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Fiscal Policies and Asset Prices ^{*}

M. M. Croce, H. Kung, T. T. Nguyen and L. Schmid[†]

Abstract

The surge in public debt triggered by the financial crisis has raised uncertainty about future tax pressure and economic activity. We examine the asset pricing effects of fiscal policies in a production-based general equilibrium model in which taxation affects corporate decisions by: i) distorting profits and investment; ii) reducing the cost of debt through a tax shield; and iii) depressing productivity growth. In settings with recursive preferences, these three tax-based channels generate sizable risk premia making tax uncertainty a first order concern. We document further that corporate tax smoothing can substantially alter the effects of public expenditure shocks.

Keywords: Cost of Equity, Corporate Tax Uncertainty, Tax Smoothing

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1 Introduction

Fiscal stabilization policies arising in response to the recent financial crisis have led to a surge of public debt that will eventually require budget consolidation. At this stage, however, there is significant uncertainty about the future policies that will be implemented to achieve budget balance. The distortionary nature of the most relevant fiscal policy instruments raises concern that the effects of fiscal uncertainty on current economic activity, long-run growth, and welfare may be substantial.

We contribute to the public budget debate by examining the effects of fiscal policies affecting corporate decisions, and hence asset prices, through corporate taxation. We propose a production-based economy subject to risky government expenditure shocks that generate tax risk through the government's budget. The extent of this uncertainty depends on the government's financing policy which pins down long-run tax dynamics. Our main results show that both volatility and the intertemporal distribution of tax rates are first-order determinants of the cost of equity and capital accumulation. Quantitatively, each of these features of the tax rate process is as important as the average level of taxation (Gomes, Michaelides, and Polkovnichenko (2009)). At a broader level, therefore, our results are significant because they convey the need to include risk considerations in fiscal policy analysis.

We conduct a tax-based asset pricing and welfare analysis in the spirit of Lucas (1987) and Lucas (1978) using a general equilibrium model with the goals of (1) capturing the most significant channels through which taxes can alter corporate decisions, and (2) producing reasonable implications for the cost of equity even in a baseline environment without tax uncertainty. We believe that a realistic model of corporate taxation that produces plausible results for both cost of equity and investment decisions will yield a reasonable assessment of the asset pricing role of corporate tax uncertainty.

We identify three primary channels through which corporate taxes mainly affect firm decisions. The first is the investment channel: taxes affect profits and therefore the after-tax marginal product of capital, which gives rise to investment distortions. Since we assume that capital accumulation is subject to adjustment costs as in Jermann (1998), our model features sizeable variations in the marginal price of capital that can be amplified by tax shocks.

Second, in line with the US tax code we assume that taxes lower the cost of debt, since interest

payments on corporate debt are tax-deductible. Departing from the Modigliani-Miller benchmark, we capture this financing channel by explicitly modeling financial leverage. Specifically, we introduce a dynamic trade-off model of capital structure into an asset pricing model along the lines of Livdan, Sapriz, and Zhang (2009). The marginal benefit of corporate debt corresponds to the expected tax shield. The marginal cost of debt is related to distress and debt adjustment costs in the spirit of Jermann and Quadrini (2011). Through this combination of frictions, in equilibrium, the volatilities of our net equity payouts and equity excess returns are closer to those observed in the data (see, among others, Larrain and Yogo (2008)). Corporate financing, therefore, is a dimension that helps us to better characterize the dynamics of equity returns and ultimately their exposure to tax risk. This is relevant to obtain reliable estimates on the effects of taxation on the cost of equity.

Third, reflecting recent empirical evidence (see Djankov, Ganser, McLiesh, Ramalho, and Shleifer (2010), and Lee and Gordon (2005)), we allow for a productivity channel that accounts for interdependence between taxation and productivity growth. Specifically, in our benchmark model an increase in taxes produces a small but persistent slowdown in long-run productivity growth.¹

In order to keep our fiscal analysis focused, we simplify government behavior in several ways. In particular, our government finances an exogenous cash-flow stream calibrated to mimic the corporate tax flows observed in the data (McGrattan and Prescott (2005)). This cash-flow stream is financed through a mix of public debt and corporate taxes, according to an exogenous rule that determines the extent of fiscal stabilization through tax-smoothing, i.e., the persistence and the volatility of the tax rate. Our exogenous fiscal policies can be interpreted as the fiscal counterpart of Taylor rules in monetary economics. In this sense, our approach is methodologically close to that of Palomino (2011), and Gallmeyer, Hollifield, Palomino, and Zin (2011).

We consider three alternative policy scenarios. The government can either (1) implement a zero-deficit policy, implying that all tax shocks in the economy are absorbed by a one-to-one contemporaneous adjustment of corporate taxes (no tax smoothing); or (2) use public debt to smooth corporate taxes in

¹For the sake of simplicity, we model this link in reduced form, similarly to Pastor and Veronesi (2011b). This channel can be micro-founded in models with endogenous growth in which innovation and R&D sustain balanced growth, as in Croce, Nguyen, and Schmid (2011). Croce, Nguyen, and Schmid (2011) focus on the link between the return of the consumption claim and labor taxation and abstract from physical capital, capital structure and corporate taxes.

order to stabilize consumption over time and across contingencies; or (3) use public debt to stabilize investment. Under the zero-deficit policy, the tax rate dynamics reflect the *exogenous* fluctuations of the public liabilities. This policy is, therefore, a good benchmark to quantify the impact of purely exogenous expenditure shocks. Under the two alternative debt-financing policies, in contrast, the tax rate properties are *endogenously* pinned down by the tax-smoothing attitude of the government. The long-run budget balance determines the future tax adjustment required to consolidate public debt across different histories of expenditure and productivity shocks. These two alternative tax smoothing policies enable us to determine under which circumstances public debt financing can endogenously amplify or reduce the asset pricing and welfare impacts of exogenous shocks. We find this second experiment particularly relevant for the current fiscal debate for a simple reason: while public liability shocks are mostly outside of government control, financing decisions are mainly within the discretion of the fiscal authorities and should be made to maximize welfare.

Since both our productivity channel and the government tax-smoothing rules generate significant trade-offs between current and future growth and taxation, we employ Epstein and Zin (1989) recursive preferences to capture agents' sensitivity to the intertemporal distribution of risk. The relevance of this last element of our model is twofold. On the one hand, it allows us to disentangle the intertemporal elasticity of substitution (IES) from relative risk aversion (RRA). This enables us to match several features of quantities, driven by the IES (see Tallarini (2000)), and asset prices, driven by RRA. On the other hand, recursive preferences make our household more or less favorable to public debt policies that alter the level of short-run and long-run consumption risk. In particular, as in Bansal and Yaron (2004), our household dislikes late resolution of uncertainty, i.e., long-lasting shocks to consumption prospects. Therefore, in our welfare investigation we treat tax-smoothing policies as a device to reallocate consumption risk across different horizons.

In this set-up, we obtain three relevant results regarding corporate taxation. First, average corporate taxation matters for both the level and the composition of the cost of capital. When the tax rate is time invariant, higher taxation reduces capital accumulation and investment, the only hedging devices available in our economy. In equilibrium, higher average taxation results in a higher cost of equity, as in Gomes, Michaelides, and Polkovnichenko (2009), and lower after-tax cost of debt.

Second, when the productivity channel is active, persistent government expenditure shocks affect long-run corporate productivity and thereby constitute a significant risk factor. We find that even a moderate increase in the volatility of the expenditure shocks can substantially increase the equity premium in the economy. This makes the level of fiscal risk as important as the average level of tax pressure in fiscal policy decisions.

The previous effects are independent of explicit financing policies; rather, they reflect production distortions arising from taxation. Our third result, however, relates to the intertemporal equilibrium effects resulting from tax smoothing. We show that conventional tax smoothing aimed at stabilizing short-run consumption volatility can produce a substantial increase in the equity premium and ultimately in the average excess return of total wealth. Since aggregate wealth mirrors welfare (Epstein and Zin (1989)), this implies substantial welfare losses. This result can be explained as follows. In general equilibrium, the alteration of corporate tax rates to smooth consumption comes at the cost of an increase in the volatility of investment. This tax-smoothing scheme therefore increases the volatility of capital accumulation, i.e., the driver of long-run consumption growth. Since our household strongly dislikes long-run consumption uncertainty, welfare declines. The opposite occurs when the government smooths corporate taxation to stabilize corporate investment: in this case, tax smoothing acts as a stabilizer of long-run consumption growth, ultimately producing welfare benefits.

Our paper belongs to a growing literature examining the links between government policies, economic activity and asset prices. In two closely related studies, Pastor and Veronesi (2011a,b) examine the effect of uncertainty about government policy on stock prices. They stress learning about government interventions and political motives. Our paper, in contrast, focuses on tax-related fiscal uncertainty and examines its implications for aggregate risk premia in a macroeconomic setting with perfect information and commitment. We view the learning channel of Pastor and Veronesi (2011a,b) as an important complementary mechanism to be incorporated into our macro model in future research.

Gomes, Michaelides, and Polkovnichenko (2009) and Gomes, Michaelides, and Polkovnichenko (2010), like us, examine the effects of fiscal policy using calibrated models with realistic risk premia. In their incomplete market models with heterogeneous agents, they focus on portfolio reallocations between agents and crowding-out effects through the public supply of debt. In our paper, we retain a representative

agent framework but stress fiscal uncertainty and the intertemporal distributions of tax distortions and consumption as important determinants of risk premia and welfare. Our paper is also related to work by Gomes, Kotlikoff, and Viceira (2008), who calibrate a life-cycle model to measure the welfare losses from uncertainty about taxes and social security; however, they do not consider the cost of equity. Glover, Gomes, and Yaron (2010) also examine asset pricing and macroeconomic implications of corporate taxation in a model with endogenous financial leverage, but they focus on credit spreads and do not consider policy uncertainty.

While we focus on the government's financing problem, Belo, Gala, and Li (2011) and Belo and Yu (2011) empirically examine the effects of government spending on the cross-section of returns and the aggregate stock market. They find that government investment is an important risk factor that predicts aggregate stock returns.

Broadly, our paper is related to a long list of studies examining the effects of fiscal policy on the macroeconomy. Among others, Dotsey (1990), Ludvigson (1996)) and more recently David, Leeper, and Walker (2010), and Leeper, Plante, and Traum (2010) explicitly examine the implications of dynamic fiscal policies for the macroeconomy in stochastic real business cycle models. In contrast to our study, these papers abstract from asset prices and risk considerations.

We link welfare costs to risk premia in asset markets similarly to Tallarini (2000), Alvarez and Jermann (2004), and Croce (2006). While these researchers focus on economic fluctuations abstracting from policy interventions, our work explicitly considers tax policies and their impact on asset markets and consumption at various frequencies.

Our paper is also related to the growing literature examining asset pricing in production-based general equilibrium models with recursive preferences (Ai (2009); Backus, Routledge, and Zin (2010); Campanale, Castro, and Clementi (2008); Gourio (2011); Lochstoer and Kaltenbrunner (2010); Kuehn (2008); Kuehn, Petrosky-Nadeau, and Zang (2011)). In the spirit of the existing literature, we provide a handy production economy able to produce sizeable Sharpe ratios and equity premia. We differ from previous work, however, for our mix of investment and financing frictions and our focus on the link between long-run tax risk and equity premia.

The rest of the paper is organized as follows. We present the model in section 2, where we also

detail the link between corporate taxation and productivity. Quantitative model results are presented and discussed in sections 3 and 4. Section 5 concludes. Details concerning data construction and solution methods are presented in Appendix A and B, respectively.

2 Model

We use a general equilibrium model to quantitatively examine the links between fiscal shocks, leverage, macroeconomic aggregates, and asset prices. Our economy is populated by a representative firm that optimally chooses investment and financial leverage; a representative agent with Epstein and Zin (1989) preferences who supplies labor and saves using corporate equity, corporate bonds, and public bonds; and a government that determines the corporate tax rate. In this section, we describe in detail the behavior of these agents.

2.1 Government and Productivity

Public Liabilities. In the tax literature it is common to assume that the government levies taxes in order to finance an exogenous demand for goods and services. Under this assumption, the role of government is twofold. On the one hand, the government generates distortionary effects (substitution effects) induced by proportional taxation. On the other hand, government expenditure reduces the amount of resources available to the private sector (a crowding-out or, equivalent, income effect). We focus only on the distortionary effect, and following Santoro and Wei (2011), we assume that all taxes are used to finance a lump-sum transfer to the household, TR_t . By doing so, we ignore the negative income effect associated with government expenditure and obtain a lower (upper) bound on the potential costs (benefits) of corporate taxation.

The exogenous public cash flow to be financed, TR_t , evolves as follows:

$$\begin{aligned}
TR_t &= \tau_t^* \cdot \text{tax base}_t, \\
\tau_t^* &= \frac{1}{1 + \exp(-\omega_t)}, \\
\omega_t &= (1 - \rho)\mu_\tau + \rho\omega_{t-1} + \epsilon_{\tau^*,t}, \\
\epsilon_{\tau^*,t} &\sim N(0, \sigma_\tau^2).
\end{aligned} \tag{1}$$

This formulation guarantees that the expenditure–tax base ratio, τ_t^* , is positive and smaller than 100%.

