, the government will rely mostly on external borrowing to minimize the consequences of the shock. However, the planner will find it difficult to react to highly persistent shocks when $\psi_b \neq 0$. The best option is to increase taxes by less today (when $\rho_R = 0.95$ the optimal policy is to cut taxes) so that the tax rate follows a hump-shaped path. However, the more persistent the shock, the more detrimental are the consequences for public expenditure and the higher is the level of external debt. In both cases, the hump-shaped response of tax rates (under $\psi_b \neq 0$) or the larger tax cuts (under $\psi_b = 0$) cause consumption smoothing in the private sector for reasons explained in section 5.1.

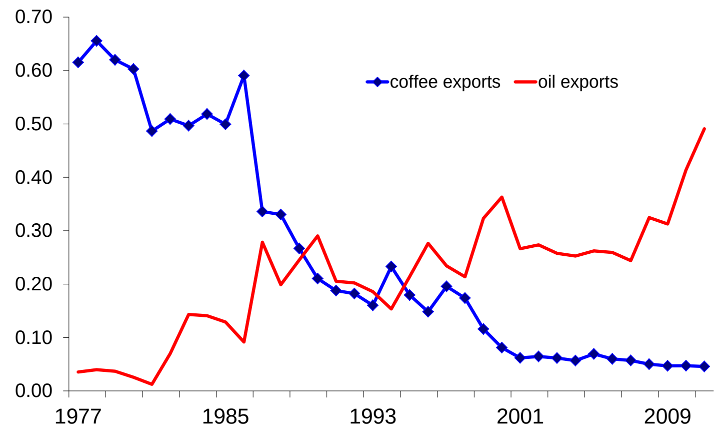
6 Conclusion

In this paper I use data from Latin American developing countries and G-7 countries to show that public consumption and public investment behave differently over the business cycle in both developed and developing countries. I then formulate a DSGE model in which these two components of government expenditure, public consumption and public investment, are treated separately and explore how a government's choice of optimal fiscal policy in the face of an adverse external shock varies with its country's degree of access to international capital markets. Simulations of this model are shown to be consistent with the observed empirical regularities in the cyclical behavior of fiscal policy in both developed and developing countries.

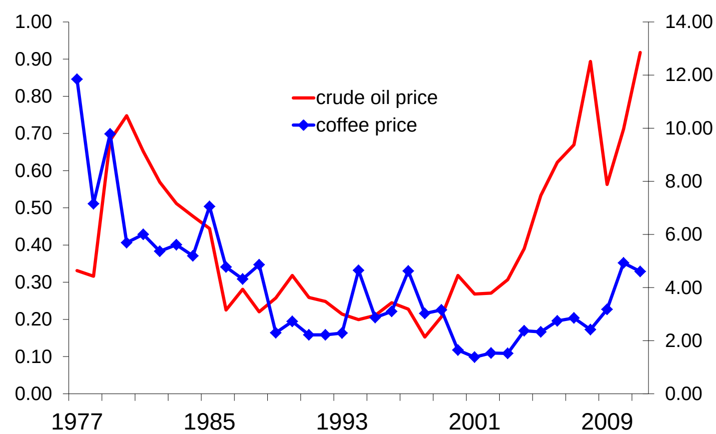
In developed countries with unlimited access to external borrowing at a given world interest rate, governments borrow heavily abroad to finance the shortfalls in resource revenue and cut taxes to induce consumption smoothing by the private sector. In contrast, the governments of developing countries tend to avoid external borrowing in adjusting to adverse shocks because of its high costs and instead find it optimal to cut public investment (far more than public consumption) and to raise taxes. The governments squeeze public investment more than public consumption because cuts in public consumption affect consumer utility directly and immediately, whereas cuts in public investment affect consumer utility indirectly and their effects are spread over multiple time periods. Large cuts in public investment are preferable to large rises in tax rates, which would cause substantial intertemporal distortions. The model thus confirms the importance of modeling financial frictions in explaining business cycles in emerging economies.

The analysis of the paper can be extended in a number of ways. First, empirical evidence is required that analyzes public consumption and public investment responses to external resource shocks for a sizable set of developing countries. Second, the theoretical framework can be extended to include additional features, such as a time-to-build process from public investment to public capital, which can help explain the hump-shaped responses of both public investment and public consumption to shocks in developing countries. I leave these extensions for future research to delve into.

7 Appendix

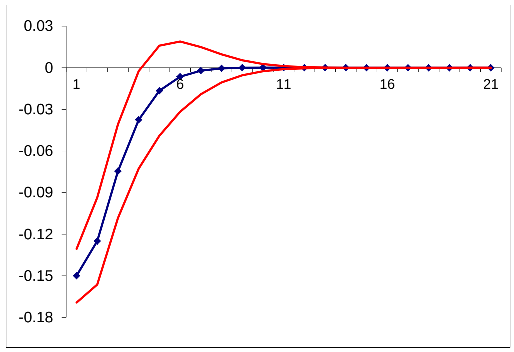


(a) Share of oil exports and coffee exports in total exports, Source: DANE (National statistics department)

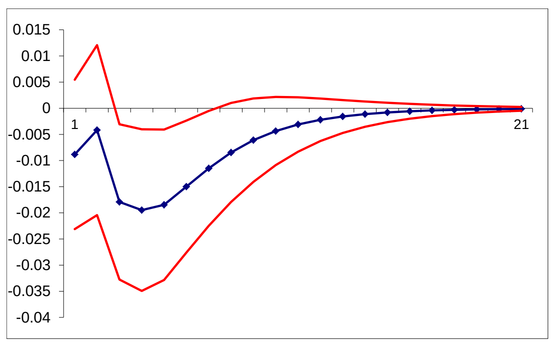


(b) Real crude oil and real coffee prices. Source: GFD, IMF

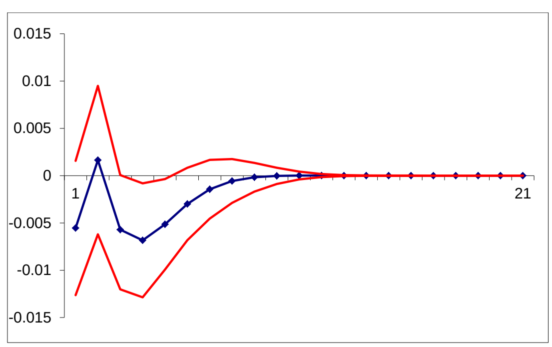
Figure 1: The Colombian commodity exports and real commodity prices



