

Fiscal Policy and the Distribution of Consumption Risk*

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Abstract

Recent fiscal interventions have raised concerns about US public debt, future fiscal pressure, and long-run economic growth. This paper studies fiscal policy design in an economy in which: (i) the household has recursive preferences and is averse to both short- and long-run uncertainty, and (ii) growth is endogenously sustained through innovations whose market value is sensitive to the tax system. By reallocating tax distortions through debt, fiscal policy alters the composition of intertemporal consumption risk and the incentives to innovate, ultimately affecting long-term growth. When the price of long-run uncertainty is calibrated to match the consumption risk premium, we find that countercyclical tax policies promoting short-run stabilization substantially increase long-run fiscal uncertainty and reduce welfare.

Keywords: Fiscal Policy, government debt, long-run uncertainty, risk premia, endogenous growth, innovation, R&D, welfare costs of fluctuations, recursive preferences.

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1 Introduction

After the onset of the financial crisis in fall 2008, the world has witnessed government interventions on a unprecedented scale. All over the globe, governments massively increased spending in an attempt to prevent the world economy from slipping into a major global depression. While the recent return of the world economy to positive growth appears to indicate that the governments' efforts at short-run stabilization were successful, the question about the long-term effects of these policies arises naturally. In line with such fiscal stimulus packages go sharp increases in projected government debt. In the United States, the congressional budget office estimates government debt to reach the level of GDP by 2012, and to be around 277% of GDP by 2040. While these projections are conditional on current tax regimes, it is clear that such massive bursts in government expenditures need to be financed, either by further increases in government debt or by increases in taxes, or both. This raises considerable uncertainty about the future stance of fiscal policy. Given the distortionary nature of these fiscal policy instruments, current deficits may therefore have substantial effects on the long-term prospects of the economy. In particular, short-run stabilization of the economy may come at the cost of dimmer and uncertain long-term growth prospects.

In this paper, we examine fiscal policy design in an environment in which the government faces an explicit trade-off between short-run stabilization and long-run welfare prospects. In the spirit of Stokey and Lucas (1983), our public authorities finance an exogenous stochastic government expenditure stream through a mix of public debt and labor income taxes. Our model, however, differs substantially from that of Stokey and Lucas (1983) in at least two dimensions. First, our economy grows at an endogenous rate determined by incentives to innovate as in Romer (1990). By altering labor taxes, therefore, fiscal policy can affect the market value of innovative products and ultimately long-run growth. Second, we adopt Epstein and Zin (1989) recursive preferences so that agents care about the intertemporal distribution of consumption risk. Specifically, we assume that agents have a preference for early resolution of uncertainty and hence are averse to long-run growth risks as defined by Bansal and Yaron (2004).

In this setting, we analyze both exogenous fiscal policy as well as optimal Ramsey policy. We start by examining the implications of simple policy rules that link the stance of fiscal policy to

macroeconomic quantities. This analysis allows us to develop useful intuition about the tensions that the Ramsey planner faces when designing optimal fiscal policies in a setting with recursive preferences and endogenous growth. In a second step, we characterize optimal policies and the dynamics of allocations under the Ramsey plan.

Our first quantitative result concerns commonly observed countercyclical fiscal policies seeking to stabilize short-run fluctuations by means of public debt or, equivalently, tax smoothing in the sense of Barro (1979). Using exogenously specified fiscal policy rules (similarly to Dotsey (1990), Ludvigson (1996), Schmitt-Grohe and Uribe (2005), Schmitt-Grohe and Uribe (2007), Davig, Leeper, and Walker (2010), Leeper, Plante, and Traum (2010) and Li and Leeper (2010)), we show that countercyclical policies can produce substantial welfare costs as high as of 2% of life-time consumption. Intuitively, while tax cuts stabilize the economy in the short-run upon the realization of adverse exogenous shocks, the subsequent financing needs associated with long-run budget balance produce uncertainty about future distortionary taxation. When tax distortions endogenously affect growth rates, this leads to more uncertainty about long-term growth prospects. Hence, in asset pricing language, reducing the extent of short-run growth risk comes at the cost of increasing the economy's exposure to long-run risk.

In a setting with aversion to long-run uncertainty, the reallocation of consumption risk from the short- to the long-run can negatively affect welfare through two channels. First, as documented by Croce (2006)'s welfare calculations in endowment economy, when agents have a preference for early resolution of uncertainty, long-run consumption risk matters much more than short-run risk. Second, in a Romer (1990) economy the unconditional average of consumption growth depends on the market value of cash-flows of new products created through innovation. By increasing long-run uncertainty, countercyclical fiscal policies depress the present value of future cash-flows and hence the incentive to grow. We discipline this asset pricing mechanism by calibrating the model to reproduce key feature of both U.S. consumption and wealth-consumption ratio as measured by Lustig, Van Nieuwerburgh, and Verdelhan (2010) and Alvarez and Jermann (2004). Quantitatively, these two welfare cost channels outweigh the benefits of short-run stabilization, implying that common tax smoothing prescriptions obtained with time-additive preferences (see, among others, Aiyagari, Marcet, Sargent, and Seppala (2002)) are no longer optimal in settings with recursive

preferences and endogenous growth.

More generally, these results suggest a relevant tension between short-run stabilization and long-term growth that an optimal policy has to balance. We formalize this intuition by analyzing the optimal Ramsey plan in our model and show that the optimal policy in our setting reflects two important intertemporal considerations absent in the benchmark Stokey and Lucas (1983) model. First, with recursive utility the Ramsey planner has to take into account the entire intertemporal distribution of tax distortions in order to optimize the intertemporal distribution of consumption risk. In a similar spirit as the results of Karantounias (2012) obtained in a robust fiscal policy framework, we find that in our model the planner uses debt as a device to reallocate tax distortions, and hence consumption risk, over time and across states to smooth continuation utility risk. Second, in a Romer (1990) economy the planner has to provide optimal intertemporal incentives for innovation in order to optimize endogenous growth. Our Ramsey plan, therefore, has the notable feature of reflecting market valuations of cash-flow streams generated by the innovation process. Since in our setup continuation utilities are an important component of the pricing kernel, the planner is called to take into account the entire future path of tax distortions to optimize the market value of innovation.

Although arising from independent elements of our model, these two intertemporal features of our Ramsey plan are tightly connected and quantitatively reinforce each other. Together, endogenous growth and recursive preferences let the intertemporal distribution of consumption risk be an important determinant of fiscal policy design. Ignoring the intertemporal composition of consumption risk can substantially bias our welfare costs-benefits analysis of fiscal interventions. At a broader level, therefore, our study conveys the need of introducing risk considerations in the current fiscal policy debate.

Our methodological approach is related to several papers that study optimal fiscal policy in real business cycle models with uncertainty, from Chari, Christiano, and Kehoe (1994) to Chugh and Ghironi (2010). We differ from them because of our joint focus on recursive preferences and endogenous growth. Jones, Manuelli, and Rossi (1993) consider Ramsey policies in an endogenous growth model as well, but they analyze accumulation of human capital and abstract from uncertainty and asset pricing considerations. In our analysis, in contrast, we link welfare costs of

aggregate consumption fluctuations to asset prices in the spirit of Tallarini (2000), and Alvarez and Jermann (2004). We differ from them because we explicitly consider the welfare implications of government policies and link them to the market value of innovation and the intertemporal distribution of consumption risk.

Recently, several studies have focused on evaluating fiscal policies in asset pricing settings. Gomes, Michaelides, and Polkovnichenko (2010) calculate the distortionary costs of government bailouts in a model which is consistent with basic asset market data. Gomes, Michaelides, and Polkovnichenko (2009) analyze fiscal policies in an incomplete markets economy with heterogeneous agents. Panageas (2010a) and Panageas (2010b) study optimal taxation and the incentive to manage risk in the presence of public bailouts and liquidation costs. On the other hand, Pastor and Veronesi (2010) analyze announcement effects on stock prices after policy changes. None of these papers addresses optimal taxation and welfare costs in a risk-sensitive environment similar to ours. To the best of our knowledge, we are the first ones to identify fiscal policy as an important macroeconomic source of costly low-frequency fluctuations.

The remainder of this paper is organized as follows. We present the model in section 2, and discuss our quantitative results in section 3 and 4. In section 5 we introduce the Ramsey problem. Section 6 concludes.

2 Model

In this section we describe in detail the stochastic model of endogenous growth that we use to examine the link between long-run growth, fiscal policy and the distribution of consumption risk. As in Romer (1990), the only source of sustained productivity growth is related to the accumulation of new patents on innovations that facilitate the production of the final good. In this class of models, the speed of patents accumulation, ie, the growth rate of the economy, depends on the market value of the additional cash-flows generated by such innovations. Since we assume that the representative household has Epstein-Zin preferences, the market value of a patent is sensitive to both short-run and long-run growth risk. Asset pricing considerations are therefore required to explain the impact of a tax system on the equilibrium growth rate of the economy.

For simplicity, we abstract from physical capital accumulation. The production of the final good is assumed to depend only on three elements: (i) an exogenous stochastic and stationary productivity process, (ii) the stock of patents, and (iii) the endogenous amount of labor supplied. In our model, labor income is taxed proportionally by the government to finance an exogenous stochastic expenditure stream. In what follows, we show that smoothing distortional taxation using public debt affects both short- and long-run patents' cash-flows, ultimately altering the equilibrium growth rate of the economy. In this sense, choosing a tax system is equivalent to choosing a specific intertemporal distribution of growth risk.