Corporate Taxation and Financing. To keep the fiscal side of our model as focused as possible on corporate tax rate fluctuations, τ_t , we abstract from labor taxes and other non corporate taxes and define the total tax in flow simply as:

$$\begin{aligned}
T_t &= \tau_t \cdot \text{tax base}_t, \\
\text{tax base}_t &= (Y_t - W_t H_t - r_{f,t-1} B_{t-1}),
\end{aligned} \tag{2}$$

where Y_t measures corporate sales, W_t is the real wage rate, H_t measures labor and $r_{f,t-1} B_{t-1}$ refers to corporate interest payments on corporate debt, B_{t-1} . We anticipate that at the equilibrium there will be no default and, therefore, corporate bonds pay the short-term risk-free rate, $r_{f,t-1}$. The exclusion of corporate interest payments from the tax base captures the tax-shielding effects of corporate debt, in line with the US tax code. This feature of the model represents a departure from the Modigliani-Miller assumptions typically maintained in the asset pricing literature and gives rise to an incentive to issue corporate debt.

To highlight the relevance of corporate tax smoothing, we allow the government to finance expenditure through a mix of corporate taxes, T_t , and public debt, B_t^G , according to the following budget constraint:

$$\begin{aligned}
B_t^G &= (1 + r_{f,t-1})B_{t-1}^G + TR_t - T_t \\
&= (1 + r_{f,t-1})B_{t-1}^G + (\tau_t^* - \tau_t)\text{tax base}_t.
\end{aligned} \tag{3}$$

Productivity. Aggregate productivity is denoted by Z_t . Empirical work in growth economics (for example, Lee and Gordon (2005), and Djankov, Ganser, McLiesh, Ramalho, and Shleifer (2010)) suggests that an increase in tax pressure reduces long-run growth. Croce, Nguyen, and Schmid (2011) explain this empirical finding in a model in which growth is endogenously promoted by accumulation of patents (as in Romer (1990)). They find that taxes inhibit profits and R&D activity, two main drivers of productivity growth. Since our analysis focuses mainly on the link between corporate tax uncertainty and the cost of equity, we abstract from endogenous growth and directly impose the condition that the log growth rate of productivity, $\Delta z_t \equiv \log(Z_t) - \log(Z_{t-1})$, evolves as follows:

$$\begin{aligned} \Delta z_t &= \mu + \phi_\tau \cdot (\tau_{t-1} - E[\tau_t]) + \epsilon_t, \\ \epsilon_t &\sim N(0, \sigma_\epsilon), \quad \text{corr}(\epsilon_{\tau^*, t}, \epsilon_t) = 0, \end{aligned} \tag{4}$$

where $\phi_\tau \leq 0$ captures the results of Croce, Nguyen, and Schmid (2011). We assume that productivity is affected by the deviation of the tax rate, τ_{t-1} , from its unconditional mean, $E[\tau_t]$, just to normalize the unconditional growth rate of the economy to μ . We impose the condition $\text{corr}(\epsilon_{\tau^*, t}, \epsilon_t) = 0$ in order to study fiscal policy shocks purely unrelated to the productivity dynamics. In section 3.1, we focus on US data and provide direct empirical evidence supporting our productivity specification.

2.2 Representative Household

Our household has Epstein and Zin (1989) preferences defined over consumption goods, C_t :

$$U_t = \left\{ (1 - \beta) C_t^{1 - \frac{1}{\psi}} + \beta (E_t[U_{t+1}^{1 - \gamma}])^{\frac{1 - \frac{1}{\psi}}{1 - \gamma}} \right\}^{\frac{1}{1 - \frac{1}{\psi}}},$$

where γ is the coefficient of relative risk aversion and ψ is the elasticity of intertemporal substitution. When $\psi \neq \frac{1}{\gamma}$, the agent cares about news regarding long-run growth prospects and taxation. In line with the literature on long-run risks in asset prices, we assume $\psi > \frac{1}{\gamma}$, such that the agent dislikes shocks to long-run expected growth rates. This assumption allows the intertemporal distribution of tax rates to

influence asset prices.

We assume that the agent experiences no disutility from working, so that the supply of hours worked, H_t , is fixed and normalized to 1 for simplicity. As shown in Epstein and Zin (1989), the stochastic discount factor in this setting is

$$M_{t+1} = \delta \left(\frac{C_{t+1}}{C_t} \right)^{-\frac{1}{\psi}} \left(\frac{U_{t+1}}{E_t [U_{t+1}^{1-\gamma}]^{\frac{1}{1-\gamma}}} \right)^{\frac{1}{\psi} - \gamma}.$$

The objective of the household is to maximize lifetime utility, subject to a standard budget constraint:

$$U_t = \max_{\{C_j, H_j, S_j, B_j, B_j^G\}_{j=t}^{\infty}} \left\{ (1 - \beta) C_t^{1-1/\psi} + \beta E_t [U_{t+1}^{1-\gamma}]^{\frac{1-1/\psi}{1-\gamma}} \right\}^{\frac{1}{1-1/\psi}} \quad (5)$$

s.t.

$$\begin{aligned} C_t + S_t P_t + B_t^{tot} &\leq (1 + r_{f,t-1}) B_{t-1}^{tot} + S_{t-1} (D_t + P_t) + W_t H_t + TR_t, \\ B_t^{tot} &= B_t + B_t^G, \end{aligned}$$

where S_t is number of equity shares (in equilibrium, $S_t = 1 \quad \forall t$); P_t is the ex-dividend price per share; D_t is the equity payout; and B_t^{tot} is the sum of corporate and public bonds as specified in section 2.1. In each period, the household determines its consumption and its allocation of savings among equity, corporate debt, and public debt. The optimal investment policy implies the following no-arbitrage pricing equations:

$$\begin{aligned} 1 &= E_t \left[M_{t+1} \frac{P_{t+1} + D_{t+1}}{P_t} \right], \\ r_{f,t} &= \frac{1}{E_t [M_{t+1}]} - 1. \end{aligned} \quad (6)$$

Equation (6) shows that in our economy the first-order conditions of the household are not directly affected by any marginal tax distortion. In this paper, therefore, we consider only distortions that directly affect the firm side.

2.3 Representative Firm and Market Clearing

Production technology. The representative firm has access to a standard constant returns-to-scale production technology:

$$Y_t = (Z_t H_t)^{1-\alpha} K_{t-1}^\alpha,$$

where Y_t is output, H_t measures labor, and K_t denotes the physical capital stock that we specify as in Jermann (1998):

$$\begin{aligned} K_t &= (1 - \delta)K_{t-1} + \phi \left(\frac{I_t}{K_{t-1}} \right) K_{t-1} \\ \phi \left(\frac{I_t}{K_{t-1}} \right) &:= \left[\frac{\alpha_1}{1 - 1/\xi} \left(\frac{I_t}{K_{t-1}} \right)^{1-1/\xi} + \alpha_2 \right]. \end{aligned}$$

The introduction of investment adjustment cost, ϕ , allows us to work with an upward-sloping supply curve of new capital and produce variations in marginal Tobin's Q that are required to match equity return dynamics.

Financing. We assume that the firm can finance investment by issuing either equity or one-period bonds sold at par with face value B and interest rate r_f . Since we allow interest payments on corporate debt to be tax-deductible, there is scope for optimal leverage decisions, in line with the dynamic trade-off models of capital structure proposed in Hennessy and Whited (2005), Hennessy and Whited (2007), Livdan, Sapriza, and Zhang (2009), and Gomes and Schmid (2010).

While the marginal benefit of debt is determined by the tax advantage, the cost of debt depends on indirect financial distress costs, C_t^E :

$$C_t^E = \phi_0 e^{-\phi_1 \cdot \left(\frac{\eta K_t}{B_t} - 1 \right)} \cdot Z_{t-1},$$

where η , ϕ_1 and ϕ_0 are positive constants, and the factor Z_{t-1} ensures that these costs do not vanish along the balanced growth path. The parameter η captures the liquidation value of the collateral as a fraction of its book value, K , and is set so that $\eta < (1 - \delta)$, implying that distressed capital is sold at a

discount. The parameter ϕ_1 is set high to discourage the firm from borrowing more than the collateral value. The parameter ϕ_0 is set low so that the firm will choose $B = \eta K$ at the steady-state. We choose this cost formulation mainly to ‘convexify’ the following occasionally non binding enforcement constraint:

$$B_t \leq \eta K_t, \tag{7}$$

which allows the firm to borrow up to the value of its collateral, i.e., the liquidation value of the capital stock. Modeling C_t^E as a continuous and differentiable function approximating (7) enables us to easily solve the model with standard numerical methods. This modeling choice makes our production economy very straightforward to solve and versatile for future extensions.

The constraint (7) implies that all debt is secured by the firm’s capital, and hence no default ever occurs in equilibrium. Similarly to Glover, Gomes, and Yaron (2010), our C^E process captures indirect costs of financial distress, i.e., costs of financial leverage outside of bankruptcy. Such indirect costs arise in highly levered firms when, for example, they find it more difficult to find new lenders or recruit new employees. All these activities require more time and effort and are costly.

To generate realistically persistent dynamics for leverage (Leary and Roberts (2005), Lemmon, Roberts, and Zender (2008)), we introduce capital structure rigidities, modeled through the following quadratic debt adjustment cost function centered around the steady-state, $\frac{B_{ss}}{Y_{ss}}$:

$$C_t^B = \nu \cdot \left(\frac{B_t}{Y_t} - \frac{B_{ss}}{Y_{ss}} \right)^2 \cdot Z_{t-1}.$$

Since in our model output, Y_t , and earnings before interest and taxes (EBIT), $Y - W = \alpha Y$, are proportional to each other, variations in the cost of debt are a function of the debt-EBIT ratio, an accounting measure very frequently used in debt covenants. This formulation makes the issuance costs of new debt counter-cyclical, meaning that an increase debt is more costly in downturns, when output is low, and cheaper in good economic times. Repaying debt, on the other hand, is less costly in bad times, when output is low. This friction generates an incentive for pro-cyclical debt issuance, consistent with the empirical findings of Jermann and Quadrini (2011) on aggregate debt payouts.

In each period, the objective of the firm is to maximize equity-holders' wealth cum dividend ($V_t = P_t + D_t$) by optimally choosing physical investment, I_t , hours worked, H_t , and corporate debt, B_t :

$$\begin{aligned}
V_t &= \max_{\{D_j, I_j, H_j, K_j, B_j\}_{j=t}^{\infty}} E_t \left[\sum_{j=t}^{\infty} M_{j|t} D_j \right] \\
&\text{s.t.} \\
D_t &\leq Y_t - W_t H_t - T_t - I_t + B_t - (1 + r_{f,t-1}) B_{t-1} - C_t^B - C_t^E, \\
K_t &\leq (1 - \delta) K_{t-1} + \phi \left(\frac{I_t}{K_{t-1}} \right) K_{t-1}.
\end{aligned} \tag{8}$$

In the system of equations (8), $M_{j|t} = M_{t+1} \cdot \dots \cdot M_{t+j}$ is the j -step stochastic discount factor, which is taken as given by the firm. If $D_t < 0$, then the firm is a net equity issuer at time t . Total corporate taxes are denoted by T_t . Taxes are proportional to corporate profits and embody a shield on corporate interest payments, as detailed in section 2.1, equation (2). We assume that the firm takes into account all tax margins implied by the tax code and knows the stochastic evolution of τ_t determined by the fiscal policies that we study in the next sections. The firm takes as given the evolution of productivity detailed in equation (4).

Optimal Investment and Financing Decisions. The optimal investment policy must satisfy the following Euler equation:

$$q_t = E_t \left[M_{t+1} \left\{ (1 - \tau_{t+1}) \frac{\partial Y_{t+1}}{\partial K_t} - \frac{\partial C_{t+1}^B}{\partial K_t} + q_{t+1} \left(1 - \delta - \frac{\phi'_{t+1} I_{t+1}}{K_t} + \phi_{t+1} \right) \right\} \right] - \frac{\partial C_t^E}{\partial K_t} \tag{9}$$

where $q_t \equiv \frac{1}{\phi'_t}$ and ϕ' denotes the first derivative of the investment adjustment cost function ϕ . Equation (9) differs from the optimality condition of Jermann (1998)'s in three respects. First, the firm cares about the after-tax marginal product of capital and is exposed to tax rate uncertainty. Second, the term $-\frac{\partial C_t^E}{\partial K_t}$ reflects the reduction in the distress costs, which is generated through additional capital. Third, the term $-\frac{\partial C_{t+1}^B}{\partial K_t}$ reflects the fact that each additional unit of capital also affects future borrowing costs by increasing output.

Turning our attention to capital structure, the following holds:

$$\frac{\partial C_t^B}{\partial B_t} + \frac{\partial C_t^E}{\partial B_t} = E_t [M_{t+1} \tau_{t+1}] r_{f,t}. \quad (10)$$

The left-hand side of this equation is related to marginal distress and debt adjustment costs (i.e., the marginal cost of debt). The right-hand side refers to the value of the tax advantage obtained with an extra unit of debt (the marginal benefit of debt). Further details of the firm's optimization are reported in Appendix B.