(a) Oil price



(b) Public investment



(c) Government consumption

Figure 2: Impulse responses to a 1 standard deviation decrease in oil prices: VAR

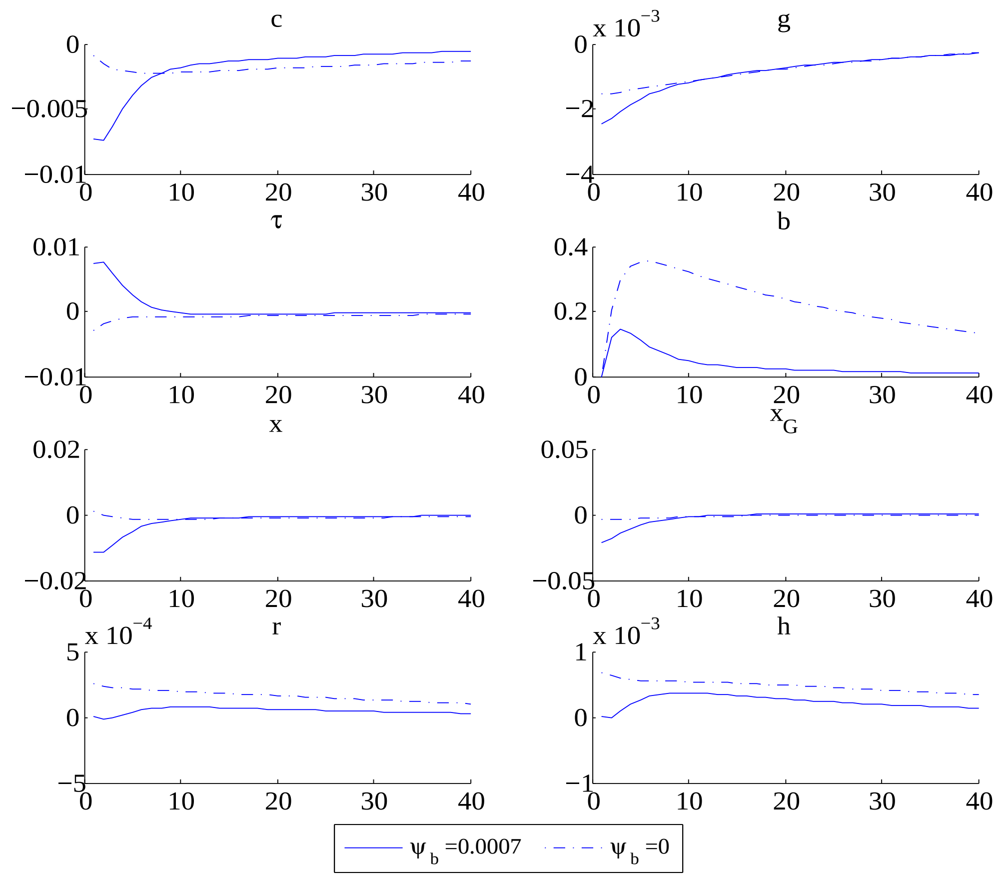


Figure 3: Impulse responses to adverse resource income shock: high-income ($\psi_b = 0$) and developing countries ($\psi_b \neq 0$)

8 Appendix (For the Online Publication)

8.1 Extension: private capital investment adjustment costs

The baseline model assumes that only public capital investment faces adjustment costs, and in this section I extend the analysis such that public and private capital investment face the same adjustment costs. An individual's budget constraint and FOC in this setting are given by the following equations:

$$(1+\tau_t)c_t + x_t(1+\varphi(\frac{x_t}{k_t})) \leq w_t h_t + r_t k_t + T_t, \tag{37}$$

$$w_t = -\frac{u'_h(t)}{u'_c(t)}(1+\tau_t) \tag{38}$$

$$\frac{c_t^{-\kappa}}{1+\tau_t}[1+\varphi(\frac{x_t}{k_t}) + \frac{x_t}{k_t}\varphi'(\cdot)] = \beta E_t \frac{c_{t+1}^{-\kappa}}{1+\tau_{t+1}} \times$$
$$\left[(1-\delta)[1+\varphi(\frac{x_{t+1}}{k_{t+1}}) + \frac{x_{t+1}}{k_{t+1}}\varphi'(\cdot)] + r_{t+1} + \frac{x_{t+1}^2}{k_{t+1}^2}\varphi'(\frac{x_{t+1}}{k_{t+1}})\right], \tag{39}$$

where private capital investment adjustment costs defined as:

$$\varphi(\frac{x_t}{k_t}) = \frac{\alpha_{p\varphi}}{2}(\frac{k_{t+1}}{k_t} - (1-\delta))^2,$$

The social planner's problem is similar to the problem in Section 3.5, with the implementability conditions of the Ramsey problem now incorporating private capital adjustment costs as shown in the following equations:

$$(1+\tau_t)c_t + [k_{t+1} - (1-\delta)k_t]\,(1+\varphi(\frac{x_t}{k_t})) = \frac{1}{1-\alpha}h_t^{1+\psi}c_t^{\kappa}(1+\tau_t) \tag{40}$$

$$g_t + [k_{Gt+1} - (1-\delta_G)k_{Gt}]\,\{1+\varphi\left(\frac{x_{Gt}}{k_{Gt}}\right)\} + b_t(1+r_{Gt}) + c_t +$$
$$[k_{t+1} - (1-\delta)k_t]\,(1+\varphi\left(\frac{x_t}{k_t}\right)) = y_t + R_t + b_{t+1} - \frac{\omega_G}{2}(b_{t+1}-b)^2 \tag{41}$$

And the counterpart of FOC (26) in the Ramsey problem is now:

$$\lambda_{p,t}\left[1+\varphi(\frac{x_t}{k_t})\right]+\lambda_{p,t}\left[k_{t+1}-(1-\delta)k_t\right]\alpha_{p\varphi}(\frac{k_{t+1}}{k_t}-(1-\delta))\frac{1}{k_t}+$$
$$\chi_t\left[1+\varphi(\frac{x_t}{k_t})\right]+\chi_t\left[k_{t+1}-(1-\delta)k_t\right]\alpha_{p\varphi}(\frac{k_{t+1}}{k_t}-(1-\delta))\frac{1}{k_t}-$$
$$-\beta E_t\lambda_{p,t+1}(1-\delta)\{1+\varphi(\frac{x_{t+1}}{k_{t+1}})\}-$$
$$-\beta E_t\lambda_{p,t+1}\{k_{t+2}-(1-\delta)k_{t+1}\}\alpha_{p\varphi}\left(\frac{k_{t+2}}{k_{t+1}}-(1-\delta)\right)\frac{k_{t+2}}{k_{t+1}^2}-$$
$$-E_t\beta\chi_{t+1}y_k(t+1)-E_t\beta\Omega_{t+1}\mu_t r_k(t+1)-\beta E_t\chi_{t+1}(1-\delta)\{1+\varphi(\frac{x_{t+1}}{k_{t+1}})\}-$$
$$-\beta E_t\chi_{t+1}\{k_{t+2}-(1-\delta)k_{t+1}\}\alpha_{p\varphi}\left(\frac{k_{t+2}}{k_{t+1}}-(1-\delta)\right)\frac{k_{t+2}}{k_{t+1}^2}=0 \tag{42}$$