2.1 Household

The representative household has Epstein and Zin (1989) preferences,

$$U_t = \left[(1 - \beta)u_t^{1-\frac{1}{\psi}} + \beta(\mathbb{E}_t U_{t+1}^{1-\gamma})^{\frac{1-\frac{1}{\psi}}{1-\gamma}} \right]^{\frac{1}{1-\frac{1}{\psi}}}, \quad (1)$$

defined over a CES aggregator, u_t , of consumption, C_t , and leisure, $1 - L_t$:

$$u_t = \left[\theta_c C_t^{1-\frac{1}{\nu}} + (1 - \theta_c)[A_t(1 - L_t)]^{1-\frac{1}{\nu}} \right]^{\frac{1}{1-\frac{1}{\nu}}}.$$

We let L_t , γ , ψ and ν denote labor, relative risk aversion, elasticity of intertemporal substitution, and degree of complementarity between leisure and consumption, respectively. Leisure is multiplied by A_t , our measure of standards of living, to guarantee balanced growth when $\nu \neq 1$.

When $\psi = \frac{1}{\gamma}$, these preferences collapse to the standard time additive CRRA case. When, instead, $\psi \neq \frac{1}{\gamma}$, the agent cares about the timing of resolution of uncertainty, meaning that long-run growth news affect her marginal utility differently than short-run growth news. In what follows, we always assume that $\psi \geq \frac{1}{\gamma}$ so that when the agent cares about the intertemporal composition of consumption risk, she dislikes uncertainty about the long-run growth prospects of the economy.

In each period, the household chooses labor, consumption, equity shares, Z_{t+1} , and state contingent public debt holdings, $B_{t+1}(h_{t+1})$, to maximize utility according to the following budget

constraint:

$$C_t + Q_t Z_{t+1} + \int_{h_{t+1}} Q_t^B(h_{t+1}) B_{t+1}(h_{t+1}) = (1 - \tau_t) W_t L_t + (Q_t + \mathcal{D}_t) Z_t + B_t, \quad (2)$$

where \mathcal{D}_t denotes aggregate dividends (specified in equation (14)), Q_t is the market value of an equity share, and $Q_t^B(h_{t+1})$ is the price of a public bond paying one unit of consumption at time $t + 1$ in state h_{t+1} . Wages, W_t , are taxed at a possibly time-varying rate τ_t .

In our setup the stochastic discount factor in the economy is given by

$$M_{t+1} = \beta \left(\frac{u_{t+1}}{u_t} \right)^{\frac{1}{\nu} - \frac{1}{\psi}} \left(\frac{C_{t+1}}{C_t} \right)^{-1/\nu} \left(\frac{U_{t+1}^{1-\gamma}}{\mathbb{E}_t[U_{t+1}^{1-\gamma}]} \right)^{\frac{1/\psi - \gamma}{1-\gamma}}, \quad (3)$$

where the last factor captures aversion to continuation utility risk, ie, long-run growth risk. Optimality implies the following asset pricing conditions:

$$\begin{aligned} Q_t &= \mathbb{E}_t[M_{t+1}(Q_{t+1} + \mathcal{D}_{t+1})] \\ Q_t^B(h_{t+1}) &= M_{t+1} f(h_{t+1}) \end{aligned}$$

where $f(\cdot)$ is the equilibrium conditional probability density function. At the equilibrium, the representative agent holds the entire supply of equities, normalized to be one for simplicity (i.e., $Z_t = 1 \quad \forall t$), and bonds. The intratemporal optimality condition on labor takes the following form:

$$\frac{1 - \theta_c}{\theta_c} A_t^{(1-1/\nu)} \left(\frac{C_t}{1 - L_t} \right)^{1/\nu} = (1 - \tau_t) W_t, \quad (4)$$

and implies that the household's labor supply is directly affected by fiscal policy.

2.2 Technology

Final Good Firm. There is a representative and competitive firm that produces the single final output good in the economy, Y_t , using labor, L_t , and a bundle of intermediate goods, X_{it} . We

assume that the production function for the final good is specified as follows:

$$Y_t = \Omega_t L_t^{1-\alpha} \left[\int_0^{A_t} X_{it}^\alpha di \right] \quad (5)$$

where, Ω_t denotes an exogenous stationary stochastic productivity process

$$\log(\Omega_t) = \rho \cdot \log(\Omega_{t-1}) + \epsilon_t, \quad \epsilon_t \sim N(0, \sigma^2),$$

and A_t is the total measure of intermediate goods in use at date t .

This competitive firm takes prices as given and chooses intermediate goods and labor to maximize profits as follows:

$$D_t = \max_{L_t, X_{it}} Y_t - W_t L_t - \int_0^{A_t} P_{it} X_{it} di,$$

where P_{it} is the price of intermediate good i at time t . At the optimum:

$$X_{it} = L_t \left(\frac{\Omega_t \alpha}{P_{it}} \right)^{\frac{1}{1-\alpha}}, \quad \text{and} \quad W_t = (1 - \alpha) \frac{Y_t}{L_t}. \quad (6)$$

Intermediate Goods Firms. Each intermediate good $i \in [0, A_t]$ is produced by an infinitesimally small monopolistic firm. Each firm needs X_{it} units of the final good to produce X_{it} units of its respective intermediate good i . Given this assumption, the marginal cost of an intermediate good is fix and equal to one. Taking the demand schedule of the final good producer as given, each firm chooses its price, P_{it} , to maximize profits, Π_{it} :

$$\Pi_{it} \equiv \max_{P_{it}} P_{it} X_{it} - X_{it}.$$

At the optimum, monopolists charge a constant markup over marginal cost:

$$P_{it} \equiv P = \frac{1}{\alpha} > 1.$$

Given the symmetry of the problem for all the monopolistic firms, we get:

$$\begin{aligned} X_{it} &= X_t = L_t(\Omega_t\alpha^2)^{\frac{1}{1-\alpha}}, \\ \Pi_{it} &= \Pi_t = \left(\frac{1}{\alpha} - 1\right)X_t. \end{aligned} \tag{7}$$

Equation (5) and (7) allow us to express final output in the following compact form:

$$Y_t = \frac{1}{\alpha^2}A_tX_t = \frac{1}{\alpha^2}A_tL_t(\Omega_t\alpha^2)^{\frac{1}{1-\alpha}}. \tag{8}$$

Since both labor and productivity are stationary, the long run growth rate of output is determined by the expansion of intermediate goods variety, A_t . This expansion is originated in the research and development sector that we describe below.

Research and Development. Innovators develop new intermediate goods for the production of final output and obtain patents on them. At the end of the period, these patents are sold to new intermediate goods firms in a competitive market. Starting from next period on, the new monopolists produce the new varieties and make profits. We assume that each existing variety dies, ie, becomes obsolete, with probability $\delta \in (0, 1)$. In this case, its production is terminated. Given these assumptions, the value cum-dividend of an existing variety, V_{it} , is equal to the present value of all future expected profits and can be recursively expressed as follows:

$$V_{it} = \Pi_{it} + \phi E_t [M_{t+1}V_{it+1}] \tag{9}$$

Let $1/\vartheta_t$ be the marginal rate of transformation of final goods into new varieties. The free-entry condition in the R&D sector implies that at the equilibrium:

$$\frac{1}{\vartheta_t} = E_t [M_{t+1}V_{t+1}]. \tag{10}$$

The left-hand side of the free-entry condition measures the marginal cost of producing an extra variety. The right-hand side, instead, is equal to the end-of-the-period market value of the new patents. Equation (10) is extremely relevant in this class of models because it implicitly pins down

the optimal level of investment in R&D and ultimately the growth rate of the economy. To better explain this point, let S_t denote the units of final good devoted to R&D investment, and notice that in our economy the total mass of varieties evolves according to

$$A_{t+1} = \vartheta_t S_t + (1 - \delta)A_t, \quad (11)$$

from which we obtain

$$\frac{A_{t+1}}{A_t} - 1 = \vartheta_t \frac{S_t}{A_t} - \delta.$$

As often done in the literature, we impose

$$\vartheta_t = \chi \left(\frac{S_t}{A_t} \right)^{\eta-1} \quad \eta \in (0, 1), \quad (12)$$

in order to capture the idea that concepts already discovered make it easier to come up with new ideas, $\partial\vartheta/\partial A > 0$, and that R&D investment has decreasing marginal returns, $\partial\vartheta/\partial S < 0$.

Combining equations (10)—(12), we obtain the following optimality condition for investment:

$$\frac{1}{\chi} \left(\frac{S_t}{A_t} \right)^{1-\eta} = E_t \left[\sum_{j=0}^{\infty} M_{t+j|t} (1 - \delta)^j \left(\frac{1}{\alpha} - 1 \right) (\Omega_{t+j} \alpha^2)^{\frac{1}{1-\alpha}} L_{t+j} \right] \quad (13)$$

where $M_{t+j|t} \equiv \prod_s^j M_{t+s|t}$ is the j -steps ahead pricing kernel and $M_{t|t} \equiv 1$. Equation (13) suggests that the amount of innovation intensity in the economy, S_t/A_t , is directly related to the discounted value of future profits and, ultimately, future labor conditions. When agents expect labor above steady state, they will have an incentive to invest more in R&D, ultimately boosting long-run growth. Viceversa, when agents expect labor to remain below steady state, they will revise downward their evaluation of patents and will reduce their investment in innovation and, therefore, future growth. We discuss this intuition further in section 2.3.