Market Clearing. Since we assume that all taxes are rebated lump-sum to the household, the market-clearing condition in the goods market is simply

$$Y_t = C_t + I_t - C_t^E - C_t^B. \quad (11)$$

Under our benchmark calibration, equilibrium financial costs are small:

$$E \left[\frac{C_t^E + C_t^B}{Y_t} \right] < .17\%,$$

and therefore C^E and C^B will play no direct relevant role in the determination of output composition.

3 Exogenous Tax Uncertainty

We begin the quantitative analysis of our model by focusing on the special case in which the government is committed to a zero-deficit policy. Since we always initialize the economy with zero public debt, $B_0^G = 0$, equation (3) implies that a zero-deficit policy requires the following:

$$\tau_t = \tau_t^* \quad \forall t. \quad (12)$$

For the purposes of this section, therefore, the corporate tax rate is a purely exogenous stochastic process. This case functions as a useful benchmark highlighting the basic features of our model. More realistic

Table 1: Calibrated Parameter Values

MODEL:		1	2	3
Key Elements				
Tax Uncertainty		YES	YES	NO
Growth Channel		YES	NO	NO
Zero-Deficit Tax Rate (τ_t^*)				
Constant	$\frac{1}{1+e^{-\mu\tau}}$	36.5%	36.5%	36.5%
Volatility	σ_τ	1.19%	1.19%	0
Long-run Risk Exposure	ϕ_τ	-0.05	0	0
Autocorrelation	ρ^4	0.980	0.980	-
COMMON PARAMETERS				
Preferences				
Discount Factor	β^4	0.983		
Risk Aversion	γ	10		
Intertemporal Elasticity of Substitution	ψ	2.0		
Technology				
Capital Share	α	0.33		
Depreciation Rate	δ	0.021		
Elasticity of Investment Adj. Costs	ξ	2		
Intensity of Debt Adj. Costs	ν	.4		
Debt-Book Ratio	η	33%		
Intensity of Distress Costs	ϕ_1	2000		
Productivity				
Average Productivity Growth	μ	.006		
Short-run Productivity Volatility	σ_ϵ	2.64%		

Notes - This table reports the parameter values used for our quarterly calibrations. The parameters in the top panel of the table refer to the process that determines taxation needs, τ_t^* , defined in equation (1). The parameters in the bottom panel of the table are common to all model specifications considered in the paper.

scenarios with time-varying public debt are addressed in section 4.

3.1 Calibration

In order to disentangle the different mechanisms at work in our economy, we focus on the results of three different model specifications reported in table 1. Model 1 is our benchmark. It features both short- and long-run productivity risk through the tax channel ($\phi_\tau < 0$). In model 2 we maintain stochastic tax fluctuations, but we shut down the growth channel by imposing the condition $\phi_\tau = 0$. A comparison of

model 1 and 2 allows us to quantify the relevance of tax uncertainty when taxes affect the average drift of equity payouts.

In model 3, we eliminate tax uncertainty ($\sigma_\tau = 0$) in order to study the implications of a constant corporate tax rate. In this model, therefore, both quantity and price dynamics are purely driven by *i.i.d.* Gaussian shocks to productivity.

The parameters of the zero-deficit tax rate, τ^* , are set to mimic US data on average corporate taxation, measured as in McGrattan and Prescott (2005). For more details, see Appendix A. We believe that average taxation is a better measure of corporate tax pressure than the stated marginal tax rate, as it captures multiple margins. Inflation, accelerated depreciation changes, unexpected variations in the tax shield on investment, and R&D expenditures all are important sources of variation in the effective real corporate tax rate, as pointed out in Backus, Henriksen, and Storesletten (2008). Modeling the average corporate tax rate as an AR(1) process is a parsimonious way to include all these margins in our asset pricing model. Our AR(1) process for taxes can alternatively be seen as a continuous version of a persistent Markov process with “high” and “low” marginal taxation regimes. Using a Gaussian AR(1) process is particularly advantageous because it allows us to solve our model using very standard approximation methods. The annual volatility of the average corporate tax rate (measured starting from 1948) is 6.3%. To be as conservative as possible, we target a much lower level of zero-deficit tax-rate volatility, specifically, about 2.1% (i.e., one-third of that in the data), and we also make sure that under the active tax smoothing policy this volatility does not exceed 3.2% (i.e., half of tax rate volatility measured in the data).

In order to calibrate the exposure of productivity to long-run tax rate uncertainty, ϕ_τ , we estimate equation (4) using US annual data for the post-World War II sample. All details are reported in Appendix A. We obtain a point estimate $\hat{\phi}_\tau = -0.058$ with a Newey-West adjusted standard error of 0.026. Our estimate is significant at a 4% confidence level and is consistent with Lee and Gordon (2005). Specifically, using panel data from a multi-country dataset, Lee and Gordon (2005) obtain an estimate of -0.05. Just to be conservative, we set $\phi_\tau = -0.05$ so that our results can be interpreted as a lower bound on the relevance of fiscal risk.

The preference and technology parameters are common across all specifications and are chosen in the

spirit of the long-run risk and real business cycle literatures (e.g., Bansal and Yaron (2004) and Kydland and Prescott (1982)). The investment adjustment cost elasticity, ξ , is set to a moderate level to avoid implausibly high adjustment costs. On average these costs are in the order of .15% of GDP. The leverage level, η , is consistent with US data, while the intensity of the debt adjustment costs, ν , is set to match the volatility of investment. We describe our solution method in Appendix B.

3.2 Taxation, Financing, and Investment

We begin our analysis by highlighting the basic implications of distortionary taxation for corporate financing and investment in our economy. Since the main intuition underlying these implications for corporate financing and investment can be explained even with a constant tax rate, in this subsection we focus only on model 3. We compare it to other model specifications that more closely resemble standard production-based asset pricing models by removing debt adjustment costs ($\nu = 0$) and financial leverage ($\eta = 0$). We consider the more general case with stochastic fluctuations in tax rates in the next subsection.

In figure 1 we show the impulse responses generated by model 3, the model without debt adjustment costs, and the model without financial leverage (the RBC model), respectively. The RBC model with recursive preferences presents all the major problems already documented in the literature, namely, low volatility of the equity risk premium, smooth investment, and volatile consumption. By comparing the RBC model to the model with financial leverage and no debt adjustment costs, we see that financial leverage alone produces slightly more volatile excess returns, but it does not significantly alter the quantity dynamics. Quantitatively, therefore, the RBC model with leverage is close to a model in which the Modigliani-Miller assumptions hold. This result is due to the ability of the firm to costlessly substitute debt for equity. Essentially, in this specification, the preferential tax treatment of debt acts as a pure subsidy to debt holders.

The results change significantly after the introduction of counter-cyclical debt adjustment costs in model 3. These costs eliminate the costless substitution between debt and equity and allow financing to have real effects. In good times, issuing more debt is cheaper and hence attractive. To avoid severe distress costs, all resources collected through the additional debt are used to increase the collateral

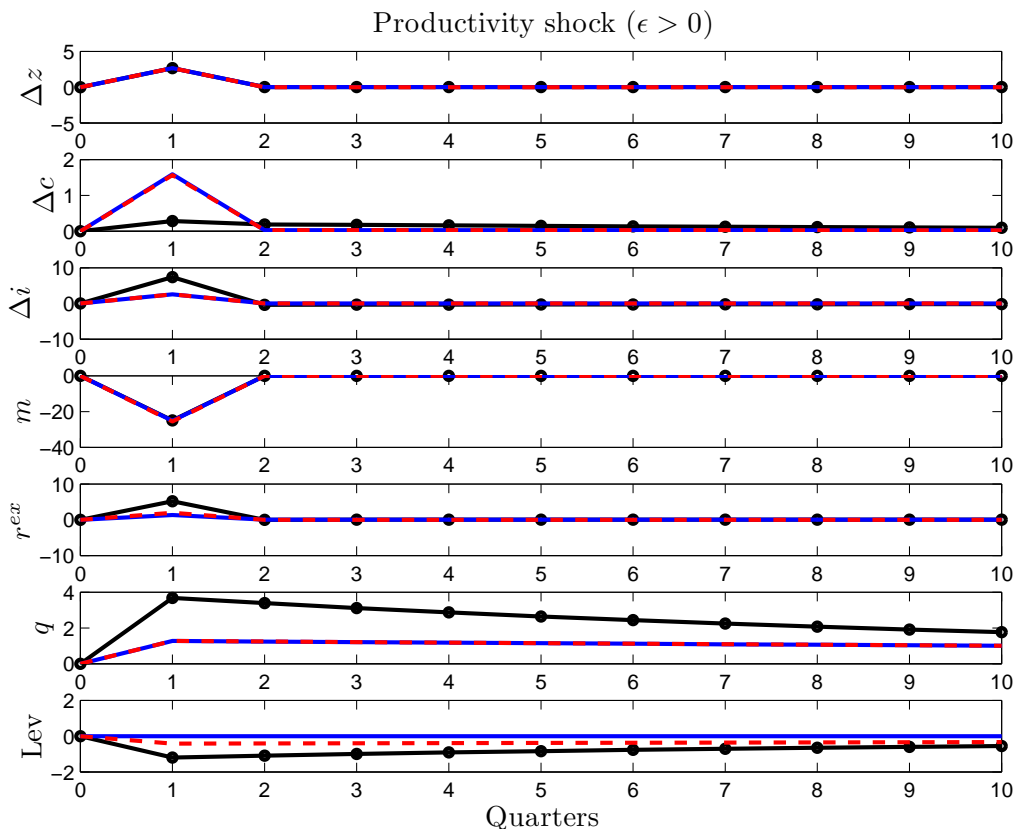


Fig. 1: Financial Frictions and Investment in Model 3.

Notes - This figure shows quarterly log-deviations from the steady-state multiplied by 100. In each panel, the line marked with circles refers to model 3, the solid line refers to the RBC model (model 3 with $\nu = \eta = 0$), and the dashed line refers to model 3 without debt adjustment costs ($\nu = 0$). All the parameters are calibrated to the values reported in table 1. We denote the value of debt and equity as B and P , respectively. We use q for the marginal value of capital; r^{ex} for the equity excess returns; m for the pricing kernel; Δi , Δc and Δz for the growth rate of investment, consumption, and productivity, respectively.

stock, K , through investment, I . It is well known that when the IES is high enough, even small capital adjustment costs are enough to discourage investment volatility. For the same reason, in our economy even a moderate amount of counter-cyclical debt adjustment cost is sufficient to generate an incentive to significantly adjust debt and ultimately investment. Thanks to both distress and debt adjustment costs, the response of investment to exogenous productivity shocks is much more intense than in the RBC model with recursive preferences.

Our mix of financial and real frictions, therefore, alleviates a longstanding problem of RBC models

with recursive utility and IES greater than one, by simultaneously producing more realistic dynamics for investment, equity payouts, and returns. As can be seen in table 2, the volatility of investment is seven times greater than the consumption volatility in model 3, consistent with the data. The high volatility of investment allows both equity payouts and the price of capital to be volatile and pushes the annualized volatility of equity excess returns to almost 10%. Although neither equity payouts nor excess returns are as volatile as in the data, we regard our results as very encouraging since, to the best of our knowledge, only Gomes, Kogan, and Yogo (2009) and Kuehn, Petrosky-Nadeau, and Zang (2011) obtain similar results in economies with recursive preferences and fixed capital stock. Ultimately, our model generates an equity premium of 4.24% and an implied equity Sharpe ratio reasonably close to its empirical counterpart.

Furthermore, under our debt adjustment cost function, the time-series properties of consumption growth are consistent with the data. Our results, therefore, are not driven by implausible consumption dynamics.

Finally, as seen in the bottom panel of figure 1, we show that after a positive productivity shock, the value of equity increases more than the value of corporate debt, making corporate leverage counter-cyclical, consistent with what documented among others by Korajczyk and Levy (2003) and Covas and DenHaan (2011).

3.3 The Role of Corporate Tax Uncertainty

In this section we turn our attention to the role of tax uncertainty. In figure 2, we plot impulse response functions for models 1 and 2. Because the corporate tax rate is stochastic, the figure shows two columns of plots. The plots on the right focus on an adverse tax shock, while those on the left refer to a negative short-run productivity shock, the opposite case from that shown in figure 1.² In models 1 and 2 the response to short-run productivity shocks is the mirror image of that seen in figure 1 for model 3. The responses to a tax shock merit special attention, as they raise several noteworthy points.

²Since in the next section we describe the main intuition of our tax-smoothing policy in reference to either bad productivity or fiscal shocks, we focus on adverse shocks in figure 2 as well. The impulse response functions (IRFs) produced by the model after positive productivity or tax shocks are the reverse of those shown in figure 2.