There is only one new parameter in this extension, $\alpha_{p\varphi}$, which I set equal to 11.11. The value of $\alpha_{p\varphi}$ is chosen to yield a steady-state value of $\varphi(x_t/k_t) = 0.01$. This implies that private capital investment adjustment costs are equal to 1% of private investment.

Figure 13 shows the responses for the main variables of interest, and it compares the responses obtained from the extension with those of the original model for the case $\psi_b \neq 0$. The continuous line presents the original model and the dash-dotted line presents the model with both private and public capital investment adjustment costs. Note that the original model and the extension deliver qualitatively similar responses. Any differences between the responses of the two models can be explained as follows. A negative shock to resource revenues leads to a fall in private investment, resulting in private capital de-cumulation. However, due to the temporary nature of the shock, when the shock is over and the economy returns to its initial equilibrium, there is a need to re-install private capital stock. Such movements in the capital stock are likely to be prolonged due to the real adjustment costs for private investment, and thus are unsatisfactory from a welfare point of view. Thus, in the presence of private investment adjustment costs, it is optimal to reduce such medium-run fluctuations in private capital stock and absorb the shock through the use of fiscal policy to a greater extent than in the absence of the adjustment costs. This explains why the government resorts to greater external borrowing, the tax rate increases by less, and both public investment and public consumption fall by more in the initial period in the extension than in the original model. The smaller increase in the tax rate leads to a smaller decrease in private investment and consumption in the extension than in the original model in the initial periods.

9 Data Appendix

(For the Online publication)

The dataset used for calculating the correlation coefficients of the cyclical components of fiscal variables and GDP is annual and in real terms. The variables are logged and the business cycles are recognized using the Hodrick-Prescott filter, with lambda equal to 100. The sample consists of the fourteen countries listed below, followed by the respective length of time series in parentheses:

- High income economies: Australia (1972 - 2006), Canada (1973 - 2006), France (1972 - 2006), Germany (1972 - 2006), Italy (1972 - 2006), UK (1972 - 2006), and the US (1972 - 2006).

- Latin American economies: Argentina (1978 - 2004), Brazil (1980 - 2005), Chile (1972 - 2005), Colombia (1972 - 2005), Dominican Republic (1972 - 2005), Mexico (1972 - 2000), Peru (1972 - 2005), and Venezuela (1972 - 2005).

The following is a description of series and data sources:

Real GDP Real GDP was taken from the WB's (2011) WDI series NY.GDP.MKTP.KN. The data is in constant local currency.

Real Government Consumption Real government consumption was taken from WDI series NE.CON.GOVT.KN, labelled as "General government final consumption expenditure". This variable consists of all current government expenditures for the purchase of goods and services. The data is in constant local currency.

Real Government Capital Formation Real capital formation was retrieved from the IMF (2011) for period 1972 - 1989 for all countries in the sample. The series is the sum of "Capital Expenditure IV" for central, state or province, and local governments, code 15882V. For 1990 and afterwards, the source data on Latin American countries was obtained from UN's National Accounts Official Country Data, Table 4.5: General Government, series Gross capital formation. The series is unavailable for Argentina and Peru in the given time period, and is thus excluded for the analysis. For High Income countries, OECD (2011), National Accounts (Edition December 2011) database was used post-1990, series labelled Gross capital formation (General Government). All series are transformed from nominal into real with GDP deflator.

Real Government Expenditure For all of the countries in the sample, the real central government expenditure was obtained from Central Government Consolidated Accounts in

IMF (2011) under the name Total Expenditure. It is defined as the sum of current expenditure and capital expenditure. Prior to 1990, the series are available from the Historical data tables and for 1990 and onwards from the Current data tables, Central Government Consolidated Accounts. The variable is available in national currency in nominal terms. To transform it into real terms, the GDP deflator was applied.

Real Government Revenue IMF (2011) was used. Prior to 1990, the historical data tables' Central Government Consolidated Accounts provide Total Revenue, which is the sum of current revenue and tax revenue. Data on 1990 and thereafter was taken from the current data tables. Revenue Accrual was used for this period when it was available; otherwise Cash Revenue was taken instead. The definitions for the two are similar: the sum of Tax Revenue, Other Revenue, Social Contributions, and Grants. The latter only measures cash transactions, and is phased out in the same year as Revenue Accrual is introduced for all countries in the sample. Given their similarity and the fact that none of them are available for the complete period, they are combined into a single series. Moreover, Total Revenue from the historical data is discontinued in the current data tables, thus the Cash Revenue and Revenue Accrual are used to construct a continuous dataset.

GDP Deflator GDP deflator series was retrieved from WDI series NY.GDP.DEFL.ZS. The deflator was used solely to convert the government expenditures and government revenues from nominal into real values.