¹This dynamic equation is consistent with our assumption that new patents survive for sure in their first period of life. If new patents are allowed to immediately become obsolete, equation (10) and (11) need to be replaced by $A_{t+1} = (1 - \delta)(\vartheta_t S_t + A_t)$ and $\frac{1}{\vartheta_t} = E_t [M_{t+1}(1 - \delta)V_{t+1}]$, respectively. Our results are not sensitive to this modeling choice.

Stock Market. Given the multi-sector structure of the model, various assumptions on the constituents of the stock market can be adopted. We assume that the stock market value includes all the production sectors described above, namely, the final good, the intermediate goods and the R&D sector. Taking into account the fact that both the final good and the R&D sector are competitive, aggregate dividends are simply equal to monopolistic profits net of investment:

$$\mathcal{D}_t = \Pi_t A_t - S_t. \quad (14)$$

At the equilibrium, the ex-dividends stock market value Q_t can be rewritten as follows:

$$Q_t = (V_t - \Pi_t) A_t = \frac{1 - \delta}{\vartheta_t} A_t.$$

Government. The government faces an exogenous and stochastic expenditure stream, G_t , that evolves as follows:

$$\frac{G_t}{Y_t} = \frac{1}{1 + e^{-gy_t}}, \quad (15)$$

where

$$gy_t = (1 - \rho)\overline{gy} + \rho_g gy_{t-1} + \epsilon_{G,t}, \quad \epsilon_{G,t} \sim N(0, \sigma_g y).$$

This specification ensures that $G_t \in (0, Y_t) \quad \forall t$. In order to finance this expenditure, the government can use tax income, $T_t = \tau_t W_t L_t$, or public debt according to the following budget constraint:

$$\int_{h_{t+1}} Q_t^B(h_{t+1}) B_{t+1}(h_{t+1}) = B_t + G_t - T_t. \quad (16)$$

Aggregate Resource Constraint. In this economy, the final good market clearing condition implies:

$$Y_t = C_t + S_t + A_t X_t + G_t.$$

Final output, therefore, is used for consumption, R&D investment, production of intermediate goods, and public expenditure.

2.3 Some Properties of the Equilibrium

Combining equations (10)—(13), we obtain the following expression for growth rate in the economy:

$$\begin{aligned} \frac{A_{t+1}}{A_t} &= 1 + \delta + E_t \left[\chi^2 M_{t+1} V_{t+1} \right]^{\frac{1-\eta}{\eta}} \\ &= 1 + \delta + E_t \left[\chi^2 \sum_{j=1}^{\infty} M_{t+j|t} (1-\delta)^{j-1} \left(\frac{1}{\alpha} - 1 \right) (\Omega_{t+j} \alpha^2)^{\frac{1}{1-\alpha}} L_{t+j} \right]^{\frac{1-\eta}{\eta}}. \end{aligned} \quad (17)$$

The relevance of equation (17) is twofold, since it enables us to discuss both the interaction between recursive preferences and endogenous growth, and the role played by the tax system.

First, we point out that in this framework, growth is a monotone transformation of the discounted value of future profits. This implies that the average growth in the economy is endogenously negatively related to both the discount rate used by the household and the amount of perceived risk. When the household has standard time additive preferences, only short-run profits risk matters for the determination of the value of a patent. When the agent has recursive preferences, instead, optimal growth depends also on the endogenous amount of volatility in expected long-run profits.

Second, since profits are proportional to labor, and labor supply is sensitive to the tax rate, a fiscal system based on tax smoothing ultimately introduces long-lasting fluctuations in future profits and tends to depress patent value slowing down the entire economy. Short-run tax stabilization, therefore, comes at the cost of reduced long-run growth. This tension is the core of our welfare analysis.

3 Calibration

We report our benchmark calibration in table 1, and the implied main statistics of the model in table 2. Since the main focus of the paper is on the implications of fiscal policy on consumption, we calibrate our productivity process to match the unconditional volatility of consumption growth observed in the US over the long sample 1929–2008. The parameters for the government expenditure-output ratio are set to have an average share of 10% at the deterministic steady-state and an annual volatility of 4%, consistent with U.S. annual data over the sample 1929–2008. Rela-

Table 1: Calibration

Description	Symbol	Value
Preference Parameters		
Consumption-Labor Elasticity	ν	0.8
Utility Share of Consumption	θ_c	0.25
Discount Factor	β	0.997
Intertemporal Elasticity of Substitution	ψ	1.7
Risk Aversion	γ	10
Technology Parameters		
Elasticity of Substitution Between Intermediate Goods	α	0.7
Autocorrelation of Productivity	ρ	0.97
Survival rate of intermediate goods	ϕ	0.97
Elasticity of New Intermediate Goods wrt R&D	η	0.8
Standard of Deviation of Technology Shock	σ	0.006
Government Expenditure Parameters		
Level of Expenditure-Output Ratio (G/Y)	\overline{gY}	-2.2
Autocorrelation of G/Y	ρ_G	0.98
Standard deviation of G/Y shocks	σ_G	0.008

Notes - This table reports the benchmark quarterly calibration of our model. All parameters are chosen according to the discipline proposed by Kung and Schmid (2010).

tive risk aversion, intertemporal elasticity of substitution and subjective discount factor are set to replicate the low historical average of the risk-free rate and the consumption claim risk premium estimated by Lustig, Van Nieuwerburgh, and Verdelhan (2010). Replicating these asset-pricing moments is important because it imposes a strict discipline on the way in which innovations are priced and average growth is determined. All other parameters are chosen consistently with the endogenous growth literature (see Kung and Schmid (2010) for a broader discussion).

4 A simple exogenous fiscal policy

In this section we use an exogenous fiscal policy generating tax smoothing in order to have some insights on the trade-off between short-run stabilization and long-run growth faced by the government. The optimal debt financing policy is the focus of section 5. Here we use a simple and flexible debt policy to analyze endogenous variations in the composition of consumption risk for given characteristics of the tax system. In particular, we assume for the time being that the government has access to state uncontingent debt. Therefore, we substitute equations (2) and (16) with the

Table 2: Main Statistics under Zero-Deficit

	Data	Zero deficit $\phi_B = 0$
$E(\Delta c)$	2.83	2.13
$\sigma(\Delta c)$ (%)	2.34	2.57
$ACF_1(\Delta c)$	0.44	0.30
$E(L)$	33.0	35.59
$E(\tau)$	33.5	33.50
$\sigma(\tau)$		2.01
$\sigma(m)$		53.20
$E(r_f)$	0.93	1.28
$E(r^C - r_f)$		1.51

Notes - This table reports the summary statistics of our model calibrated as in Table (1). $E(L)$ is the fraction of hours worked. All moments are annualized. All figures are multiplied by 100, except $ACF_1(\Delta c)$, the first-order autocorrelation of consumption growth. The log discount factor is denoted by m , and τ is the tax rate. r^C and r_f are the return of the consumption claim and the risk-free bond, respectively.

following expressions:

$$\begin{aligned}
C_t + Q_t Z_{t+1} + B_t &= (1 - \tau_t) W_t L_t + (Q_t + D_t) Z_t + (1 + r_{f,t-1}) B_{t-1}, \\
B_t &= (1 + r_{f,t-1}) B_{t-1} + G_t - T_t,
\end{aligned} \tag{18}$$

where

$$1 + r_{f,t} = E_t[M_{t+1}]^{-1}.$$

We specify the following fiscal policy rule on debt-output ratio:

$$\begin{aligned}
\frac{B_t^G}{Y_t} &= \rho_B \frac{B_{t-1}^G}{Y_{t-1}} + \epsilon_{B,t} \\
\epsilon_{B,t} &= \phi_B \cdot (\log L_{SS} - \log L_t),
\end{aligned} \tag{19}$$

where L_{SS} is the steady state level of labor, and $\rho_B \in (0, 1)$ and $\phi_B \geq 0$ measure the inverse of the speed of repayment of debt and the intensity of the policy, respectively.

When $\phi_B > 0$, this policy rule captures the behavior of a government that is concerned about employment and wants to minimize labor fluctuations. In particular, the government cuts labor taxes (increases debt) when labor is below steady state and increases them (reduces debt) in periods

of boom for the labor market. The convenience of working with this policy is twofold. First, with time-additive preferences, this simple policy improves welfare against a zero-deficit policy, ie, against the no tax smoothing case, $\phi_B = 0$. This is relevant because it implies that we are working with a policy that can bring the economy closer to the Ramsey second best, at least with time additive preferences. We prove and explain this point in detail in section 4.2. Second, this policy rule allows us to focus only on the two most important dimensions of a tax system, namely the intensity of tax-smoothing, ϕ_B , and its persistence, ρ_B .

The condition $\rho_B < 1$ ensures that the public administration wants to keep the debt-output ratio stationary. In the language of Leeper, Plante, and Traum (2010), we anchor expectations about debt and rule out unsustainable paths. Since in our economy with recursive preferences the following holds:

$$E \left[\frac{1 + r_{f,t}}{\exp\{\Delta y_{t+1}\}} \right] < 1,$$

the unconditional average of both debt and deficit is zero. Under this policy, therefore:

$$E[\tau_t] = E \left[\frac{G_t}{W_t L_t} \right] = \frac{1}{\alpha} E \left[\frac{G_t}{Y_t} \right].$$

In absence of uncertainty $E[\tau_t]$ depends only on α and $\bar{g}y$. In the model with uncertainty, in contrast, $E[\tau_t]$ becomes an inverse function of the average amount of labor that the household optimally supplies.