Table 2: Summary Statistics

	Data	Model 1	Model 2	Model 3
First Moments				
$E[I/Y]$	0.23	0.21	0.21	0.21
$E[r_f](\%)$	0.86	0.82	1.96	1.95
$E[r_d - r_f](\%)$	5.70	5.04	4.28	4.24
Second Moments				
$\sigma(\tau)$ (%)	6.21	2.31	2.30	0.00
$\sigma(\Delta i)/\sigma(\Delta c)$	6.95	6.70	6.97	7.07
$\sigma_{\Delta c}$ (%)	2.31	2.05	1.99	1.95
$ACF_1(\Delta c)$	0.44	0.18	0.19	0.19
$\sigma_{r_d - r_f}$ (%)	20.14	9.67	9.70	9.64
σ_{Lev} (%)	8.65	2.65	2.65	2.57
$\sigma(\text{NEPO/Profits})$ (%)	63.50	28.25	31.15	28.97
σ_{r_f} (%)	1.35	0.22	0.22	0.21

Notes - All models are calibrated as in table 1 at a quarterly frequency. All entries for the models are obtained from 1,000 repetitions of short-sample simulations (320 periods, equivalent to 80 years). All figures are annualized. Our sample period is 1930 to 2008. Output is measured as $Y = C + I$. NEPO stands for net equity payout. Details about our data are reported in Appendix A.

Response of investment. Although small, tax shocks are very persistent, and for this reason they have significant effects on both quantities and prices.³ On the one hand, a negative tax shock produces an incentive to invest less as after-tax profits persistently decrease (substitution effect). This effect is amplified when higher taxes depress productivity growth over the long horizon (model 1). On the other hand, an increase in the tax rate causes the household to feel poorer and generates an incentive to decrease consumption (income effect). As in Croce (2006), when the intertemporal elasticity of substitution is calibrated above one, the substitution effect dominates. This implies that the representative investor finds it beneficial to invest less when the corporate tax rate increases, consistent with the empirical evidence in Leeper, Plante, and Traum (2010). In our model, therefore, when the tax rate rises, the demand of capital decreases, causing a strong decline in the price of capital. As shown in the bottom three panels of figure 2 (right column), small adverse tax shocks produce significant negative adjustments in price of capital, excess returns, and capital structure.

³Under our benchmark calibration, the impact of tax shocks on the productivity growth rate is quite small ($\phi_\tau \sigma_\tau \approx 2.2\% \sigma_\epsilon$); hence, our results are not driven by implausibly high long-run productivity risk.

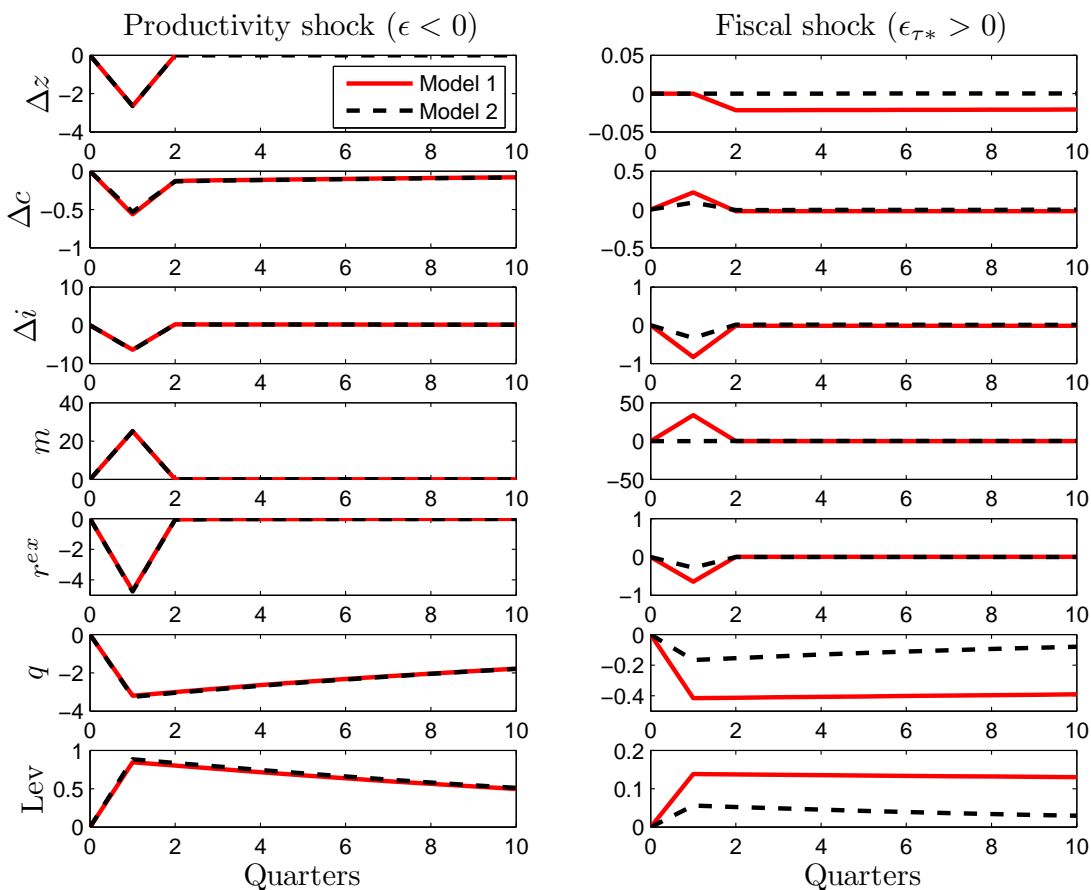


Fig. 2: Prices and Quantities in Models 1 and 2.

Notes - This figure shows quarterly log deviations from the steady state multiplied by 100. In each panel, the solid (dashed) line refers to model 1 (model 2). The panels in the left column show responses to a negative short-run productivity shock. The plots to the right refer to a negative tax shock. Parameters values are reported in table 1. Variables are the same as those described in figure 1.

Response of the pricing kernel when $\phi_\tau = 0$. Turning our attention to table 2, we can see that models 2 and 3 generate very similar average equity premia. As shown in the fourth panel of figure 2, right column, this is because tax shocks do not generate significant adjustments in the log stochastic discount factor, m . A persistent increase in the tax rate produces bad news for long-run consumption and hence an increase in marginal utility. However, by the substitution effect, short-run consumption increases and the marginal utility tends to decrease. At the equilibrium, the final adjustment of the pricing kernel is negligible. When the growth channel is ignored ($\phi_\tau = 0$), therefore, tax shocks produce sizeable endogenous long-run fluctuations in dividend growth—reflected in the persistent dynamics of the

value of capital, q —that at the equilibrium effectively carry a zero risk-premium.

Response of the pricing kernel when $\phi_\tau < 0$. When adverse tax shocks have a negative impact on long-run productivity growth ($\phi_\tau < 0$), they introduce a significant and persistent decline in expected consumption growth. With Epstein and Zin (1989) utility, our household is very averse to such expected consumption adjustments, as reflected by the significant move of the stochastic discount factor. This explains why in model 1 an adverse tax shock (bad news for long-run productivity) produces such a strong increase in the marginal utility of the representative investor and a greater decline in the equity excess return (figure 2, fourth and fifth panels, right column).

The equity premium generated by model 1 is 5.04%, about 0.8% higher than in model 2 (see table 2). The risk-free rate, in contrast, is about 1% lower because of the additional precautionary saving motives generated by tax uncertainty. This variation in the composition of the equity returns shows that tax uncertainty can substantially increase risk premia and alter capital accumulation decisions. In our economy, therefore, small news about future taxes and productivity can have large and persistent effects on quantities and prices.

In figure 3 we report the effect of a permanent change in the average level of corporate taxation, μ_τ , on the cost of equity.⁴ Across all models considered so far, corporate taxation substantially depresses capital accumulation (top left panel) and investment (top right panel). Because of decreasing marginal returns to capital, this implies an increase in the average return on capital. In model 3, where the tax rate is constant and known with certainty, the increase in the capital return appears as an increase in the cost of equity (bottom right panel), while the pretax cost of debt remains the same (bottom left panel). Average corporate taxation alone, therefore, strongly affects the cost of equity, consistent with the findings of Gomes, Michaelides, and Polkovnichenko (2009) in the context of a model with heterogenous agents and incomplete markets.

Comparing models 1 and 3 (bottom two panels, figure 3), we see that when the growth channel is active, tax uncertainty plays an important role in the determination of the subcomponents of the cost

⁴In most of the panels, the dotted line that we use for model 3 is not visible because it coincides with the dashed line used for model 2. Consistent with our previous findings, therefore, models 2 and 3 produce similar results.

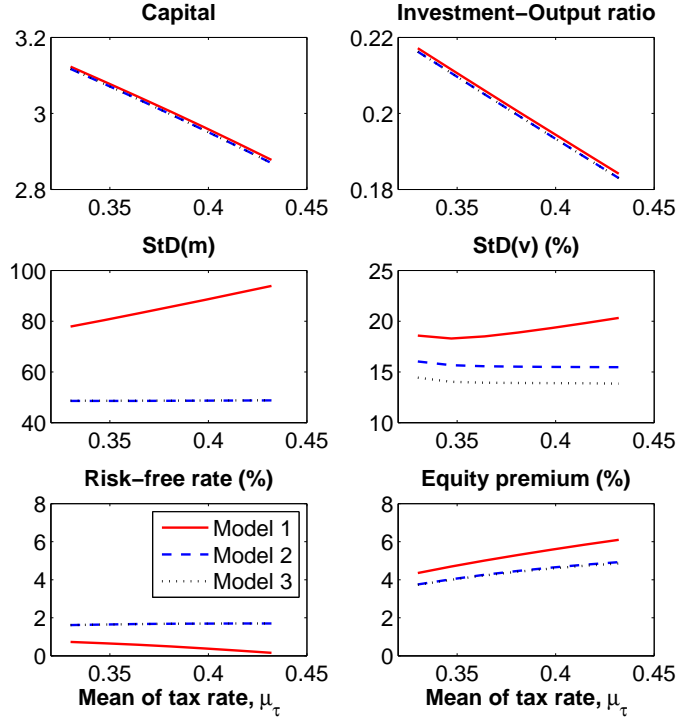


Fig. 3: Average Taxation, Investment, and Cost of Capital

Notes - The top two panels show the capital-productivity ratios (left panel) and investment-output ratios for different levels of average taxation in models 1–3. The plots in the middle row show the volatility of the log stochastic discount factor (left panel) and the value of the firm (right panel). The bottom panels focus on pretax cost of debt (left) and the equity premium. All parameters are calibrated as in table 1, except for μ_τ , which is allowed to vary.

of capital. In particular, the link between average tax rate and equity premium changes in at least two significant dimensions.

First, we observe that tax-driven productivity uncertainty can add 20–200 basis points to the cost of equity. This jump in the equity premium is explained by the simultaneous increase in the volatility of the stochastic discount factor (middle row, left panel) and the cum-dividend value of the firm (middle row, right panel) caused by long-run productivity risk. The additional long-run growth risk related to tax dynamics basically shifts the demand of assets toward riskless bonds, causing the cost of debt (bottom left panel) to decline and the cost of equity to increase for every possible μ_τ .

Second, when long-horizon productivity is affected by tax uncertainty, even a small increase in the average taxation level can produce a substantial run-up in the cost of equity. This is because as the average

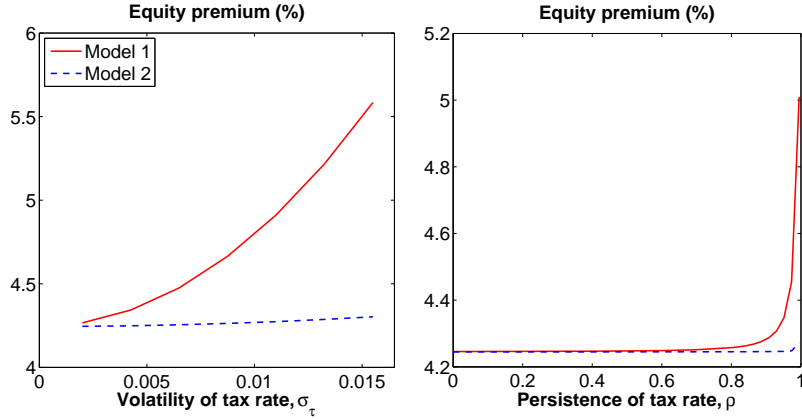


Fig. 4: Cost of Equity and Tax Rate Volatility and Persistence

Notes - This figure shows the annualized equity premia produced by model 1 and 2 as a function of the tax rate volatility. All parameters are calibrated as in table 1, except for σ_τ , which is allowed to vary in the left panel, and for ρ , which is allowed to vary in the right panel.

tax rate increases, the optimal level of accumulated capital falls, in turn reducing average investment and therefore the ability to hedge exogenous shocks. In an economy in which taxes generate long-run uncertainty, such a reduction in the consumption smoothing possibilities strongly penalizes equity value.

These results suggest that tax uncertainty should be a first-order concern in the current fiscal policy context, as uncertainty can actually amplify the effect of average tax pressure. To further highlight this point, in the left panel of figure 4 we show the equity premium in models 1 and 2 when the average taxation level is fixed at its benchmark level of 36.5% and tax volatility, σ_τ , is allowed to vary. When the volatility of the tax rate is low, the equity premia produced by both models 1 and 2 converges to 4.28%, the level obtained in model 3 with a constant tax rate. When taxes do not directly affect long-run productivity growth (model 2), tax rate volatility alters the cost of equity only marginally. However, when taxes affect growth (model 1), even a marginal increase in the volatility of the tax rate can produce a substantial rise in the cost of equity. In the right panel of figure 4, we let the persistence of the tax rate, ρ , vary while fixing all other parameters. This graph shows that as long as ρ is sufficiently high, our small but persistent tax-based growth risk factor produces relevant effects on the cost of capital.