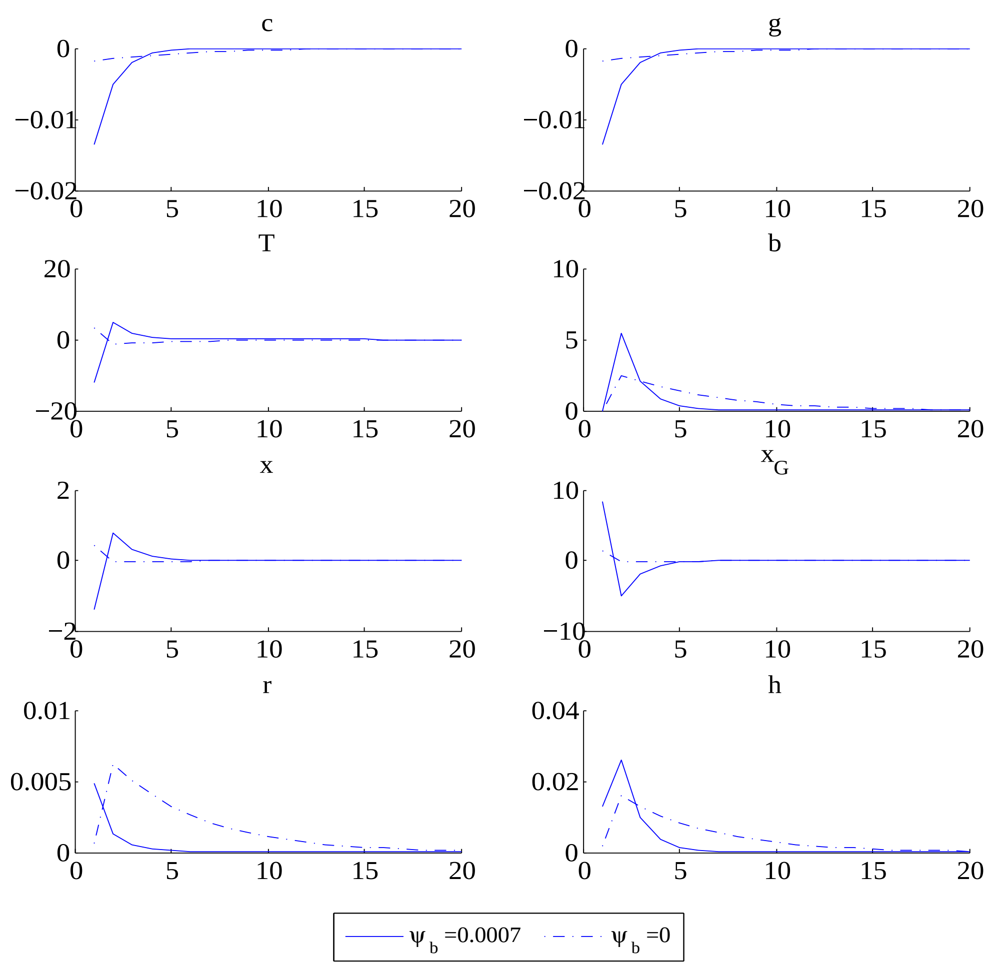


Figure 4: Impulse responses to adverse resource revenue shock: the case of lump-sum transfers

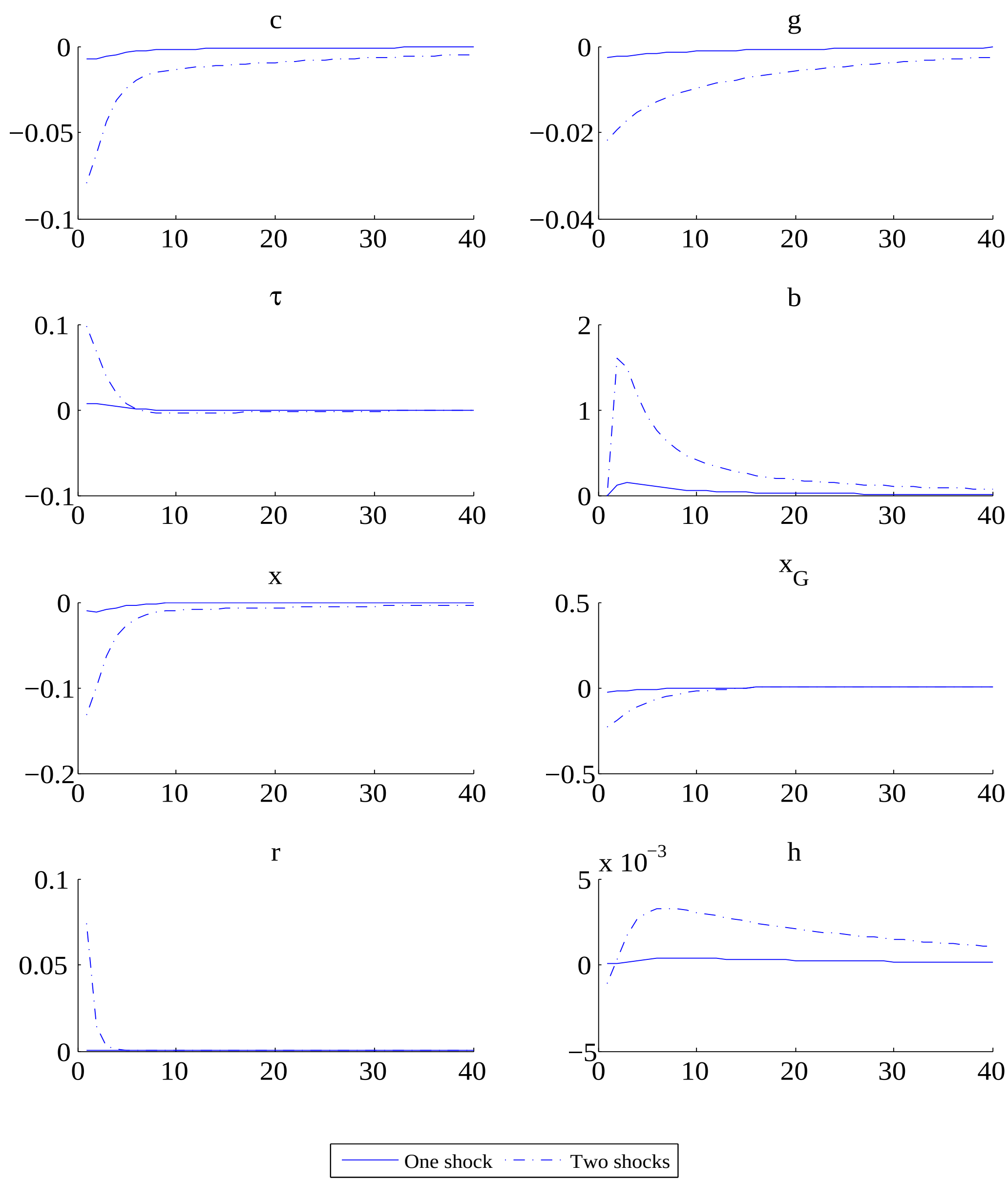


Figure 5: Comparing impulse responses: resource revenue shock vs. productivity + resource revenue shocks, $\psi_b \neq 0$