The dynamics of τ_t around its unconditional mean, $E[\tau_t]$, are implicitly determined by (18) and (19). Given $\phi_B > 0$, panel a) and b) of figure ?? show the response of the tax rate after a positive shock to government expenditure and a negative shock to productivity, respectively. According to (19), in both cases the government responds to these shocks by initially lowering the tax rate below the level required to have zero deficit. Over the long-horizon, instead, the government increases taxation above average in order to run surpluses and repay debt. This is true both with recursive and time-additive preferences. In the next section, we show in detail how this tax smoothing behavior alters the composition of output and consumption risk.

Table 3: Main Statistics

	Data	Zero deficit $\phi_B = 0$	Weak $\phi_B = .3\%$	Medium $\phi_B = .45\%$	Strong $\phi_B = .6\%$
$E(\Delta c)$	2.83	2.13	2.10	2.09	2.08
$\sigma(\Delta c)$	2.34	2.57	2.53	2.52	2.51
$ACF_1(\Delta c)$	0.44	0.30	0.31	0.31	0.31
Half-life $E_t(\Delta c_{t+1})$		34.64	59.54	65.02	69.65
$E(L)$	33.0	35.59	35.52	35.48	35.46
$E(\tau)$	33.5	33.50	33.57	33.59	33.61
Welfare costs		0.00	0.24	0.36	0.46

Notes - This table reports the summary statistics of our model as calibrated in Table (1). $E(L)$ is the fraction of hours worked. The half-life of $E_t[\Delta c_{t+1}]$ is expressed in quarters. All moments except the half-life and the autocorrelation of consumption growth, $ACF_1(\Delta c)$, are annualized and in percent. The log discount factor is denoted by m , and τ is the tax rate. Columns correspond to different levels of intensity of the countercyclical fiscal policy described in equation (19). The speed of debt repayment is determined by $\rho_B = .98$.

4.1 Inspecting the mechanism

Terminology. Let Z_t be a stochastic process generated by our model. We can always decompose Z_t as follows:

$$Z_t = X_{Z,t-1} + \epsilon_{Z,t},$$

$$X_{Z,t-1} \equiv E_{t-1}[Z_t].$$

In what follows, we refer to X_Z and ϵ_Z as the long- and short-run component of Z , respectively. In our economy, the unpredictable changes of Z and X_Z are a function of the both government expenditure and the productivity shocks, and the fiscal policy parameters, ρ_B and ϕ_B :

$$\epsilon_{Z,t} = f_Z(\epsilon_{G,t}, \epsilon_t | \rho_B, \phi_B),$$

$$\epsilon_{X,t} \equiv X_{Z,t} - E_{t-1}[X_{Z,t}] = f_{X_Z}(\epsilon_{G,t}, \epsilon_t | \rho_B, \phi_B).$$

In the next sections, we use impulse response functions to characterize f_Z and f_{X_Z} for several variables of interest across different fiscal policies. Ultimately, this helps us to characterize the four main dimensions of the distribution of risk of any random variable Z_t , i.e., the amount of short-

run risk, $\text{StD}_t(Z_{t+1})$, the magnitude of long-run risk, $\text{StD}(X_{Z,t})$, the persistence of the long-run component, $\text{ACF}_1(X_{Z,t})$, and the unconditional average $E[Z_t]$.

When we impose $Z_t = \Delta c_t$, this decomposition allows us to study the asset pricing and the welfare implications of our model in the spirit of Bansal and Yaron (2004) and Croce (2006), respectively. Abstracting from time-varying volatility, they model consumption as follows:

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

What we denote as $\text{StD}_t(\Delta c_{t+1})$ is the equivalent of σ_c ; $\text{ACF}_1(E_t[\Delta c_{t+1}])$ 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 .

Recursive preferences case. We start our analysis by comparing a zero-deficit policy with countercyclical fiscal policies characterized by different intensity level, ϕ_B . We denote as ‘Weak’, ‘Medium’ and ‘Strong’ the case in which ϕ_B is equal to .3%, .45%, and .6%, respectively. The zero-deficit policy corresponds to setting $\phi_B = 0$.

The main results obtained from these four calibrations are reported in table 3. In figure 1 and 2 we plot the impulse response of key variables of interest after a positive one-standard deviation shock to G/Y , and a negative one-standard deviation shock to productivity, respectively. In these figures, we plot impulse responses only for the extreme cases of zero-deficit and strong countercyclical policy.

The top-left panel of figure 1 shows that when an adverse government shock materializes, labor tends to fall. This is due to the substitution effect: a higher level of government expenditure requires a higher tax rate that depresses the supply of labor services. When the government implements a strong tax smoothing policy, the immediate increase in the tax rate is less severe and for this reason labor falls less than under the zero-deficit policy. The top-right panel of figure 1 shows that this short-run stabilization comes at the cost of a lower expected recovery speed. At all possible horizons, indeed, the expected growth rate of labor under the tax-smoothing policy is lower than

under the zero-deficit policy. This effect is due to the fact that over time the government keeps taxes at a higher level in order to repay public debt. In this sense, the government is trading off short-run labor volatility for long-run labor volatility by making the effects of government expenditure shocks less severe on impact, but more long-lasting.

According to equation (8), labor growth is relevant to understand what happens to aggregate output growth in both the short- and the long-run. The two middle panels of figure 1 show that under the tax-smoothing policy, the government is able to reduce the drop in output growth when the shock materializes (left panel). This stabilization effect, however, comes at the cost of amplifying the drop in expected long-run growth (right panel). The impulse response of both realized and expected output growth reflect what happens to labor growth and take also into account the fact that after an increase in government expenditure there are less resources allocated to R&D, hence, the innovation speed, A_{t+1}/A_t , declines as well.

What discussed so far is also true when the economy is subject to a negative productivity shock. As shown in figure 2, the tax-smoothing policy is able to reduce the short-run fall in employment only at the cost of having a slower recovery for both employment and output.

Finally, the bottom two panels of figure 1 and 2 show that the tax-smoothing policy alters the consumption growth composition exactly as it does for output growth: smoothing labor taxes implies a reduction of short-run consumption volatility against an increase in the volatility of expected future growth after both G/Y and productivity shocks. Furthermore, the tax-smoothing policy tends to make expected consumption growth more persistent, ie, it makes the impact of the exogenous shocks on consumption more long-lasting. This trade-off can be better seen in table 3 where we show that as ϕ_B increases, the volatility of consumption, $\sigma(\Delta c)$, declines while the half-life of the consumption long-run component, $E_t[\Delta c_{t+1}]$, increases. Since the long-run component of consumption is relatively small, the overall persistence of consumption growth, $ACF_1(\Delta c)$, is only marginally affected and is consistent with the data.

Table 3 also shows that the unconditional growth rate of consumption is declining in the intensity of tax smoothing, ϕ_B . This result follows directly from the afore mentioned reallocation of risk from the short- to the long-run. In order to better explain this point, note that the unconditional growth rate in the economy is determined by the no-arbitrage equation (17), in which the

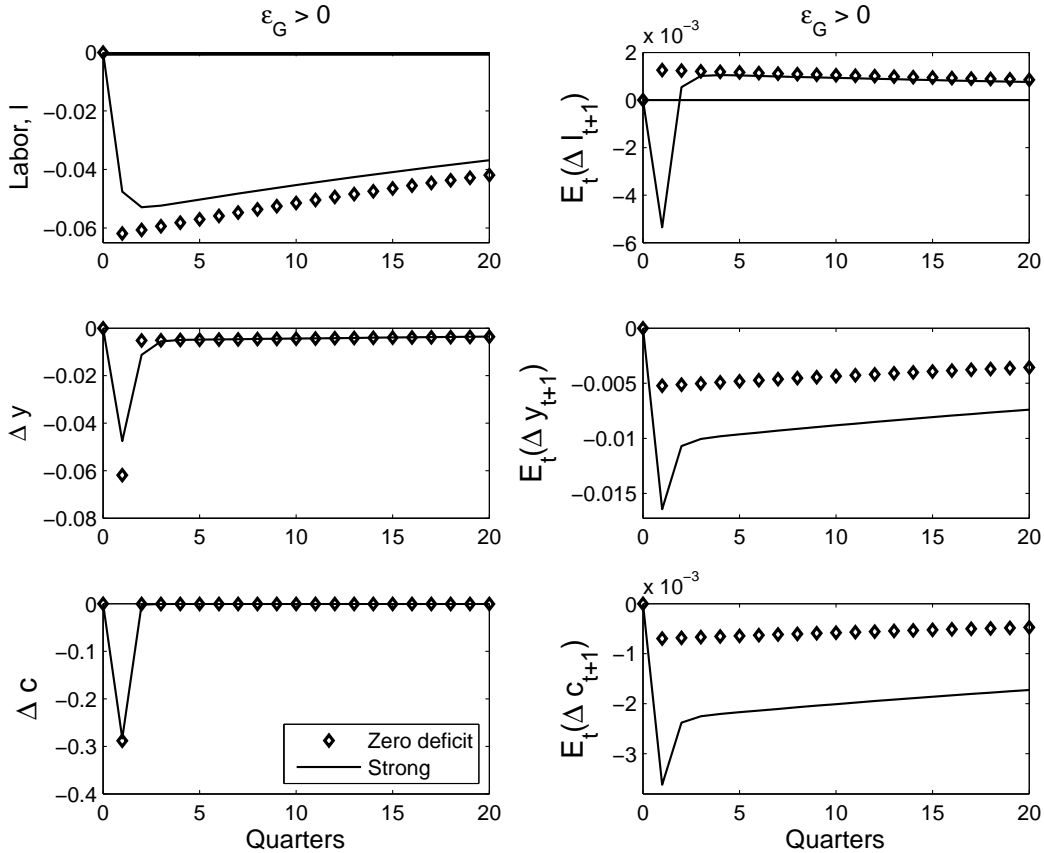


Fig. 1: Zero-deficit vs Strong Tax Smoothing: adverse G/Y shock

Notes - This figure shows quarterly log-deviations from the steady state. All deviations are multiplied by 100. All the parameters are calibrated to the values used in Tables 1 and 3. The diamond shaped markers refer to the zero-deficit policy ($\phi_B = 0$). The solid line is associated to a strong countercyclical fiscal policy ($\phi_B = .6\%$).

growth of the economy depends on the value of patents. In an economy with recursive preferences, the intertemporal distribution of consumption and profits risk matters when pricing patent and innovation benefits.