4 Public Debt and Endogenous Tax Uncertainty

In the previous section, we focused on a tax process, τ , that perfectly mimics the properties of an exogenously specified expenditure process, τ^* . In this section, we now let the tax rate differ from τ^* by allowing the government to accumulate public debt and thus reallocate taxation over time. We can therefore examine to what extent such tax-smoothing reduces or amplifies the cost of equity.

As shown in Leeper, Plante, and Traum (2010), there are several ways to specify tax smoothing behavior. One of the main technical problems with using an exogenous tax smoothing rule is the need to guarantee stationarity of the debt-output ratio in order to rule out “unsustainable” public debt paths. One possible way to solve this problem is to define the public financing rule directly:

$$\frac{B_t^G}{Y_t} = \rho_G \frac{B_{t-1}^G}{Y_{t-1}} + \phi_G \cdot \epsilon_t^G, \quad (13)$$

where ϵ_t^G is a stationary variable summarizing the state of the economy and $\rho_G \in (0, 1)$ is a measure of the speed of repayment of debt, i.e., the higher the value of ρ_G , the slower the repayment of debt relative to output. The fact that $\rho_G < 1$ guarantees stability of the debt-output ratio.⁵ It is possible to show that there is a positive monotonic mapping between ρ_G and the persistence of the tax rate process determined by equations (1)–(2) and (13). Choosing a higher ρ_G is equivalent to increasing the degree of tax smoothing.

The parameter $\phi_G > 0$ measures the intensity of the government’s fiscal response to changes in the state of the economy, ϵ_t^G . In our analysis we consider two different specifications for ϵ_t^G . We first focus on the case in which the government responds to short-run consumption growth:

$$\epsilon_t^G \equiv \Delta c_t - \mu. \quad (14)$$

This policy rule captures the behavior of a government that reduces current corporate taxes every time

⁵In economies with standard time-additive preferences, the debt-output ratio tends not to be stationary because the risk-free rate puzzle makes $E[(1 + r_{f,t-1})/\exp(\Delta y_t)] > 1$. In our economy, however, at the stochastic steady-state, $E[(1 + r_{f,t-1})/\exp(\Delta y_t)] < 1$. Intuitively, the high growth rate of output dominates on the low risk-free rate.

the economy is affected by a positive shock to consumption growth. By decreasing corporate taxes, the government attempts to stimulate a reallocation of resources toward investment in order to smooth consumption growth and keep it close to its unconditional average, μ .⁶

In a second step, we highlight the relevance of tax policies aimed to stabilize the long-run dynamics of consumption:

$$\epsilon_t^G \equiv \mu - E_t[\Delta c_{t+1}]. \quad (15)$$

The properties of the corporate tax rate, therefore, are now endogenously pinned down by our public debt policy. In what follows we first show that a tax smoothing policy aimed at stabilizing short-run consumption growth can produce substantial welfare costs. We then show that a tax-smoothing policy stabilizing long-run consumption dynamics can generate, in contrast, significant welfare benefits. The main goal of this section is to illustrate that in a model with recursive preferences built to replicate several asset price features, welfare-enhancing tax smoothing is quite different from that normally obtained in the macroeconomic-RBC literature.

4.1 Short-run consumption growth tax smoothing

Equations (13) and (14) jointly imply the following debt policy:

$$\frac{B_t^G}{Y_t} = \rho_G \frac{B_{t-1}^G}{Y_{t-1}} + \phi_G \cdot (\Delta c_t - \mu).$$

To explain what this public financing policy does, in figure 5 we show the response of tax rate, consumption, and investment growth after an adverse shock to productivity (top panels) and to expenditure (bottom panels). The intensity of the active policy, ϕ_G , is set to 0.3 to ensure that the implied annualized

⁶In principle, tax smoothing and debt sustainability could be enforced by a fiscal rule of this kind:

$$\tau_t = \phi_1^G \tau_t^* + \phi_2^G (\mu - E_t[\Delta y_{t+1}]) + \phi_3^G \frac{B_{t-1}^G}{Y_{t-1}},$$

in which $\phi_1^G \in (0, 1)$ defines the intensity of smoothing with respect to expenditure shocks, ϕ_2^G defines the countercyclicality of the tax policy, and $\phi_3^G > 0$ captures repayment attitude. While this policy specification might appear easier at first sight, we find it less parsimonious as it requires us to examine the role of three parameters, instead of simply two. It is also more opaque in regard to the cross-parameter restrictions required to guarantee a stationary debt-output ratio.

volatility of the tax rate does not exceed 3.1%, i.e., half of the observed standard deviation of the average corporate tax rate. We set the parameter ρ_G initially to 0.98 to replicate the persistence of the public debt-output ratio observed in the US data (see Appendix A.), we then allow this parameter to vary in order to alter the persistence of the corporate tax rate. All other parameters are calibrated as in model 1. We let Δc^{ZD} and Δi^{ZD} denote consumption and investment growth, respectively, under the zero-deficit policy adopted for model 1 in the previous section.

Adverse productivity shock. Under the zero-deficit policy an adverse productivity shock produces a decline in consumption growth (top middle panel) both on impact (time 1) and in subsequent periods, leaving the tax rate constant. Thus, in the top-left panel of figure 5, the solid line is flat. Under the active short-run tax-smoothing policy, however, the government actually increases the corporate tax rate in order to discourage the demand for new capital (top right panel of figure 5) and allow more resources to be allocated toward private consumption. The top middle panel of figure 5 shows that the government is indeed able to mitigate the immediate drop in consumption growth (at time 1, $\Delta c_t - \Delta c_t^{ZD} > 0$), but at the cost of actually depressing further long-run consumption growth, or equivalently, the recovery speed. This long-run effect occurs because the short-run stabilization of consumption is obtained through a more severe decline in investment and, ultimately, a slower process of capital accumulation. Thus, this policy reduces short-run volatility of consumption, i.e., $\text{StD}_t(\Delta c_{t+1})$, at the cost of amplifying long-run volatility, i.e., $\text{StD}(E_t[\Delta c_{t+1}])$.

Adverse fiscal shock. The bottom left panel of figure 5 compares the dynamic behavior of the tax rate under the active policy against the tax rate required to perfectly balance the public budget. Under our specification, at time 1 the government increases the tax rate less than required to fully finance current expenditure, consistent with tax-smoothing behavior. This comes at the cost, however, of having to increase taxation further later on to pay back the accumulated debt. Given the moderate size of our fiscal shocks, these tax fluctuations are actually small and produce less severe adjustments in the dynamics of consumption and investment. Nevertheless, after the moderate increase in taxes prescribed by the smoothing policy, private investment increases less than it would under the zero-deficit policy.

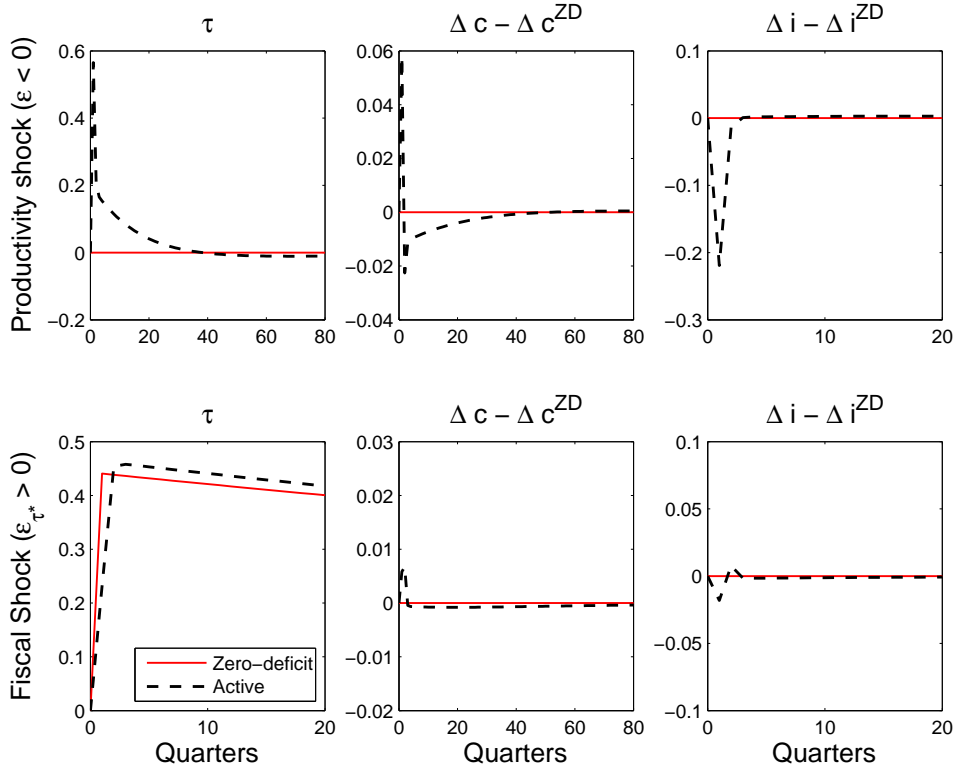


Fig. 5: Short-Run Tax Smoothing at Work

Notes - This figure shows corporate tax rate, consumption, and investment growth responses to an adverse shock to productivity (top panels) and to government expenditure (bottom panels). In each panel, the solid line refers to model 1 under the zero-deficit policy obtained by setting $\phi_G = 0$ in equation (13). The dashed line refers to the model with active tax smoothing aimed to stabilize short-run consumption growth, as determined by equations (13) and (14). In this case, we set $\phi_G = 0.3$ in equation (13) and let all other parameters be calibrated as in model 1 (see table 1). We let Δc^{ZD} and Δi^{ZD} denote consumption and investment growth, respectively, under the zero-deficit policy adopted for model 1.

Although this might appear counterintuitive at first, note that such tax smoothing comes at the cost of persistent increases in future taxation and reductions in future growth over the long horizon. At the equilibrium, the representative firm actually has less incentive to invest and accumulate capital. With respect to expenditure shocks, therefore, the active financing policy is not capable of smoothing investment and consumption volatility over the long run.

Implications for cost of equity and welfare. In the middle row panels of figure 6 we report key moments of the distribution of consumption under the zero-deficit and the active policy considered so far, for different values of speed of debt repayment, ρ_G . In the spirit of the long-run risk literature, we

report short-run volatility of consumption growth, $\text{StD}_t(\Delta c_{t+1})$; the persistence of the conditional mean of consumption growth, $\text{ACF}_1(E_t[\Delta c_{t+1}])$, and the volatility of the long-run component in consumption, $\text{StD}(E_t[\Delta c_{t+1}])$.⁷ The solid line is flat in all panels because in our zero-deficit economy there is no debt and therefore the speed of repayment does not matter. The dashed line shows the effects of our fiscal policy parameters $\{\rho_G, \phi_G\}$ on the endogenous distribution of consumption.

As anticipated by the analysis of the impulse response functions of the model, a tax-smoothing policy aimed to stabilize short-run consumption volatility amplifies both the consumption volatility in the long run (middle right panel), and the investment volatility at all horizons (bottom row of plots). This effect is intensified by higher levels of debt persistence, implying that a government prone to repay debt at a very slow pace ends up stabilizing short-run consumption variations only by making them more and more long-lasting (higher $\text{ACF}_1(E_t[\Delta c_{t+1}])$). Our representative consumer, however, dislikes persistent sources of uncertainty and attaches to them a high market price of risk. Consistent with Bansal and Yaron (2004), in our economy the annualized returns of the consumption and equity claims are mainly driven by long-run dynamics. For this reason, their risk premia increase by 40 and 8 basis points, respectively, even though short-run consumption volatility is lower under the active public financing policy.

Using Lucas (1987) computations, we are able to map this change in risk premia into the percentage of lifetime consumption that the agent would be willing to give up to in order to live in an economy without this sort of tax smoothing.⁸ As shown in the top right panel of figure 6, short-run tax smoothing can generate substantial welfare costs, on the order of 5%. Furthermore, these costs are increasing in ρ_G , suggesting that the slow repayment of public debt (or equivalently, persistent tax adjustments) increases

⁷To be precise, we plot $E[\text{StD}_t(\Delta c_t)]$, i.e., the average conditional volatility of consumption growth. Since in the model the variation of the conditional second moment is negligible, we do not stress it in the figures. In order to better link our results to the asset pricing investigation of Bansal and Yaron (2004) and the welfare analysis of Croce (2006), we recall their exogenous consumption process:

$$\begin{aligned}\Delta c_{t+1} &= \mu + x_t + \sigma_c \epsilon_{c,t+1} \\ x_t &= \rho_x x_{t-1} + \sigma_x \epsilon_{x,t+1} \\ [\epsilon_{c,t+1}, \epsilon_{x,t+1}] &\sim i.i.d.N(0, I_2).\end{aligned}$$

What we denote as $\text{StD}_t(\Delta c_{t+1})$ is the equivalent of σ_c , the amount of short-run risk. $\text{ACF}_1(E_t[\Delta c_{t+1}])$ is our measure of ρ_x , and $\text{StD}(E_t[\Delta c_{t+1}])$ is the volatility of the long-run component x_t .