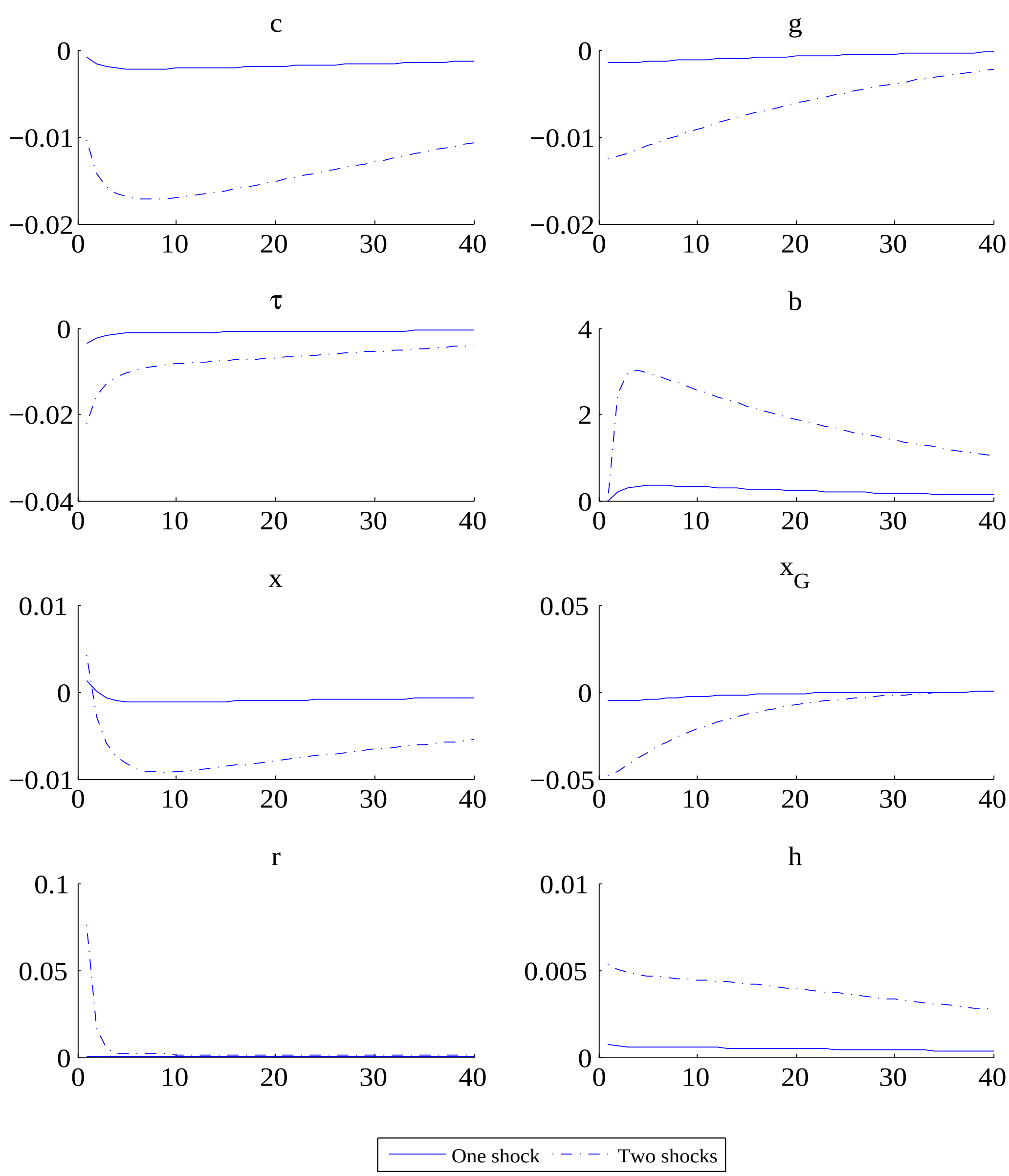


Figure 6: Comparing impulse responses: resource revenue shock vs. productivity + resource revenue shocks, $\psi_b = 0$

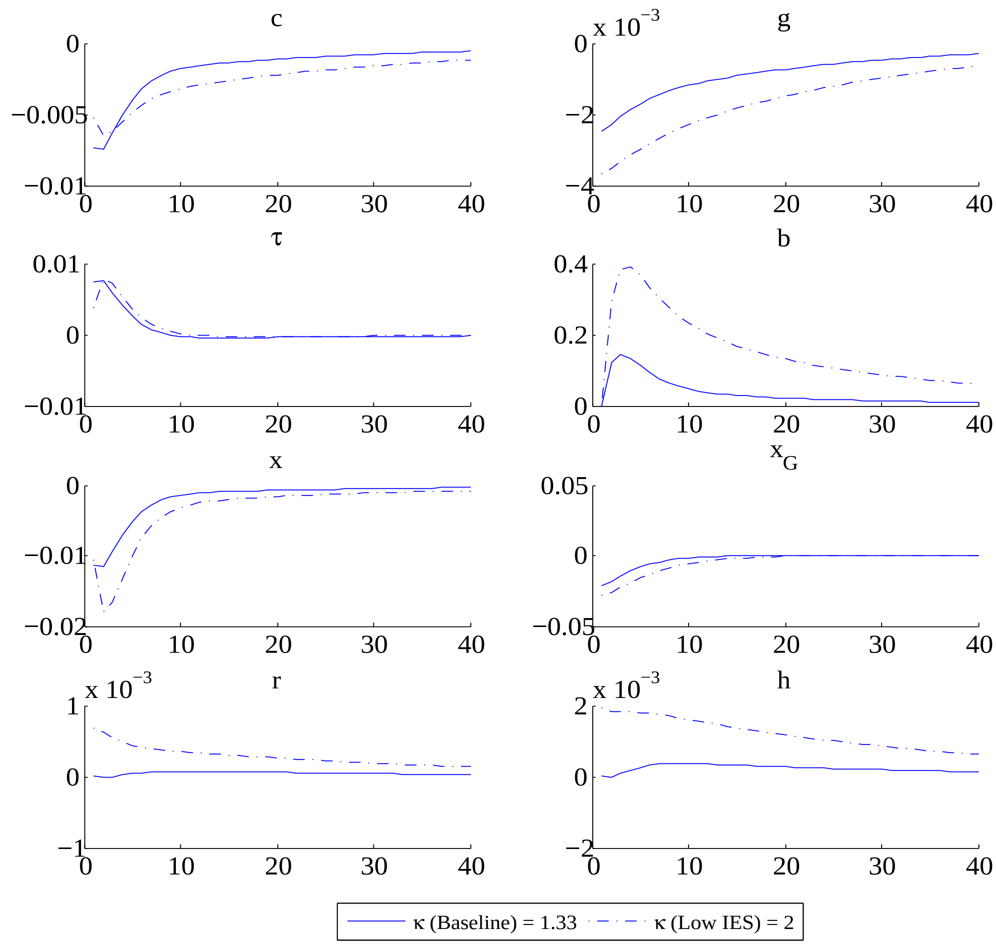


Figure 7: Robustness to varying the intertemporal elasticity of substitution (IES), $\psi_b \neq 0$