Figure 3 shows what happens to both the intertemporal composition of profits risk and the value of a patent as we change the policy parameters (ρ_B, ϕ_B). As mentioned before, for given ρ_B , as the intensity of the policy, ϕ_B , increases, the short-run volatility of profits declines (top-right panel), while simultaneously the long-run component of profits becomes more persistent (bottom-left panel), and slightly more volatile (bottom-right panel). As noticed by Bansal and Yaron (2004), long-run uncertainty carries a substantial price of risk when the household prefers early resolution of uncertainty and the persistence of expected dividends, i.e. profits, and consumption is high.

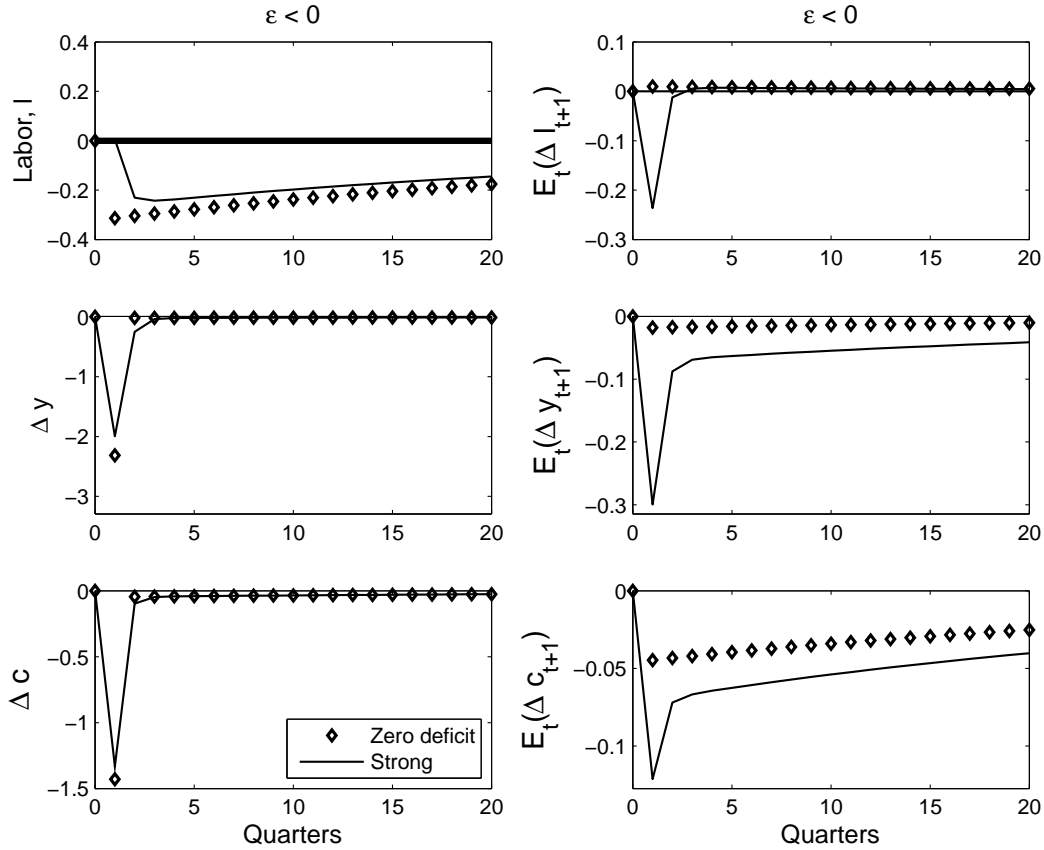


Fig. 2: Zero-deficit vs Strong Tax Smoothing: adverse productivity shock

Notes - This figure shows quarterly log-deviations from the steady state. All deviations are multiplied by 100. All the parameters are calibrated to the values used in Tables 1 and 3. The diamond shaped markers refer to the zero-deficit policy ($\phi_B = 0$). The solid line is associated to a strong countercyclical fiscal policy ($\phi_B = .6\%$).

In our case, as ϕ_B increases, the increase in long-run profits and consumption risk dominates on the decline in short-run risk and let future profits be discounted at a higher rate. This explains why a more intense tax-smoothing policy ultimately depresses patents' value and average growth. Note also that when patents' value declines, less varieties are accumulated in the economy, in turn reducing the marginal product of labor. This is the reason why in table 3 the average amount of labor supplied declines together with the unconditional mean of consumption growth. Ultimately, the average tax rate, $E[\tau]$, has to be higher in order to finance government spending with a lower level of average labor income. In a model with endogenous growth, therefore, the financing mix of taxes and debt significantly matters since it feeds-back on the average growth of the economy and alters the average amount of tax distortions required to finance a given expenditure.

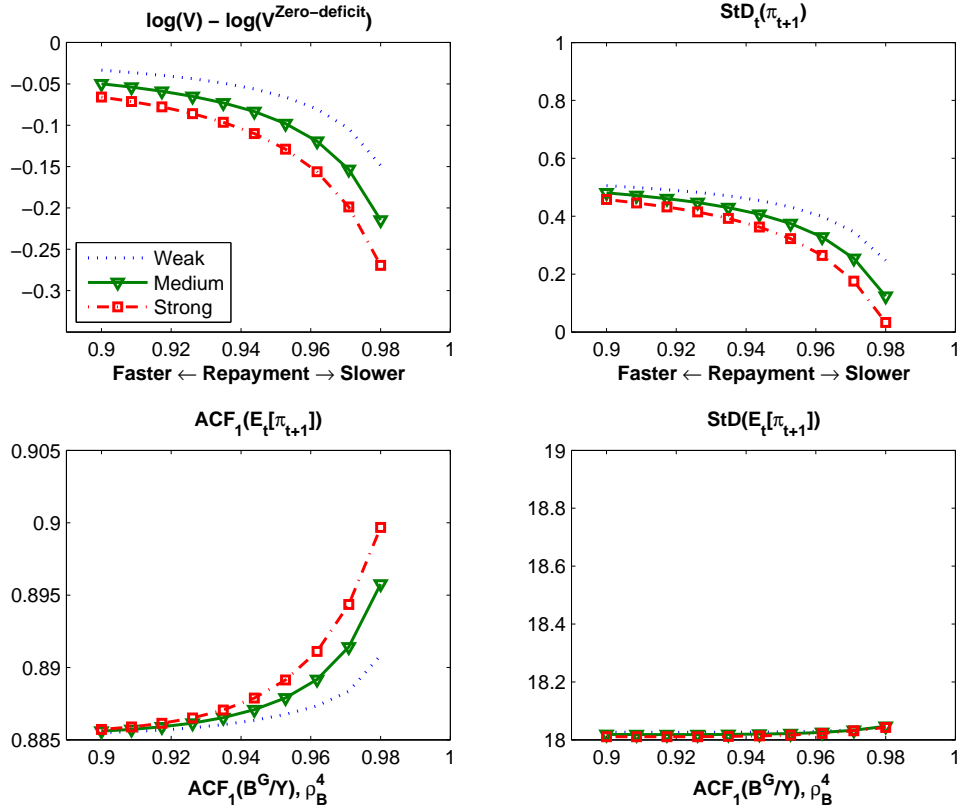


Fig. 3: Patents' Value and Profits Distribution

Notes - This figure shows the average value of patents, $E[V]$, and key moments of profits, Π . All the parameters are calibrated to the values used in Tables 1. The three lines reported in each plot are associated to different levels of intensity of the countercyclical fiscal policy described in equation (19). ‘Weak’, ‘Medium’, and ‘Strong’ policies are generated by calibrating ϕ_B to .3%, .45%, and .6%, respectively. Horizontal axis corresponds to different annualized autocorrelation, ρ_B^4 , of debt to output ratio, B^G/Y ; the higher the autocorrelation, the lower the speed of repayment.

Furthermore, figure 3 shows that the negative effects on patents valuation and growth become more and more severe when the smoothing attitude, ρ_B , increases. More persistent tax rate fluctuations amplify long lasting risk and depress growth even though short-run stabilization is achieved. Taken together, these results suggest that the intertemporal distribution of tax distortion matters when the agent has recursive preferences,.