⁸We describe in detail our welfare cost computations in Appendix B. Here we point out that our welfare analysis compares steady states of different fiscal regimes and abstracts from transition dynamics.

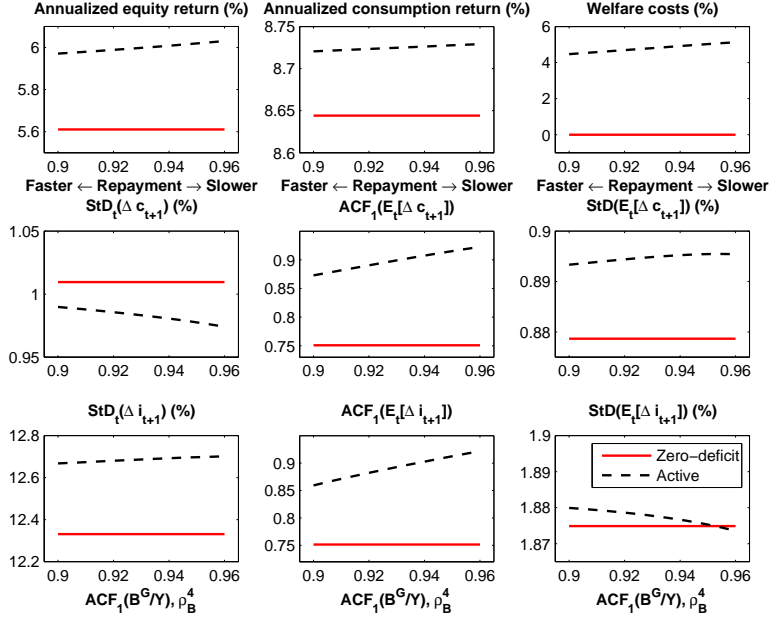


Fig. 6: The Costs of Short-Run Tax Smoothing

Notes - In each panel, the solid line refers to model 1 under the zero-deficit policy obtained by setting $\phi_G = 0$ in equation (13). The dashed line refers to the model with active tax smoothing aimed to stabilize short-run consumption growth, as determined by equations (13) and (14). In this latter case, we set $\phi_G = .3$ in equation (13) and calibrate all other parameters as in model 1 (see table 1). All moments are obtained through quarterly simulations and are annualized.

the cost of the fiscal intervention. Since we abstract from relevant sources of potential benefits of government intervention (such as, e.g., productive public investment or reduction of long-run unemployment), our welfare results should not be interpreted as discouraging any sort of public intervention. This analysis simply suggests that common tax-smoothing and debt financing policies can generate long-run swings in productivity and private investment that are quite costly when the agent cares about the timing of resolution of tax uncertainty.⁹ Since the alteration of consumption uncertainty introduced by tax smoothing can be sizeable, it should be explicitly considered in fiscal policy design. In the next section, we show that a tax-smoothing scheme aimed at stabilizing long-run consumption growth, $E_t[\Delta c_{t+1}]$, instead of short-run consumption growth, Δc_{t+1} , can actually significantly enhance welfare.

⁹Since in our model public debt is on average zero and there is no government expenditure waste, our results are not driven by crowding-out effects. Our experiment isolates the pure redistribution of intertemporal consumption risk generated by corporate tax smoothing.

4.2 Long-run consumption growth tax smoothing

Altering taxes to smooth $E_t[\Delta c_{t+1}]$. In this section we focus on a financing policy of government expenditure aimed at stabilizing long-horizon consumption dynamics measured by $E_t[\Delta c_{t+1}]$:

$$\frac{B_t^G}{Y_t} = \rho_G \frac{B_{t-1}^G}{Y_{t-1}} + \phi_G \cdot (\mu - E_t[\Delta c_{t+1}]).$$

Under this fiscal rule, the government increases public debt whenever expected consumption growth is below its unconditional average. The implied tax rate dynamics are depicted in figure 7. When an adverse productivity shock materializes, expected consumption growth drops below steady-state and the government reduces taxes to stimulate investment. While this stimulus allows consumption growth to fall even further in the first period than under the zero-deficit policy, the implied faster accumulation of capital actually improves the recovery speed of consumption over the subsequent periods. This policy, therefore, is effective in reducing long-run consumption growth risk by stabilizing investment growth and capital accumulation after productivity shocks.

When an adverse expenditure shock materializes, the government smooth taxes in the first period, but with a much lesser intensity than that seen in the previous section. This strategy allows the government to keep the corporate tax rate below the zero-deficit level over a much longer horizon. By doing so, the government mitigates the long-run negative effects of corporate taxation on productivity growth and stimulates investment and capital accumulation (bottom right panel). Thus, in this case also, this policy promotes fast long-run capital accumulation exactly when needed the most.

Welfare Benefits. As documented in the bottom row of plots depicted in figure 8, this policy is able to stabilize investment growth, and therefore capital accumulation, in both the short- and long-run. Although this financing scheme increases short-run consumption volatility, it also results in a strong stabilization of long-run consumption risk. Such stabilization can reduce the cost of equity up to 15 basis points, equivalent to welfare benefits on the order of 2.5%. Note that our previous intuition on the speed of repayment of debt continues to hold: when the government does not repay debt fast enough, it effectively makes the consumption shocks last longer and reduces the welfare benefits. Overall, this

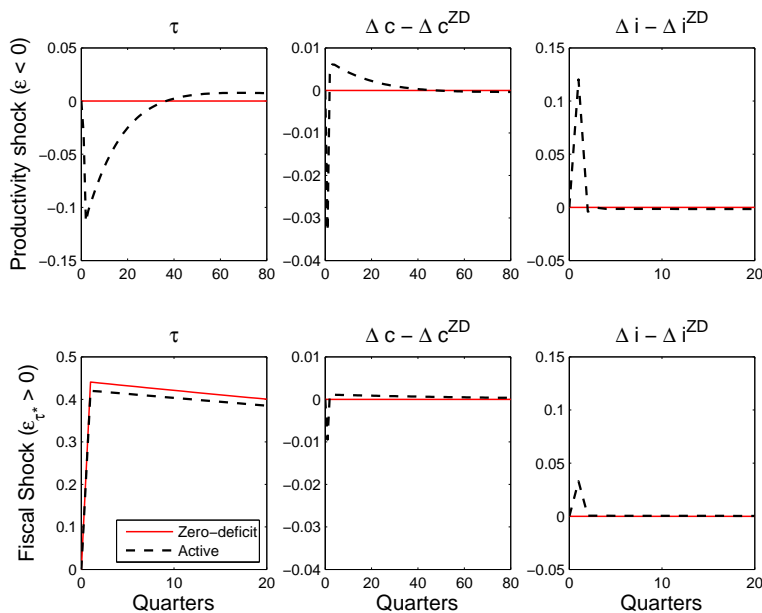


Fig. 7: Long-Run Tax Smoothing at Work

Notes - This figure shows corporate tax rate, consumption, and investment growth response to an adverse shock to productivity (top panels) and to government expenditure (bottom panels). In each panel, the solid line refers to model 1 under the zero-deficit policy obtained by setting $\phi_G = 0$ in equation (13). The dashed line refers to the model with active tax smoothing aimed to stabilize long-run consumption growth, as determined by equations (13) and (15). In this latter case, we set $\phi_G = 0.3$ in equation (13) and calibrate all the other parameters as in model 1 (see table 1). We let Δc^{ZD} and Δi^{ZD} denote consumption and investment growth, respectively, under the zero-deficit policy adopted for model 1.

simple policy shows that corporate taxation and the way in which is altered over time can have very significant impacts on asset prices and welfare.

At a broader level, these results show that the current fiscal debate should focus not only on average tax pressure on corporations, but also on the way in which the government intends to vary corporate tax rates over time and across different future states of the world. Equity market participants disliking long-run uncertainty would benefit from corporate tax policies able to stabilize long-run capital accumulation even at the cost of more severe short-run consumption fluctuations.

4.3 Asset Prices and Welfare

In the previous sections we have documented tight links between risk-premia and welfare across our fiscal policy specifications. Here we analyze to which extent our welfare implications change when the

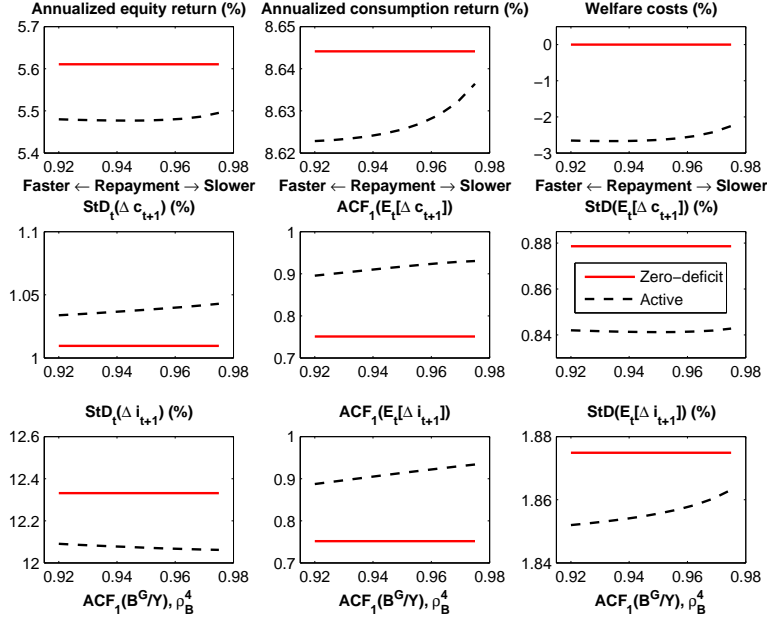


Fig. 8: The Benefits of Long-Run Tax Smoothing

Notes - In each panel, the solid line refers to model 1 under the zero-deficit policy obtained by setting $\phi_G = 0$ in equation (13). The dashed line, instead, refers to the model with active tax smoothing aimed to stabilize long-run consumption growth, as determined by equation (13) and (15). In this case, we set $\phi_G = .3$ in equation (13) and let all other parameters be calibrated as in model 1 (see table 1). All moments are obtained through quarterly simulations and are annualized.

information encoded in asset prices is neglected.

The ability of our model to account for basic asset price data relies on two main channels: (i) a preference for early resolution of uncertainty in conjunction with tax-induced long-run consumption risk, and (ii) tax-driven corporate leverage. In what follows, we show that removing either of these two channels can significantly alter our welfare results on corporate tax smoothing.

Role of preferences. The top panels of figure 9 illustrate the role of preferences by describing the welfare costs and benefits that our tax-smoothing policies could produce in an economy with standard time-additive preferences (in the spirit of Sialm (2006)). The left panel refers to the policy designed to reduce the volatility of consumption over the long horizon, as stated by equations (13) and (15). If we assume that our household has no preference for the timing of resolution of uncertainty, this tax-smoothing strategy becomes undesirable with respect to a simple zero-deficit fiscal rule: with time-

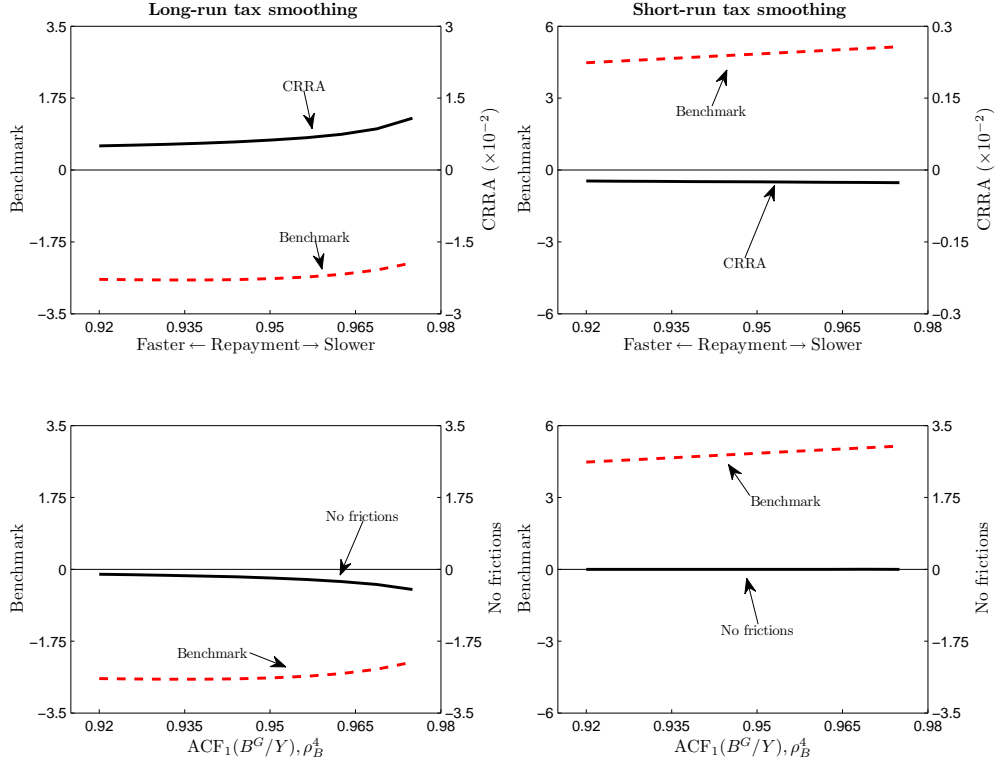


Fig. 9: Welfare Costs, Preferences and Frictions

Notes - This figure shows the welfare costs (benefits) achievable when either the representative household has time additive CRRA preferences (top panels), or all financial frictions are removed (bottom two panels). Our benchmark is model 1. For the CRRA case, all parameters are calibrated as in model 1, except the IES that is set to 0.1, so that $\gamma = 1/\psi = 10$. In the model with no frictions, we set $\nu = \eta = 1/\xi = 0$. The left panels refer to a tax smoothing scheme aimed at stabilizing long-run consumption growth, equation (13) and (15). The right panels refer to the tax smoothing policy that stabilizes capital accumulation and long-run consumption growth, equation (13) and (14). The intensity of the tax policy, ϕ_G , is set to 0.3 in all cases.

additive preferences, the agent simply does not care about the implied stabilization of the long-horizon growth of consumption. In this economy, only the higher volatility of short-run consumption growth matters for welfare.