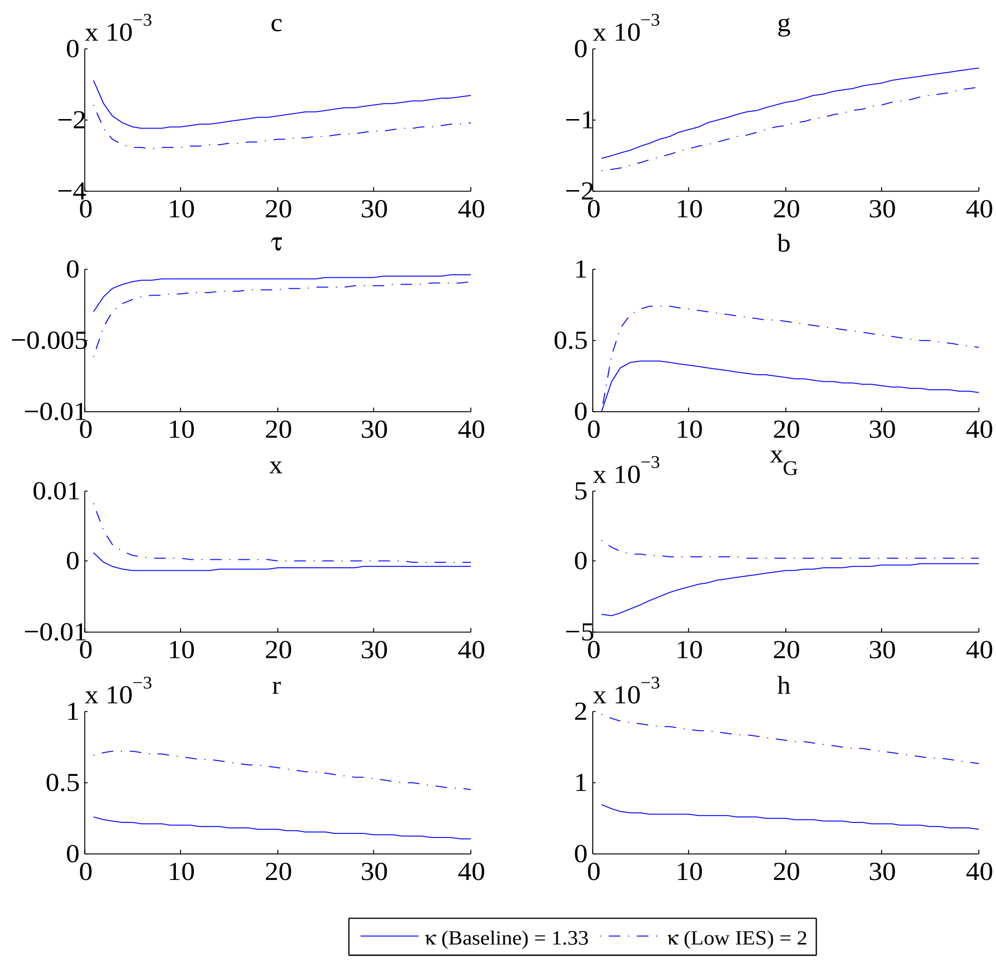


Figure 8: Robustness to varying the intertemporal elasticity of substitution, $\psi_b = 0$