Time additive preferences case. We now set $\Psi = 1/\gamma = .1$ to study the time additive preferences case, in which the intertemporal distribution of tax risk should not matter. We keep everything else constant and look at quantity dynamics in figure 4. Panel a) and b) are the analogous of figure 1 and 2, respectively. The main message of this figure is the following: with time-additive

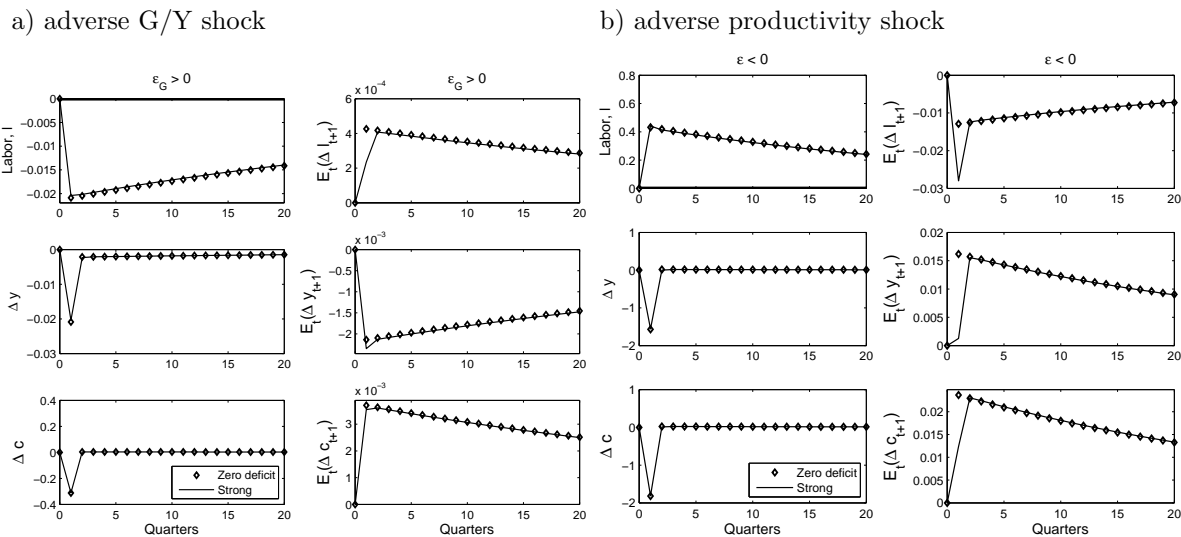


Fig. 4: Zero-deficit vs Strong Tax Smoothing with CRRA

Notes - This figure shows quarterly log-deviations from the steady state. All deviations are multiplied by 100. All the parameters are calibrated to the values used in Tables 1 and 3, except the IES that is set to $1/\gamma = .1$. The diamond shaped markers refer to the zero-deficit policy ($\phi_B = 0$). The solid line is associated to a strong countercyclical fiscal policy ($\phi_B = .6\%$). The plots in panel a) refer to the case of an adverse shock to G/Y ($\epsilon_G > 0$). Panel b), instead, refers to a negative productivity shock, $\epsilon < 0$.

preferences, long-run expectations under the tax-smoothing and the zero-deficit policy basically coincide. In other words, the optimal allocation of labor and R&D investment is not significantly sensitive to the public financing scheme. Since the agent does not care about the timing of resolution of tax uncertainty, the government is now able to promote short-run stabilization without negatively altering the long-run growth of the economy.

In figure 5 we see that a tax-smoothing policy is now able to *increase* the value of patents, independently of the persistence of the tax rate, ie, the speed of repayment of debt, ρ_B . The origin of this result is twofold. On the one end, this figure shows that with time-additive preferences the profits distribution is basically unaltered. On the other hand, figure 4 shows that the tax-smoothing policy is able to partially reduce short-run consumption growth volatility, in turn reducing the total market price of risk and the discount rate applied to profits. It is important to notice, though, that the improvement in the patents value obtained through tax-smoothing is very small, even in the case in which the intensity of the policy is 'strong'. This remark is important because in the next section we will see that the benefits of tax-smoothing with time-additive preferences are tiny.

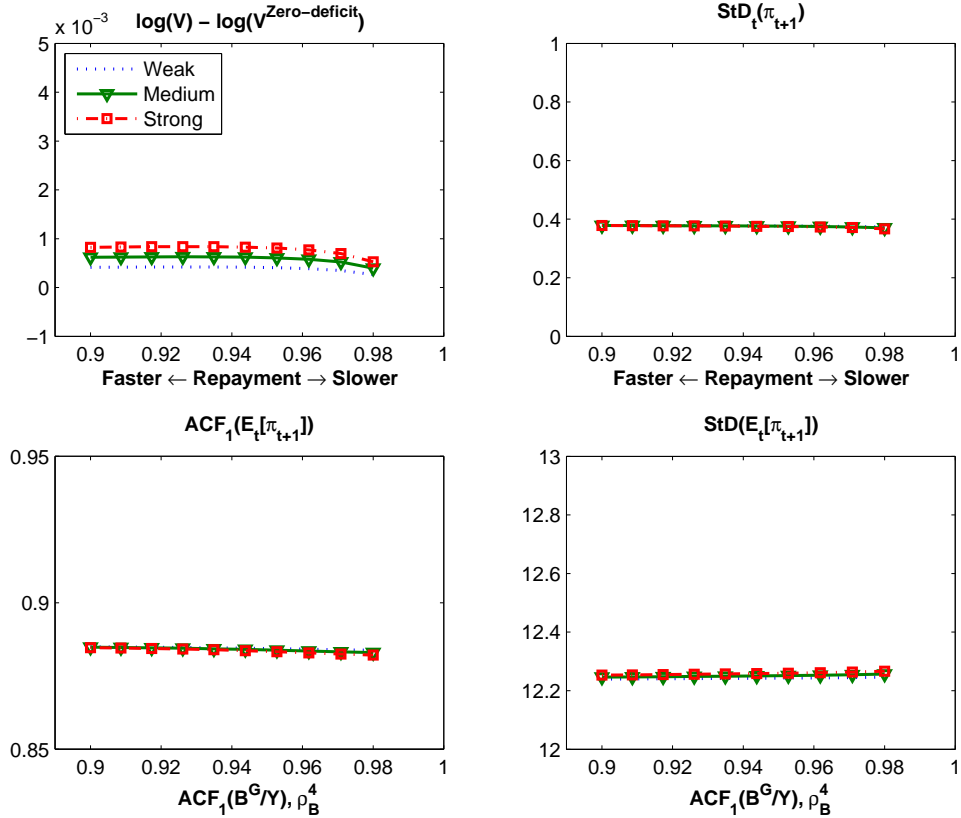


Fig. 5: Patents' Value and Profits Distribution with CRRA

Notes - This figure shows differences in the average value of patents, $E[V]$, across tax policies, and key moments of profits, Π . All the parameters are calibrated to the values used in Tables 1, except the IES that is set to $1/\gamma = .1$. The three lines reported in each plot are associated to different levels of intensity of the countercyclical fiscal policy described in equation (19). 'Weak', 'Medium', and 'Strong' policies are generated by calibrating ϕ_B to .3%, .45%, and .6%, respectively. Horizontal axis corresponds to different annualized autocorrelation, ρ_B^4 , of debt to output ratio, B^G/Y ; the higher the autocorrelation, the lower the speed of repayment.

4.2 Welfare implications of tax-smoothing

As in Lucas (1987), we compute welfare costs, WC , in terms of percentage of life-time consumption and use the zero-deficit consumption process as benchmark:

$$WC(\phi_B, \rho_B) = E[U/C | \phi_B > 0, \rho_B \in (0, 1)] - E[U/C | \phi_B = 0].$$

Note that we are comparing the welfare generated by consumption processes with different intertemporal composition of risk and that these different consumption distributions are a direct result of the intensity of the tax smoothing, ϕ_B , and the persistence of the tax rate, ρ_B .

The last two rows of table 3 show that as the government increases the intensity of its policy, the household welfare *decreases*. Figure 6 shows that the welfare costs of tax-smoothing are actually increasing in both the intensity and the persistence parameters.

These welfare costs are generated by the fact that our simple tax-smoothing policy is essentially trading off short-run volatility ($\text{StD}_t(\Delta c_{t+1})$, top-right panel) against long-run consumption risk ($\text{StD}_t(E_t[\Delta c_{t+1}])$, bottom-right panel). Furthermore, through the debt financing of government expenditure, the government is making the effects of transitory shocks on consumption growth more long lasting ($\text{ACF}_1(E_t[\Delta c_{t+1}])$, bottom-left panel). Consistent with Croce (2006), in our model long-run consumption uncertainty is the main driver of the welfare results and the main source of losses.

Furthermore, when the government implements tax-smoothing policies, the unconditional average growth rate of consumption, $E[\Delta c_t]$, declines as a result of the drop in patents' value mentioned in the previous section. To summarize, short-run stabilization, comes at the cost of slower growth and higher uncertainty for the long-run. Taking into account the fact that the annual persistence of debt-output ratio, ρ_B^A , in the US is .99, the welfare costs can be as high as 2% of lifetime consumption, a substantial amount.

In figure 7, we show that these results are totally reversed in a world with time-additive preferences. In this case, in fact, this simple tax-smoothing policy reaches its ultimate goal of improving welfare by stabilizing short-run fluctuations in labor. The resulting welfare benefits, however, are small, as small is the improvement in the average value of the patents described in the previous section.