For the same reason, the tax-smoothing policy aimed at stabilizing short-run consumption growth, as stated by equations (13) and (14), is now able to produce benefits (top right panel, figure 9). These results suggests that choosing preferences that are inconsistent with asset pricing could completely overturn our fiscal policy assessments.

Table 3: Summary Statistics for the Model with No Frictions

	Data	Model 1	Model 2	Model 3
First Moments				
$E[I/Y]$	0.23	0.22	0.21	0.21
$E[r_f]$	0.86	1.78	2.26	2.26
$E[r_d - r_f]$	5.70	0.12	0.08	0.08
Second Moments				
$\sigma_{\Delta c}$ (%)	2.31	2.07	2.12	1.92
$\sigma(\Delta i)/\sigma(\Delta c)$	6.95	6.48	6.05	6.29
$\rho_{\Delta c, \Delta i}$	0.44	0.71	0.64	0.92
σ_{r_f} (%)	1.35	0.13	0.13	0.12
$\sigma_{r_d - r_f}$ (%)	20.14	0.05	0.05	0.05
$\rho_{\Delta c, r_d - r_f}$	0.22	0.78	0.71	0.99
$\sigma(\tau)$ (%)	6.21	2.31	2.31	0.00
$ACF_1(\Delta c)$	0.44	0.16	0.13	0.16

Notes - All models are calibrated at a quarterly frequency. The parameters are set as in table 1, except for the following restriction: $\nu = \eta = 1/\xi = 0$. All entries for the models are obtained from 1,000 repetitions of short-sample simulations (320 periods, equivalent to 80 years). All figures are annualized. Our sample period is 1930 to 2008. Output is measured as $Y = C + I$. Details about our data are reported in Appendix A.

Role of frictions. The two bottom panels of figure 9 illustrate the welfare implications of fiscal policies in economies with and without financial frictions. The model without financial frictions abstracts from any preferential tax treatment of corporate debt so that corporations are optimally unlevered. This specification differs from the RBC one mentioned in our section 3 because we further remove adjustment costs to replicate the volatility of investment and consumption observed in the data. As shown in table 3, this frictionless model produces quantity dynamics in line with our model 1, but fails on the asset pricing side. Specifically, excess returns are tiny and have minimal volatility.

The asset pricing implications of this specification are again key to understanding the welfare assessments of fiscal policy objectives. While qualitatively the welfare implications are similar to those obtained in model 1, quantitatively they differ sharply. The intuition is simple: since the model is not able to produce any relevant amount of risk for unlevered returns, the impact of tax shocks is negligible as well. In our model with financial frictions, instead, levered returns are significantly exposed to aggregate risk and capital accumulation is very sensitive to long-run tax dynamics. Accounting for financial frictions thus

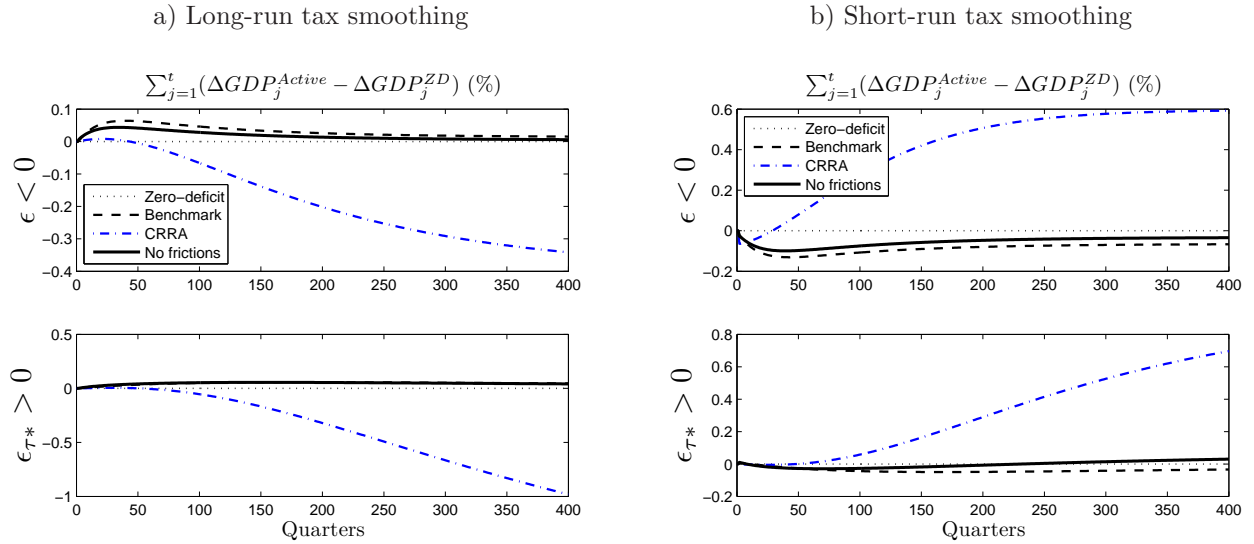


Fig. 10: Cumulative GDP gains/losses

Notes - This figure shows the response of the cumulative output growth gap between tax-smoothing policies and the zero-deficit policy to adverse productivity (top panels) and expenditure (bottom panels) shocks. Our benchmark is model 1. For the CRRA case, all parameters are calibrated as in model 1, except the IES that is set to 0.1, so that $\gamma = 1/\psi = 10$. In the model with no frictions, we set $\nu = \eta = 1/\xi = 0$. The left panels refer to a tax smoothing scheme aimed at stabilizing long-run consumption growth, equation (13) and (15). The right panels refer to the tax smoothing policy that stabilizes capital accumulation and long-run consumption growth, equation (13) and (14). The intensity of the tax policy, ϕ_G , is set to 0.3 in all cases.

allows the model to generate realistic asset price movements that entail more reliable policy assessments.

Asset prices, growth and fiscal policy design. Our welfare results can be recast in terms of long-run growth. In figure 10, we depict cumulative output growth gap between an economy with a zero-deficit policy and one with active tax smoothing. When the cumulative growth gap is positive, the active policy is generating growth benefits with respect to the zero-deficit case. In each panel, we depict the impulse responses generated by model 1, the model with CRRA preferences, and the model featuring no frictions. This figure shows three important results. First, while all these models produce very similar implications for output growth over the short-horizon, over the long-run that they differ substantially. Second, as in the case of the welfare analysis, the long-run growth implications of model 1 are overturned when focusing on CRRA preferences. Finally, the milder welfare costs (benefits) obtained in the model without frictions are the result of the milder response of capital accumulation and hence output over the long-run.

Taken together, figures 6, 8, 10 and 9 show the relevance of including asset pricing considerations in the current policy context. Asset prices dictate and discipline our calibration of preferences and financial frictions, i.e., the two main drivers of our welfare results. A model that abstracts from either financial frictions or preference for early resolution of uncertainty, even though able to replicate short-run quantity dynamics, may substantially misspecify the role of tax-based long-run growth risk.

5 Conclusion

The surge in public debt associated with the fiscal stabilization policies implemented in response to the financial crisis has raised uncertainty about future tax pressure and its potential effects on economic activity. In this paper, we examine the effects of tax shocks and fiscal stabilization policies on important aspects of economic activity, namely, asset prices and capital accumulation. We propose a production-based general equilibrium asset pricing model with recursive preferences in which fiscal policies affect corporate investment and financing decisions through corporate taxes.

We document three significant results. First, in settings with constant tax rates, tax distortions can have severely negative effects on the cost of equity and investment. Second, in our equilibrium model, tax risk generated by exogenous shocks to government liabilities produces first-order effects on capital accumulation. Specifically, high tax uncertainty has a negative impact on capital accumulation that is as severe as that of high average taxation. Third, corporate tax smoothing affects the intertemporal distribution of consumption risk and welfare. While this last effect can be dismissed with standard time-additive preferences, it is of paramount importance in our setting with recursive preferences. When the agent prefers early resolution of uncertainty, tax smoothing policies aimed at short-run consumption stabilization increase the cost of equity and result in welfare losses. Public financing policies aimed at stabilizing capital accumulation, in contrast, reduce both long-run consumption risk and the cost of capital, ultimately producing relevant welfare benefits.

More broadly, these results highlight the relevance of risk and asset pricing considerations in the current fiscal policy debate. Future research should incorporate sovereign default risk considerations (see for example, Laubach (2011) and Li and Leeper (2010)) and explore the relevance of credit shocks as in

Jermann and Quadrini (2011). It will also be important to explore optimal fiscal policy in our setting using the techniques developed in Karantounias (2011).

Appendix A. Data.

Macroeconomic quantities and tax rate. Data for real annual consumption, investment, corporate profits, and corporate taxes are from the Bureau of Economic Analysis (BEA). Output is computed as the sum of consumption and investment; government expenditures and net exports are excluded. Following McGrattan and Prescott (2005), the aggregate corporate tax rate is computed as the ratio of taxes on corporate profits to corporate profits before taxes. The sample period comprises the years 1929 to 2008. In table 2 we report the volatility of the average corporate tax rate in the sample period 1948–2007. This is a conservative choice, as the standard deviation of the measured tax rate increases to 10% for the sample period that includes the 1930s. Our results, therefore, can be amplified by targeting pre-war data.

US public debt data. We collect data on US debt from the CBO website:

<http://www.cbo.gov/doc.cfm?index=11766&zzz=41113>.

We divide debt by US total GDP to compute the persistence of debt-output ratio.

Corporate debt and equity net payouts. We compute net debt and equity payouts using Flow of Funds data as in Larrain and Yogo (2008). We thank these authors for making their dataset available on the web:

http://www.nber.org/~myogo/data/FirmValue_Data.xls

Returns and financial leverage. Monthly returns, dividends, and equity values are from CRSP. Debt values are obtained from COMPUSTAT. The risk-free rate is measured by the 3-month T-bill return. Annual dividends and returns are obtained by time-aggregating the monthly values.

To compute the aggregate leverage ratio, we first compute equity and debt values at the firm level. Specifically, for firm i , the market value of equity is computed as the product of the number of shares outstanding and the price per share, $mvequity_{i,t} \equiv PRC_{i,t} \cdot SHROUT_{i,t}$. Since the market value of debt is unavailable at the firm level, we use the book value of both short- and long-term debt to determine total debt: $totdebt_{i,t} \equiv DLC_{i,t} + DLTT_{i,t}$. Then, for a given year t , we add these figures over all firms to obtain aggregate values, $totdebt_t = \sum_i totdebt_{i,t}$ and $mvequity_t = \sum_i mvequity_{i,t}$. The aggregate leverage ratio is then computed as the ratio of the value of debt to the total value of the firm, $lev_t \equiv \frac{totdebt_t}{totdebt_t + mvequity_t}$.

Deflator. All nominal variables are converted to real units using the CPI index. The sample period is the financial variables is from 1929–2008, except for the leverage ratio, which is only available for the sample period 1950–2008.

Productivity. We compute productivity according to the following expression:

$$Z_t = \frac{Y_t}{K_t^\alpha H_t^{1-\alpha}},$$

where Y_t is measured annual output; K_t measures capital and is computed as in equation (8) with the following initialization: $K_{1929} = I_{1929}/\delta$; and H_t measures annual labor and considers both full-time and part-time employees (NIPA table 6.4).

Estimation of equation (4). We regress our measure of US productivity growth on the first lag of the corporate tax rate. We implement this regression in Eviews and compute Newey-West adjusted standard errors considering 3 lags. Focusing on the 1950–2007 sample (58 included observations), we obtain a point estimate of ϕ_τ equal to -0.058 with a standard error of 0.267 and an implied t -stat of -2.179.