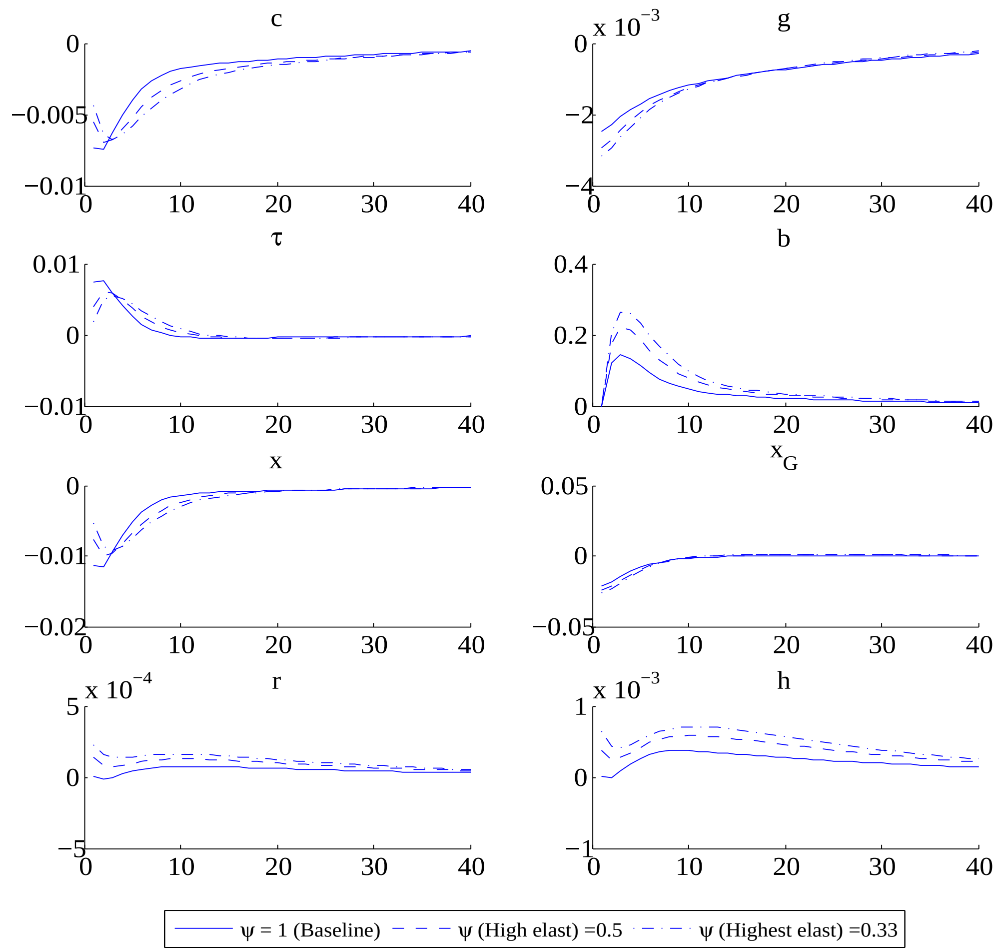


Figure 9: Robustness to varying the elasticity of labor supply, $\psi_b \neq 0$

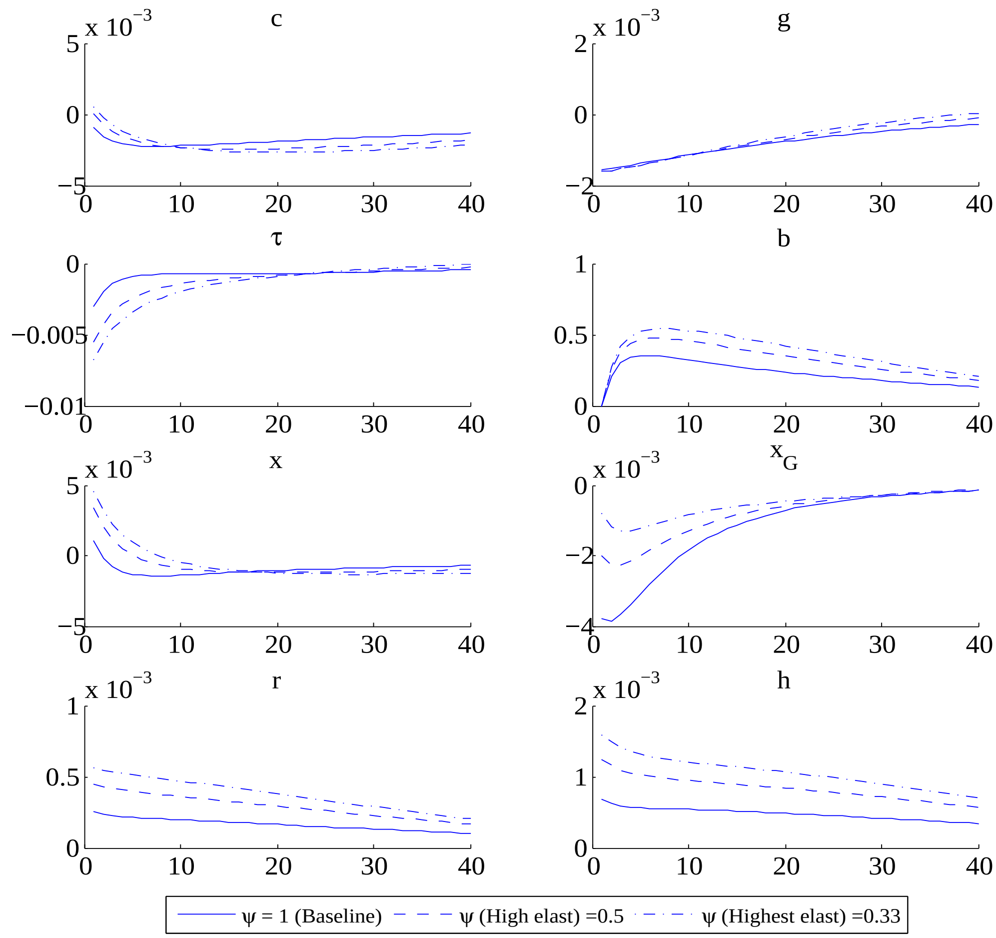


Figure 10: Robustness to varying the elasticity of labor supply, $\psi_b = 0$

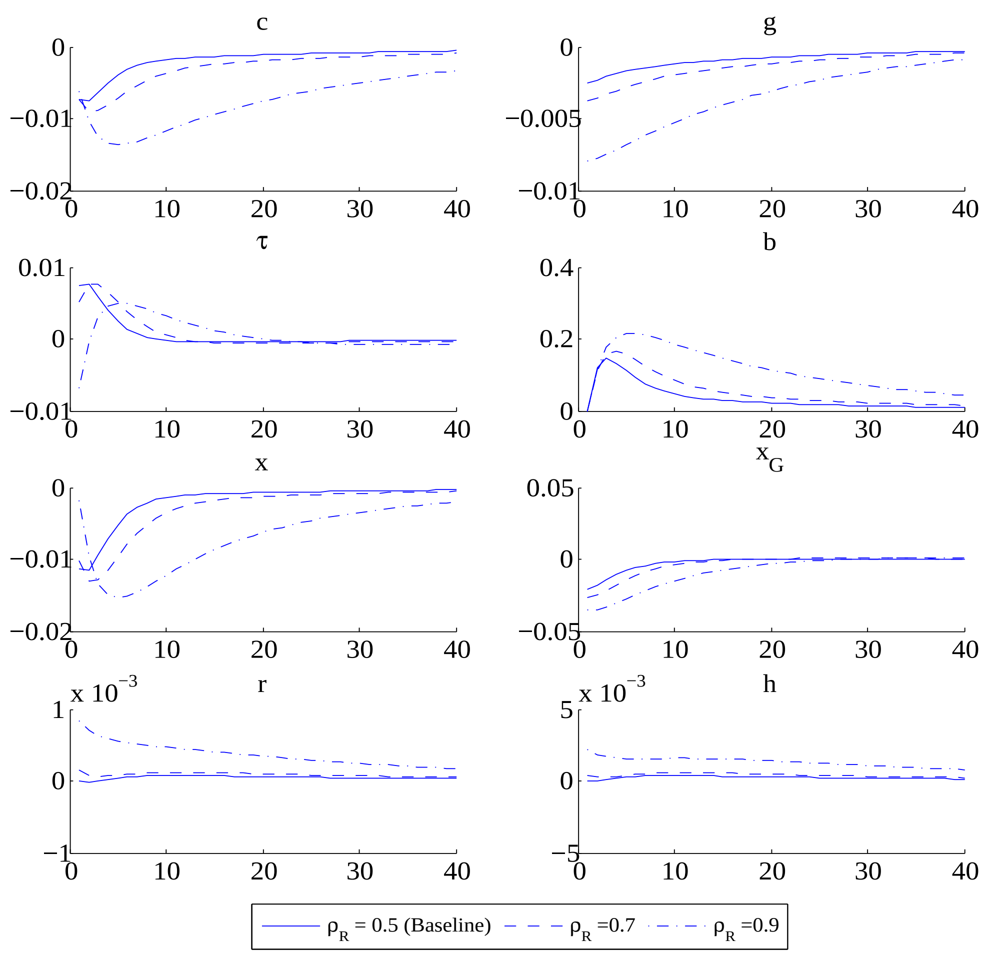


Figure 11: Robustness to varying the degree of persistence of the shock ρ_R, $\psi_b \neq 0$

