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ABSTRACT

When government debt is sluggish, consumption exhibits lower expected growth, more long-run uncertainty, and more long-run downside risk. Simultaneously, the risk premium on the consumption claim (Koijen et al. (2010), Lustig et al. (2013)) increases and features more positive (adverse) skewness. We rationalize these findings in an endogenous growth model in which fiscal policy is distortionary, the value of innovation depends on fiscal risk, and the representative agent is sensitive to the resulting distribution of consumption risk. Our model suggests that committing to a rapid reduction of the debt-to-output ratio can enhance the value of innovation, aggregate wealth, and welfare.

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1 Introduction

Since the onset of the fall 2008 financial crisis, the world has witnessed government interventions on an unprecedented scale aimed at preventing a major global depression. While the return of the world economy to positive growth suggests that these policies may have been successful at short-run stabilization, their long-term effects are still uncertain.

In many countries, policy makers are explicitly announcing their reduced commitment to a prompt consolidation of outstanding government debt. They are in favor of fiscal interventions that on the one hand, are supposed to be pro-growth, but on the other are perceived in the capital markets as very risky. This applies, for example, to the recent announcements of the Italian government that it would disregard the debt-to-output ratio reduction plan previously promised to the EU in order to provide more government expenditure and entitlements for its citizens. Similarly, the current US administration has decided to ignore the fiscal warnings of the Congressional Budget Office Outlook about the lack of sustainability (non stationarity) of the projected path of the US debt-to-output ratio (henceforth, debt-to-output).

These forecasts raise considerable uncertainty about the future stance of fiscal policy required for debt stabilization. Given the distortionary nature of tax instruments, current deficits may have substantial effects on the long-term prospects of the economy. In particular, short-run economic stabilization may come at the cost of dimmer and uncertain long-term growth, especially when the government has no specific commitment to promptly stabilize debt.

Using post–WW II US data, we estimate time variation in the speed of mean reversion of debt-to-output. This is an econometrically convenient way to quantify policy regime changes. Specifically, in our analysis we study changes in the half-life, that is, sluggishness, of the ratio of outstanding debt-to-output. In the spirit of the theoretical work of Croce et al. (2012), we then connect the autocorrelation of debt-to-output with the consumption risk distribution. In the data, we find that when debt-to-output becomes more sluggish, that is, the government is slow in adjusting debt-to-output, the distribution of consumption risk worsens. Specifically, we see that expected long-term growth declines and long-run risk both increases and features more negative skewness, that is, long-term growth downside risk. These results also apply to a broader cross section of 15 developed countries. Simultaneously, the risk premium on the consumption claim increases and features more positive (i.e., adverse) skewness.

We show that these empirical findings are a rational equilibrium outcome in a model in which (i) the representative agent cares about long-run risks; (ii) growth is endogenously supported by investments in innovation; and (iii) the government follows a fiscal policy rule consistent with US data. Through the lens of our macrofinance model, countercyclical tax policies promoting short-run stabilization substantially increase long-run uncertainty, causing a costly decline in innovation incentives and growth. These negative effects are aggravated when the government is not committed to a certain debt repayment plan speed. In contrast, tax smoothing policies aimed at stabilizing long-term growth with a commitment to a specific expected speed can significantly increase growth and welfare, even though short-run consumption risk remains substantial.

Our analysis thus identifies a novel and significant tension both in the data and in theory between short-run stabilization, "pro-growth" budget expansions, and realized long-run growth. This tension is driven by risk considerations quantified through the lens of a general equilibrium asset pricing model with endogenous growth. Given the magnitude of our welfare results, we regard long-term fiscal risk as a first-order determinant of fiscal policy design. Our study abstracts away from various channels through which fiscal stabilization may generate significant welfare benefits but helps to set the stage for future research on the net welfare effects of fiscal intervention.

On a broader level, our analysis conveys the need to introduce risk considerations into the current fiscal policy debate. Rather than exclusively focusing on average tax pressure and short-run growth gains, fiscal authorities should be concerned with the timing of and the uncertainty surrounding their fiscal policy.

Inspired by our novel empirical contribution, we study a richer version of the model of Croce et al. (2012) that features realistic fiscal dynamics estimated from US data. Our policy rule features time-varying speed of mean reversion of debt-to-output, and it enables us to go beyond the comparative static analysis of prior work. As in Barro (1979), our government finances an exogenous expenditure stream through a mix of taxes and noncontingent debt. Government expenditure is stochastic and only labor income taxes are available, as in Lucas and Stokey (1983). We extend this classic benchmark through two relevant economic mechanisms.