Appendix B. Model solution

Definitions. We start by listing key components of the technology in our economy.

$$\begin{aligned} Y_t &= (Z_t H_t)^{1-\alpha} K_{t-1}^\alpha \\ C_t^B &= \nu Z_{t-1} \left(\frac{B_t}{Y_t} - \frac{\widehat{B}_{ss}}{\widehat{Y}_{ss}} \right)^2 \\ C_t^E &= \phi_0 Z_{t-1} e^{-\phi_1 \left(\frac{\eta K_t}{B_t} - 1 \right)}. \end{aligned}$$

We can compute the following derivatives:

$$\begin{aligned} \frac{\partial Y_t}{\partial K_{t-1}} &= \alpha (Z_t H_t)^{1-\alpha} K_{t-1}^{\alpha-1} \\ \frac{\partial C_t^B}{\partial K_{t-1}} &= 2\nu Z_{t-1} \left(\frac{B_t}{Y_t} - \frac{\widehat{B}_{ss}}{\widehat{Y}_{ss}} \right) \left(\frac{-\alpha B_t}{Y_t} \right) \frac{1}{K_{t-1}} \\ \frac{\partial C_t^E}{\partial K_t} &= C_t^E \frac{-\phi_1 \eta}{B_t} \end{aligned}$$

$$\begin{aligned} \frac{\partial C_t^B}{\partial B_t} &= 2\nu Z_{t-1} \left(\frac{B_t}{Y_t} - \frac{\widehat{B}_{ss}}{\widehat{Y}_{ss}} \right) \frac{1}{Y_t} \\ \frac{\partial C_t^E}{\partial B_t} &= C_t^E \frac{\phi_1 \eta K_t}{B_t^2} \\ \frac{\partial Y_t}{\partial H_t} &= (1-\alpha) Z_t^{1-\alpha} H_t^{-\alpha} K_{t-1}^\alpha \\ \frac{\partial C_t^B}{\partial H_t} &= 2\nu Z_{t-1} \left(\frac{B_t}{Y_t} - \frac{\widehat{B}_{ss}}{\widehat{Y}_{ss}} \right) \frac{(\alpha-1)B_t}{Y_t H_t}. \end{aligned}$$

Firm's problem. Define the vector $\mathbf{A}_t \equiv (Z_{t-1}, Z_t, \tau_t, K_{t-1}, B_{t-1})$ as the aggregate state at time t . The Lagrangian formulation associated to the firm's problem described in equation (8) can be stated as

$$\begin{aligned} V_d(\mathbf{A}_t) &= \max_{I_t, K_t, B_t, H_t} (1-\tau_t)(Y_t - W_t H_t) - I_t + B_t - (1 + (1-\tau_t)r_{b,t-1})B_{t-1} - C_t^B - C_t^E \\ &+ E_t [M_{t+1} V_d(\mathbf{A}_{t+1})] \\ &+ q_t \left((1-\delta)K_{t-1} + \phi \left(\frac{I_t}{K_{t-1}} \right) K_{t-1} - K_t \right), \end{aligned}$$

where q_t is the multiplier associated to the capital accumulation constraint.

Optimality with respect to debt. The first order condition with respect to corporate debt and the Envelope

theorem jointly imply:

$$\begin{aligned} 1 &= \frac{\partial C_t^B}{\partial B_t} + \frac{\partial C_t^E}{\partial B_t} - E_t \left[M_{t+1} \frac{\partial V_{d,t+1}}{\partial B_t} \right] \\ \frac{\partial V_{d,t}}{\partial B_{t-1}} &= -(1 + (1 - \tau_t)r_{b,t-1}). \end{aligned}$$

Taking into account the fact that at the equilibrium r_b is equal to the risk-free rate:

$$\frac{\partial C_t^B}{\partial B_t} + \frac{\partial C_t^E}{\partial B_t} = E_t [M_{t+1}\tau_{t+1}]r_{f,t}.$$

The left-hand side refers to the total marginal cost of issuing an extra unit of debt. The right-hand side measures the value of the corporate interest tax advantage.

Optimality with respect to capital. Envelope and first order conditions with respect to investment and capital imply the following:

$$\begin{aligned} q_t &= \frac{1}{\phi_t'} = E_t \left[M_{t+1} \frac{\partial V_{d,t+1}}{\partial K_t} \right] - \frac{\partial C_t^E}{\partial K_t} \\ \frac{\partial V_{d,t}}{\partial K_{t-1}} &= (1 - \tau_t) \frac{\partial Y_t}{\partial K_{t-1}} - \frac{\partial C_t^B}{\partial K_{t-1}} + q_t \left(1 - \delta - \frac{\phi_t' I_t}{K_{t-1}} + \phi_t \right). \end{aligned}$$

A stationary system of first order stochastic difference equations. Given a stochastic process X_t , we define its normalized counterpart, \widehat{X}_t , as follows:

$$\widehat{X}_t \equiv \frac{X_t}{Z_{t-1}}.$$

Using this convention, we write the following set of first order stochastic difference equations.

Production side:

$$\begin{aligned} \widehat{Y}_t &= \Delta z_t^{1-\alpha} \widehat{K}_{t-1}^\alpha \Delta z_{t-1}^{-\alpha}, \\ \widehat{C}_t^B &= \nu \left(\frac{\widehat{B}_t}{\widehat{Y}_t} - \frac{\widehat{B}_{ss}}{\widehat{Y}_{ss}} \right)^2, & \widehat{C}_t^E &= \phi_0 e^{-\phi_1 \left(\frac{\eta \widehat{K}_t}{\widehat{B}_t} - 1 \right)}, \\ \widehat{K}_t &= (1 - \delta - \phi_t) \widehat{K}_{t-1} e^{-\Delta z_{t-1}}, & q_t &= \frac{1}{\phi_t'}, \\ 1 &= E_t [M_{t+1} R_{I,t+1}], \\ R_{I,t} &\equiv \frac{1}{q_{t-1}} \left((1 - \tau_t) \frac{\alpha \widehat{Y}_t \Delta z_{t-1}}{\widehat{K}_{t-1}} + 2\nu \left(\frac{\widehat{B}_t}{\widehat{Y}_t} - \frac{\widehat{B}_{ss}}{\widehat{Y}_{ss}} \right) \left(\frac{\alpha \widehat{B}_t}{\widehat{Y}_t} \right) \frac{\Delta z_{t-1}}{\widehat{K}_{t-1}} + q_t \left(1 - \delta - \frac{\phi_t' \widehat{I}_t \Delta z_{t-1}}{\widehat{K}_{t-1}} + \phi_t \right) \right) \\ &+ \frac{\phi_1 \eta \widehat{C}_t^E}{\widehat{B}_t}, \\ 1 &= 2\nu \left(\frac{\widehat{B}_t}{\widehat{Y}_t} - \frac{\widehat{B}_{ss}}{\widehat{Y}_{ss}} \right) \frac{1}{\widehat{Y}_t} + \frac{\phi_1 \eta \widehat{K}_t \widehat{C}_t^E}{\widehat{B}_t^2} + E_t [M_{t+1} (1 + (1 - \tau_{t+1})r_{b,t})], \\ \widehat{W}_t &= (1 - \alpha) \widehat{Y}_t - \frac{1}{(1 - \tau_t)} 2\nu \left(\frac{\widehat{B}_t}{\widehat{Y}_t} - \frac{\widehat{B}_{ss}}{\widehat{Y}_{ss}} \right) \frac{(\alpha - 1) \widehat{B}_t}{\widehat{Y}_t}. \end{aligned}$$

Consumption side:

$$\begin{aligned}\widehat{C}_t &= \widehat{Y}_t - \widehat{I}_t - \widehat{G}_t - \widehat{C}^E_t - \widehat{C}^B_t, \\ \widehat{U}_t &= \left\{ (1 - \beta)\widehat{C}_t^{1-1/\psi} + \beta e^{\Delta z_t} E_t [\widehat{U}_{t+1}^{1-\gamma}]^{\frac{1-1/\psi}{1-\gamma}} \right\}^{\frac{1}{1-\psi}}, \\ M_{t+1} &= \delta \left(\frac{\widehat{C}_{t+1} e^{\Delta z_t}}{\widehat{C}_t} \right)^{-\frac{1}{\psi}} \left(\frac{\widehat{U}_{t+1}}{E_t [\widehat{U}_{t+1}^{1-\gamma}]^{\frac{1}{1-\gamma}}} \right)^{\frac{1}{\psi} - \gamma}.\end{aligned}$$

Cost of equity and cost of debt:

$$\begin{aligned}\widehat{D}_t &= (1 - \tau_t)(\widehat{Y}_t - \widehat{W}_t) - \widehat{I}_t + \widehat{B}_t - (1 + (1 - \tau_t)r_{b,t-1})\widehat{B}_{t-1}e^{-\Delta z_{t-1}} - \widehat{C}_t^B - \widehat{C}_t^E \\ \widehat{V}_{d,t} &= \widehat{D}_t + e^{\Delta z_t} E_t [M_{t+1}\widehat{V}_{d,t+1}] \\ r_{d,t} &= \frac{\widehat{V}_{d,t}}{\widehat{V}_{d,t-1} - \widehat{D}_{t-1}} \cdot e^{\Delta z_{t-1}} \\ r_{b,t} &= r_{f,t} = \frac{1}{E_t [M_{t+1}]}.\end{aligned}$$

Deterministic Steady-State. At the deterministic steady state, we assume that the firm pays zero financial distress costs. This is equivalent to impose: $\widehat{B}_{ss} = \eta \widehat{K}_{ss}$. For given ϕ_1 , we use the following two Euler equations to solve for ϕ_0 and \widehat{K}_{ss} :

$$\begin{aligned}1 &= M_{ss} \left\{ (1 - \tau_{ss})\alpha \Delta Z_{ss}^{2-2\alpha} \widehat{K}_{ss}^{\alpha-1} + 1 - \delta \right\} + \frac{\phi_1 \eta}{\widehat{B}_{ss}} \phi_0 e^{-\phi_1 \left(\frac{\eta \widehat{K}_{ss}}{\widehat{B}_{ss}} - 1 \right)} \\ 1 &= \frac{\phi_1 \eta \widehat{K}_{ss}}{\widehat{B}_{ss}^2} \phi_0 e^{-\phi_1 \left(\frac{\eta \widehat{K}_{ss}}{\widehat{B}_{ss}} - 1 \right)} + M_{ss} \left(1 + (1 - \tau_{ss}) \left(\frac{1}{M_{ss}} - 1 \right) \right).\end{aligned}$$

At the steady state, the following holds:

$$\begin{aligned}\widehat{K}_{ss} &= \left\{ \left(\frac{1 - \eta \tau_{ss}(1 - M_{ss})}{M_{ss}} - 1 + \delta \right) \frac{1}{(1 - \tau_{ss})\alpha \Delta Z_{ss}^{2-2\alpha}} \right\}^{\frac{1}{\alpha-1}} \\ \phi_0 &= \frac{\eta \widehat{K}_{ss} \tau_{ss}(1 - M_{ss})}{\phi_1}.\end{aligned}$$

Given \widehat{K}_{ss} , it is possible to compute the steady state value of all other variables.

Solution Method. We solve the model in `dynare++4.2.1` using a second order approximation. The policies are centered about a fix-point that takes into account the effects of volatility on decision rules. In the MatLab workspace file generated by `dynare++`, the vector with the fix-point for all our endogenous variables is denoted as `dyn_ss`. All conditional moments are computed by means of simulations with a fixed seed to facilitate the comparison across fiscal policies.

Welfare Costs. Consider two consumption bundle processes, $\{C^1\}$ and $\{C^2\}$. We express welfare costs as the additional fraction λ of life-time consumption bundle required to make the representative agent indifferent between $\{C^1\}$ and $\{C^2\}$:

$$U_0(\{C^1\}) = U_0(\{C^2\}(1 + \lambda)).$$

Since we specify U so that it is homogenous of degree one with respect to C , the following holds:

$$\frac{U_0(\{C^1\})}{C_0^1} \cdot C_0^1 = \frac{U_0(\{C^2\})}{C_0^2} \cdot C_0^2 \cdot (1 + \lambda).$$

This shows that the welfare costs depend both on the utility-consumption ratio and the initial level of our two consumption profiles. In our production economy, the initial level of consumption is endogenous, so we cannot choose it. The initial level of productivity, $Z_0^i \quad i \in \{1, 2\}$, instead, is exogenous:

$$\frac{U_0(\{C^1\})}{C_0^1} \cdot \frac{C_0^1}{Z_0^1} \cdot Z_0^1 = \frac{U_0(\{C^2\})}{C_0^2} \cdot \frac{C_0^2}{Z_0^2} \cdot Z_0^2 \cdot (1 + \lambda).$$

We compare economies with different tax regimes, but same initial condition for productivity: $Z_0^1 = Z_0^2$. After taking logs, evaluating utility- and consumption-productivity ratios at their unconditional mean and imposing $Z_0^1 = Z_0^2$, we get the following expression:

$$\lambda \approx \overline{\ln U^1/Z} - \overline{\ln U^2/Z},$$

where the bar denotes the unconditional average which is computed using the values stored by `dynare++` in the vector `dyn_ss`.

Our welfare costs are computed comparing the steady-states of two separate economies subject to two different fiscal regimes. Therefore, our welfare comparisons abstract from any transition dynamics required to move from one policy regime to another.

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