4.3 Long-run distortions versus crowding out

So far we have assumed that the government uses taxes to finance an unproductive government expenditure. This assumption, however, introduces uncertainty about both the substitution effect and the crowding-out effect, i.e., the negative income effect generated by government expenditure. In order to disentangle the crowding-out effect from the pure intertemporal redistribution of consumption risk, in this section we assume that the government uses taxes to finance a mandatory lump-sum transfer to the household, TR_t , that replaces G_t in equation (15). The consumer and

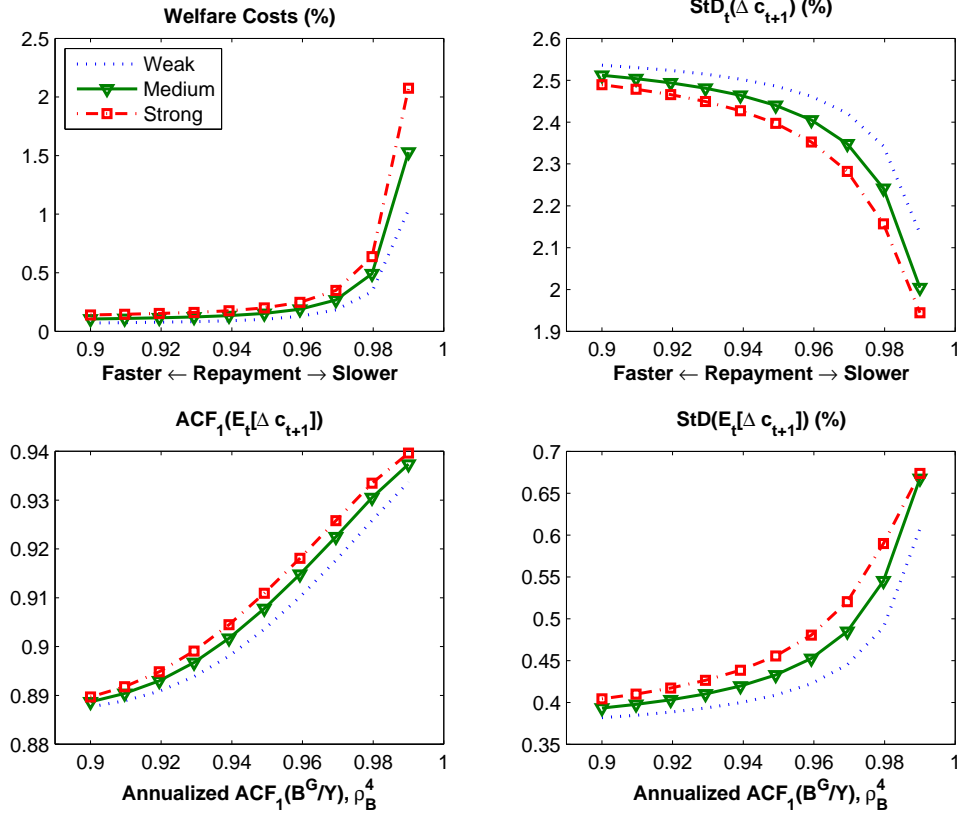


Fig. 6: Welfare Costs and Consumption Distribution

Notes - This figure shows the welfare costs and key moments of consumption growth. All the parameters are calibrated to the values used in Tables 1 and 3. The three lines reported in each plot are associated to different levels of intensity of the countercyclical fiscal policy described in equation (19). ‘Weak’, ‘Medium’, and ‘Strong’ policies are generated by calibrating ϕ_B to .3%, .45%, and .6%, respectively. Horizontal axis corresponds to different annualized autocorrelation, ρ_B^4 , of debt to output ratio, B^G/Y ; the higher the autocorrelation, the lower the speed of repayment. Welfare costs are calculated as in section 4.2.

government budget constraints and the resource constraint become, respectively:

$$\begin{aligned}
 C_t + Q_t Z_{t+1} + B_t &= (1 - \tau_t) W_t L_t + (Q_t + \mathcal{D}_t) Z_t + (1 + r_{f,t-1}) B_{t-1} + TR_t, \\
 B_t &= (1 + r_{f,t-1}) B_{t-1} + TR_t - T_t \\
 Y_t &= C_t + S_t + A_t X_t.
 \end{aligned}$$

This specification allows us to keep all marginal distortions in the first order conditions without having to deal with the change in the allocation generated by changes in G_t .

Figure 8 confirms our previous findings: it is the persistent alteration of the tax rate that changes

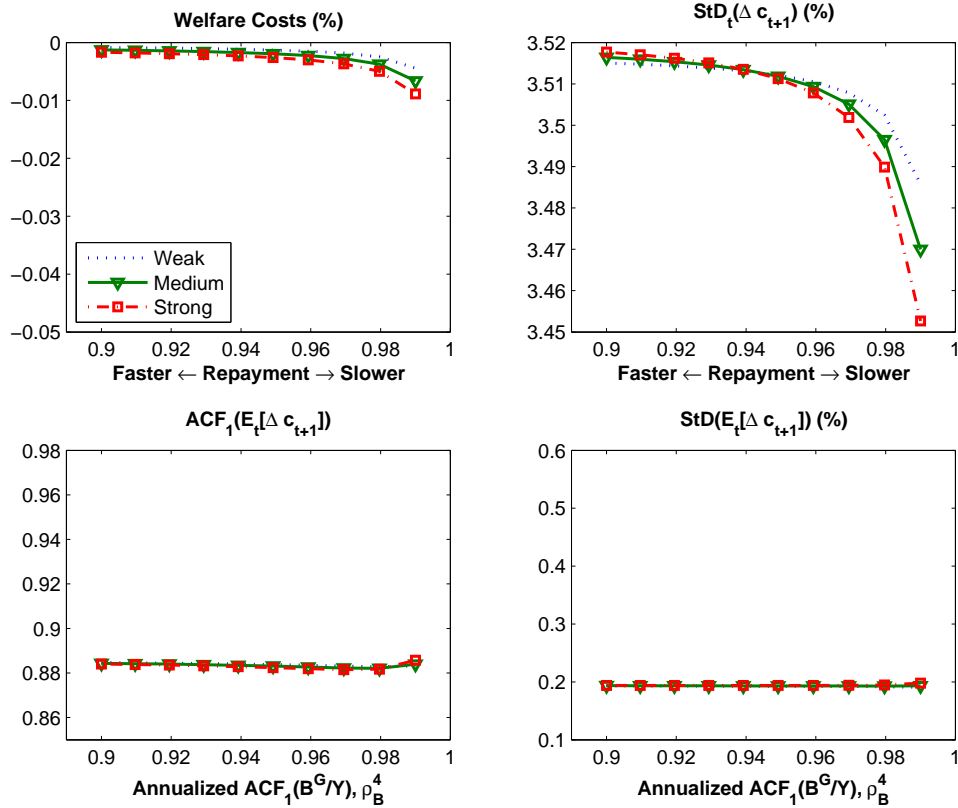


Fig. 7: Welfare Costs and Consumption Distribution (CRRA)

Notes - This figure shows the welfare costs and key moments of consumption growth. All the parameters are calibrated to the values used in Tables 1 and 3. The three lines reported in each plot are associated to different levels of intensity of the countercyclical fiscal policy described in equation (19). ‘Weak’, ‘Medium’, and ‘Strong’ policies are generated by calibrating ϕ_B to .3%, .45%, and .6%, respectively. Horizontal axis corresponds to different annualized autocorrelation, ρ_B^4 , of debt to output ratio, B^G/Y ; the higher the autocorrelation, the lower the speed of repayment. Welfare costs are calculated as in section 4.2.

the long-run behavior of consumption and produces welfare costs with recursive preferences. The crowding-out effect produced by government expenditure is relevant, but it explains just a small fraction of the welfare costs that we found in the previous section.

5 Optimal labor taxation

The time-zero problem. The time-zero Ramsey’s problem can be written as follows:

$$\max_{\{C_t, L_t, S_t, A_{t+1}\}_{ht}} U_0 = W(u_0, U_1)$$

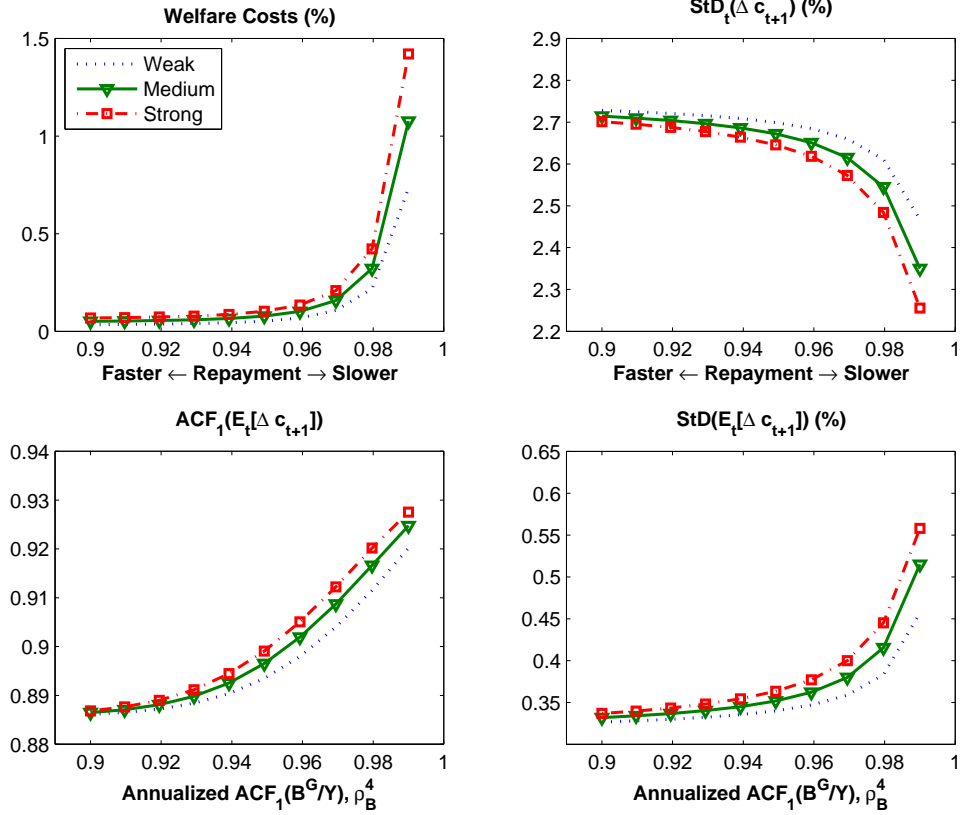


Fig. 8: Welfare Costs and Consumption Distribution with Transfer

Notes - This figure shows the welfare costs and key moments of consumption growth. All the parameters are calibrated to the values used in Tables 1, except for the IES, $\psi = 1/\gamma = .1$. The three lines reported in each plot are associated to different levels of intensity of the countercyclical fiscal policy described in equation (19). ‘Weak’, ‘Medium’, and ‘Strong’ policies are generated by calibrating ϕ_B to .3%, .45%, and .6%, respectively. Horizontal axis corresponds to different annualized autocorrelation, ρ_B^4 , of debt to output ratio, B^G/Y ; the higher the autocorrelation, the lower the speed of repayment. Welfare costs are calculated as in section 4.2. In this figure, we assumed taxes are used to finance lump-sum transfer to household.

subject to

$$\begin{aligned}
 Y_t &= C_t + A_t X_t + S_t + G_t \\
 \Upsilon_0 &= \sum_{t=0}^{\infty} \sum_{h^t} \left(\prod_{j=1}^t W_2(u_{j-1}, U_j) \right) W_1(u_t, U_{t+1}) [u_{C_t} C_t + u_{L_t} L_t] \\
 A_{t+1} &= \vartheta_t S_t + (1 - \delta) A_t \\
 \frac{1}{\vartheta_t} &= E_t [M_{t+1} V_{t+1}]
 \end{aligned}$$

where

$$W(u_t, U_{t+1}) = U_t \left[(1 - \beta) u_t^{1 - \frac{1}{\psi}} + \beta (\mathbb{E}_t U_{t+1}^{1 - \gamma})^{\frac{1 - \frac{1}{\psi}}{1 - \gamma}} \right]^{\frac{1}{1 - \frac{1}{\psi}}}$$

$$\Upsilon_0 \equiv W_1(u_0, U_1) u_{C_0} (Q_0 + \mathcal{D}_0) = W_1(u_0, U_1) u_{C_0} (1 - \delta) \frac{A_0}{\vartheta_t}$$

and $W_1 = \frac{\partial W}{\partial u}$, while $W_2 = \frac{\partial W}{\partial U}$.

The first three constraints are standard in the literature, as they capture the aggregate resource constraint, the implementability constraint, and the accumulation of the stock of varieties, respectively. The last constraint, instead, is not standard as it is based on a forward looking no-arbitrage condition that implicitly pins down the optimal accumulation of varieties in the decentralized economy.

In what follows, let $u_{C,t}^{Ram,EZ}$ be the multiplier attached to the resource constraint with recursive preferences; ξ be the multiplier related to the implementability constraint; Γ_t be the multiplier for the accumulation of varieties; O_t be the multiplier attached to the free-entry condition for patents, $\Xi_{C,t} \equiv \frac{\partial M_{t+1}/\partial C_t}{M_{t+1}}$, $\Xi_{L,t} \equiv \frac{\partial M_{t+1}/\partial L_t}{M_{t+1}}$, and $V_t^{Ram} \equiv \frac{\Gamma_t}{u_{C,t}^{Ram,EZ}}$. All these multipliers are multiplied by an appropriate common discount factor to make them stationary.

Optimality. The first order condition with respect to consumption implies what follows:

$$u_{C_t}^{Ram,EZ} = W_{1_t} u_{C_t}^{Ram,SL} + \xi W_{1_t} u_{C_t} F D_t - O_t \Xi_{C,t} V_t \quad (20)$$

where

$$F D_t \equiv (u_{C_t} C_t + u_{L_t} L_t) \left(\frac{W_{11t}}{W_{1_t}} + \frac{W_{1_t} W_{22t-1}}{W_{2_{t-1}}} \right),$$

and $u_{C_t}^{Ram,SL}$ is the multiplier obtained with time additive preferences and exogenous growth in a standard Stokey and Lucas (1983) economy.

Equation (20), shows that the shadow value of consumption under the optimal tax system can be decomposed in three different parts. The first component has to do with the multiplier that we would get with time additive preferences (i.e., when $W_{11} = W_{22} = 0$) in a model without free-entry

condition.

The second component, FD , originates from the recursive preferences of the household and captures sensitivity to future uncertainty and tax distortions. To see this, notice that both $\frac{W_{11t}}{W_{1t}}$ and $\frac{W_{1t}W_{22t-1}}{W_{2t-1}}$ depend on the continuation utility of the agent, U_t .

The last component takes into account the fact that the tax system can alter the growth of the economy by altering the private evaluation of the patents, V_t . It is this term that forces Ramsey to take seriously asset prices in order to find the optimal balance between growth and stabilization. With recursive preferences, $\Xi_{C,t}$ is sensitive to continuation utility risk on top of consumption risk. For this reason, Ramsey is called to adopt a tax system that optimally trades off current and future risk.

The first order condition with respect to labor states that:

$$MPL_t = MRS_{C_t, L_t}^{Ram, EZ} \equiv \frac{u_{L_t}^{Ram, SL} + \xi u_{L_t} FD_t - O_t \Xi_{C,t} V_t}{u_{C_t}^{Ram, SL} + \xi u_{C_t} FD_t - O_t \Xi_{L,t} V_t} \quad (21)$$

where MPL_t is the marginal product of labor, and $MRS_{C_t, L_t}^{Ram, EZ}$ is the marginal rate of substitution between consumption and labor under the optimal Ramsey plan. Equation 21 suggests two important results: i) Ramsey determines the current tax after accounting for the future distortions, FD , possibly generated by debt financing; and ii) the optimal taxation rate is a function of the private evaluation of growth opportunities, V_t .

Finally, the first order condition with respect to capital implies the following adjusted no-arbitrage equation:

$$V_t^{Ram} = E_t \left[M_{t+1}^{Ram} \left(MPA_{t+1} + (1 - \delta)V_{t+1}^{Ram} + (\eta V_{t+1}^{Ram} \vartheta_{t+1} - 1) \frac{S_{t+1}}{A_{t+1}} \right) \right] \quad (22)$$

where V_t^{Ram} denotes the shadow value of one extra patent, M_{t+1}^{Ram} is the Ramsey stochastic discount factor, $M_{t+1}^{Ram} = \frac{W_{2t} u_{C_{t+1}}^{Ram, EZ}}{u_{C_t}^{Ram, EZ}}$, and MPA_t is the marginal product of a new patent. The last term in (22) is related to the fact that increasing the variety stock improves future R&D productivity when $\eta < 1$. This term vanishes when $\eta = 1$ and $V_{t+1}^{Ram} = 1/\vartheta$.

5.1 Properties of the Optimal Labor Taxation

[TO BE ADDED]

6 Conclusion

Recent fiscal interventions have raised concerns about US public debt, future fiscal pressure, and long-run economic growth. This paper studies fiscal policy design in an economy in which: (i) the household has recursive preferences and is averse to both short- and long-run uncertainty, and (ii) growth is endogenously sustained through innovations whose market value is sensitive to the tax system. By reallocating tax distortions through debt, fiscal policy alters the composition of intertemporal consumption risk and the incentives to innovate, ultimately affecting long-term growth.

We find that countercyclical tax policies promoting short-run stabilization substantially increase long-run uncertainty and produce welfare losses as high as 2% of lifetime consumption. Intuitively, tax cuts successful at stabilizing the economy in the short-run upon the realization of adverse exogenous shocks, produce subsequent financing needs to restore long-run budget balance that generate uncertainty about future tax distortions. When tax distortions endogenously affect growth rates, this leads to more uncertainty about long-term growth prospects. Hence, in asset pricing language, reducing the extent of short-run growth risk comes at the cost of increasing the economy's exposure to long-run risk. Since our representative agent is averse to late resolution of uncertainty, more long-run risk imply lower welfare and lower incentives to invest in innovation and long-term growth.

In our setup, optimal fiscal policy corresponds to finding the distribution of consumption risk that optimizes both the market value of innovation and the timing of resolution of uncertainty. Equivalently, public debt arises as a device to reallocate tax distortions, and hence consumption risk, over time and across states, ultimately smoothing continuation utilities. At a broader level, our analysis conveys the need of introducing risk considerations in the current fiscal policy debate.

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