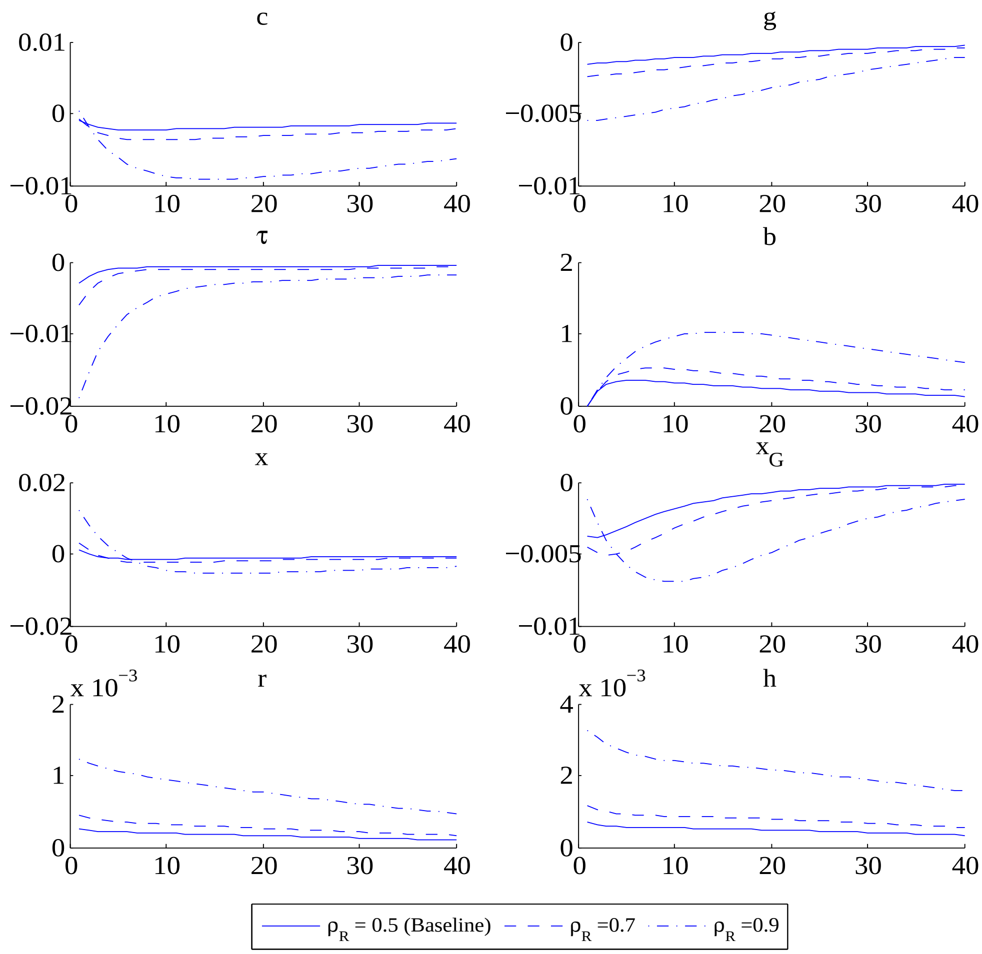


Figure 12: Robustness to varying the degree of persistence of the shock ρ_R, $\psi_b = 0$

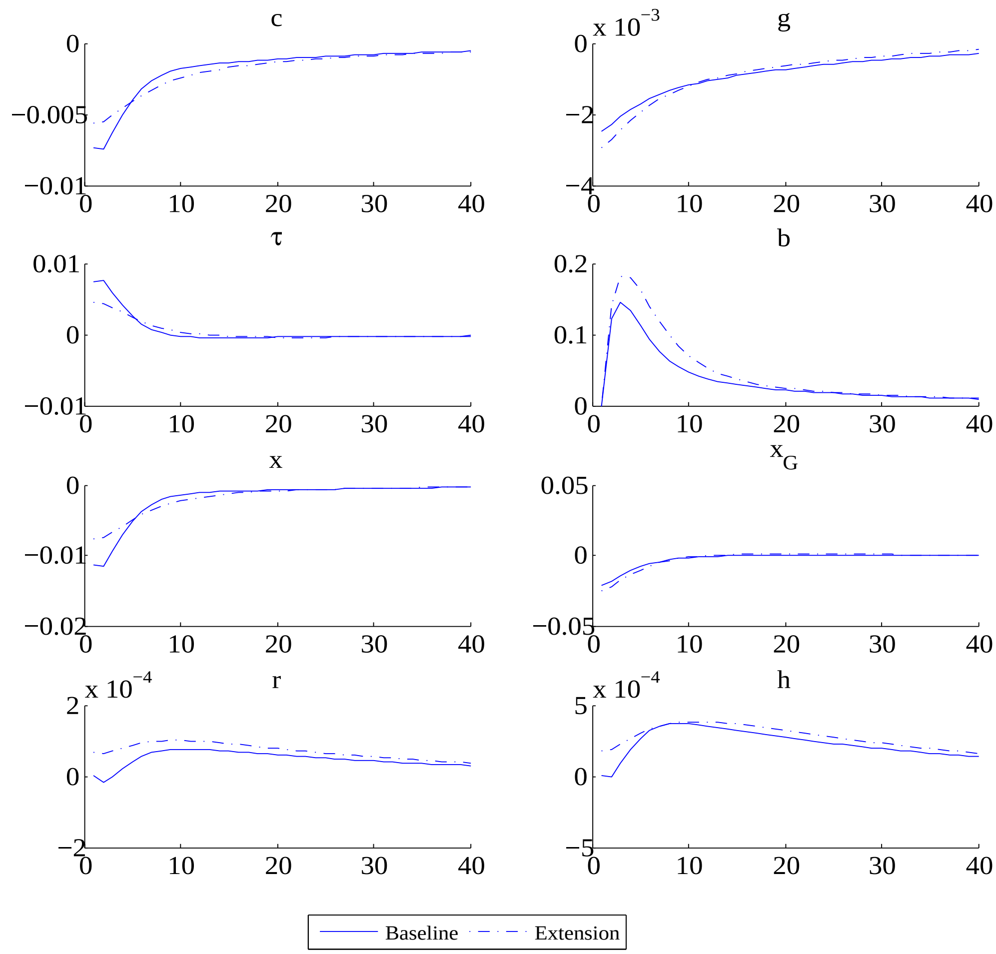


Figure 13: Comparing impulse responses: Extension vs. Original model, $\psi_b \neq 0$

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