On the technology side, our economy grows at an endogenous and stochastic rate determined by firms' incentives to innovate (Romer 1990). By altering labor supply through tax dynamics, fiscal policy can affect the market value of innovative products and ultimately long-run growth.

On the household side, we adopt the recursive preferences of Epstein and Zin (1989) and Weil (1989, 1990) so that agents care about the intertemporal distribution of growth risk, as in Bansal and Yaron (2004). Specifically, agents are sensitive to the timing of taxation because they are averse to tax policies that amplify long-run growth risk. Because of these preferences, we examine fiscal policy design in an environment in which the government faces an explicit trade-off between short-run stabilization and long-run growth.

In this setting, the government's financing policy effectively serves as a device to reallocate consumption risk across different horizons. We find that tax smoothing is welfare enhancing if it is oriented toward long-run stabilization. Tax policies promoting short-run stabilization, in contrast, increase long-run risk and depress both average growth and welfare. We thus identify a relevant and novel tension between short-run stabilization and long-term growth.

Our results are driven by two complementary channels that reinforce each other and enrich the welfare implications of common tax-smoothing prescriptions. In the economy of Lucas and Stokey (1983), the cost of future tax distortions can be summarized exclusively by their effect on short-run consumption growth (the short-run consumption smoothing margin). In our setting, in contrast, we need to consider both an asset price and an intertemporal distortion margin.

The asset price channel is related to endogenous growth. In a stochastic version of the economy of Romer (1990), indeed, growth depends on the risk-adjusted present value of expected future profits. In our setting, the tax system can directly affect long-term growth by altering the risk characteristics of both profits and the consumption-based discount factor. Equivalently, the shadow cost of future tax distortions depends also on its impact on the market value of patented intermediate goods (henceforth patents).

With recursive preferences, however, the entire intertemporal distribution of future tax distortions becomes welfare relevant, as news about future long-run taxation affects continuation utility. This implicit preference for the timing of taxation stems from the intertemporal distortion margin. When agents have a preference for early resolution of uncertainty, they care about continuation utility smoothing in addition to consumption smoothing. Since continuation utility reflects expected long-run consumption, the tax system should take into account long-run consumption stabilization.

Under aversion to long-run uncertainty, the reallocation of consumption risk from the short- to the long-run can further depress welfare because of the asset price channel. With recursive preferences, indeed, the agent prices both short- and long-run profit risk. By increasing long-run growth risk, the short-run-oriented fiscal policies that we estimate in the US data lead to a drop in the market value of patents, research and development (R&D) investment, and growth. We also consider a modified calibration in which we introduce capital income taxation in addition to labor taxes in a revenue-neutral fashion, that is, we keep the total tax revenue constant. This is a novel configuration of the model that has not been explored in prior work. We show that taxing innovators and final producers reduces welfare and amplifies many of the effects explored in our benchmark model.

This interaction between the asset-price and intertemporal-distortion channels explains the sizeable benefits created by policies seeking to stabilize long-term growth prospects by responding to asset prices and their determinants.

1.1 Related Literature

Our objective is to characterize the link between government debt management policies and distribution of aggregate risk both in the data and in an equilibrium model in which both long-run asset prices and growth are endogenous. For this reason, consumption risk premia are a critical element of our study. In this respect, our analysis is closely related to the work of Tallarini (2000) and Alvarez and Jermann (2004, 2005), who link the welfare costs of aggregate consumption fluctuations to asset prices. We differ from them in that we explicitly consider the welfare implications of government policies and link these implications to the market value of innovation and the intertemporal distribution of consumption risk. Our results are consistent with the empirical consumption risk premia estimated by Koijen et al. (2010) and Lustig et al. (2013).

More recently, several studies have focused on evaluating fiscal policies in asset pricing settings. Gomes et al. (2010) calculate the distortionary costs of government bailouts in a model that is consistent with basic asset market data. Gomes et al. (2013) analyze fiscal policies in an incomplete-markets economy with heterogeneous agents. Gomes et al. (2012), Pastor and Veronesi (2012, 2013), and Kelly et al. (2016) examine the effects of policy uncertainty on economic outcomes and stock and option returns; and Glover et al. (2012) conduct a series of fiscal policy experiments in order to assess the links between the preferential tax treatment of debt, default risk, and aggregate fluctuations.

In complementary work, Sialm (2006, 2009) examines the link between tax risk and asset returns both empirically and theoretically from a household-income perspective. Lustig et al. (2008) and Lustig et al. (2012) examine the nature of fiscal risks. Belo, Gala, and Li (2013) and Belo and Yu (2013) examine the effects of government investment and spending on asset prices. All of these studies abstract away from the endogenous technological progress highlighted in Kung and Schmid (2015) and Corhay et al. (2015). Corhay et al. (2018) examines the interplay of government debt maturity and inflation. None of these papers addresses taxation and welfare costs in a long-term-risk-sensitive environment similar to ours.

We quantitatively examine the significance of fiscal risk channels by means of simple and implementable rules linking fiscal policy stance to macroeconomic conditions (see, among others, Leeper et al. (2010), Leeper et al. (2011), and Fernandez-Villaverde et al. (2015)). In contrast to these papers, our fiscal rules account for asset prices and expectations of future tax distortions as in the monetary policy studies of Gallmeyer et al. (2005) and Gallmeyer et al. (2017). We see our tax smoothing policies as devices to quantitatively trace the risk trade-off frontier faced by the fiscal authority. This is an important contribution, since with non-time-separable preferences the quantitative assessment of optimal fiscal policies is challenging, even in much simpler economic setups (Karantounias 2013, Karantounias 2018).

Croce et al. (2012) study the link between fiscal policies and pessimism in the sense of Hansen and Sargent (2010).[1] In contrast, we provide a broad and novel empirical analysis of the link between government debt and aggregate risk. Furthermore, we focus on a richer model with realistic fiscal policy rules and show that the benefits of stabilization are both horizon dependent and crucially related to the term structure of growth risk. Our positive analysis demonstrates that obtaining welfare benefits through tax smoothing is possible, provided that fiscal policy stabilizes long-run investment and features commitment to a specific path for debt-to-output.

Barlevy (2004) finds that the costs of business cycles can be substantial in stochastic models with endogenous growth. The present study differs from this important contribution in two respects. First, we explicitly consider fiscal stabilization in a risk-sensitive framework. Secondly, because we adopt recursive preferences, the intertemporal reallocation of consumption risk is central to our results.

The remainder of this paper is organized as follows. The empirical investigation is described in Section 2. Section 3 develops our model, and Section 4 concludes.

2 Empirical Investigation

In this section we test the predictions of Croce et al. (2012) in the time series of US data. Our goal is to characterize the empirical link between debt-to-output stabilization speed and moments of the distribution of consumption and consumption returns. To further support our results, in the next section we also use international data for a large cross section of developed countries.

Specifically, we estimate $\rho_{B,t}$, that is, the speed of adjustment of debt-to-output ($DGDP$), in several ways in order to assess the reliability of our results across methods. We start by adopting

[1] The article by Croce, Nguyen, and Schmid (2012) has been solicited for the Carnagie-Rochester-NYU Conference Series on Public Policy 'Robust Macroeconomic Policy' as a contribution to the robustness literature.

a quasi-maximum-likelihood approach to estimate the following system of equations:

$$DGDP_t = a + \rho_{B,t} DGDP_{t-1} + \epsilon_t \tag{1}$$

$$\rho_{B,t} = b + \rho_{\rho,B} \cdot \rho_{B,t-1} + \upsilon_t \tag{2}$$

We estimate these equations either by leaving $\rho_{\rho,B}$ unrestricted (state space model with AR(1), SSM-AR(1)), or by setting this parameter at a predetermined value for sensitivity analysis purposes. We also consider the extreme case $\rho_{\rho,B} = 1$ (state space model with random walk, SSM-RW(1)). We define these estimates respectively as $\hat{\rho}_t(DGDP)^{AR}$ and $\hat{\rho}_t(DGDP)^{RW}$.

As an alternative to the parametric approach described above, we also estimate rolling-window AR(1) models on $DGDP$ for various window lengths. This estimation framework inherently contains a large degree of model uncertainty around the choice of window size; therefore, we adopt a forecast combination mindset and use equally weighted averages of the autocorrelation estimates across a grid of window sizes. We look at an equally spaced grid of window sizes from 10 to 50 quarters, implying that the maximum window size represents approximately 20% of our sample size. We define this estimate as $\hat{\rho}_t(DGDP)^{RollWind}$.

As a way to aggregate these different estimates, we also construct a model ensemble using equally weighted averages across the non-parametric and parametric estimates:

$$\hat{\rho}_t(DGDP)^{Combo} = \frac{1}{2}\hat{\rho}_t(DGDP)^{RollWind} + \frac{1}{2}\left(\frac{1}{2}\hat{\rho}_t(DGDP)^{AR} + \frac{1}{2}\hat{\rho}_t(DGDP)^{RW}\right). \tag{3}$$

In Appendix A we report further econometric details, and in Appendix C we use simulation methods to document that our estimation strategy produces a good proxy of the true time-varying persistence of $DGDP$. We depict our estimates in figure 1. Our estimates exhibit significant time variation (top panel). Most importantly, across all of our series there is a visible counter cyclicality in the speed of mean reversion of debt-to-output. Alternatively, the speed of debt-to-output reduction tends to be pro-cyclical, i.e., fast in good economic times and slow during recessions. In what follows, we will use these terminologies interchangeably.

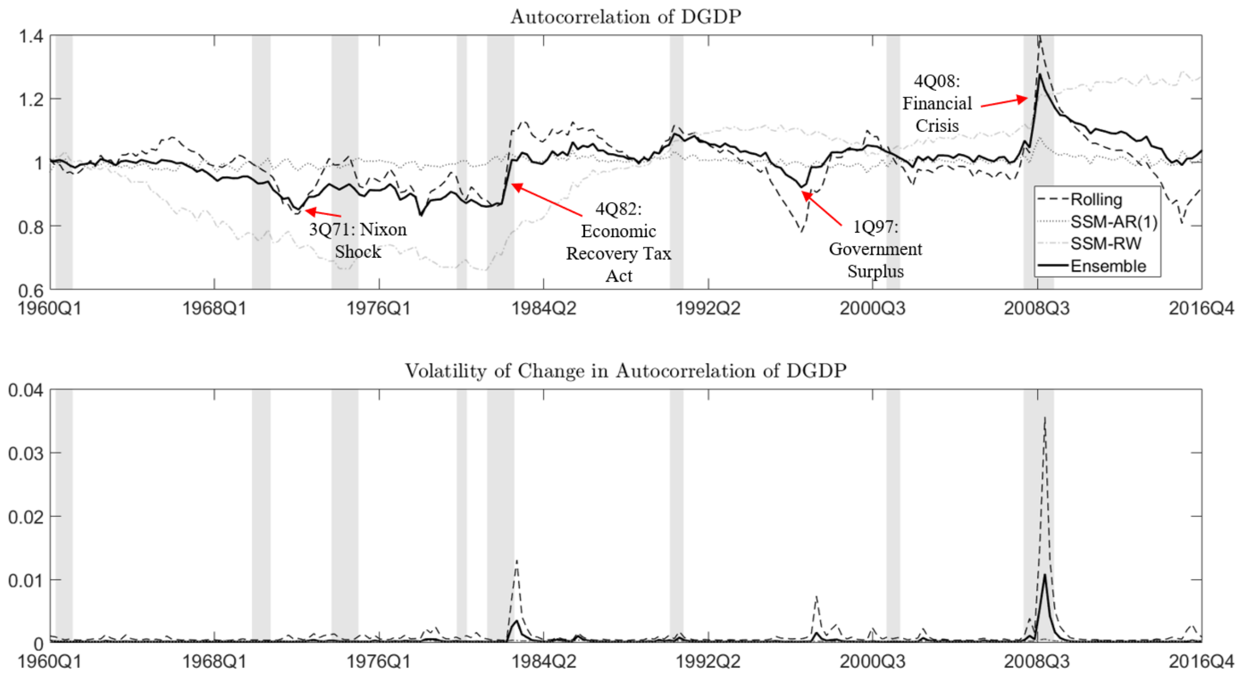


Fig. 1. Debt-to-Output Time-Varying Autocorrelation

Notes: The top panel of this figure shows estimates of time-varying mean-reversion speed for US debt-to-output, $\rho_{B,t}$, as defined in equations (1)–(2). The bottom panel shows estimates of the conditional volatility of shocks to the mean-reversion of debt-to-output extracted from a GJR-GARCH(1,1) model. All estimation details are reported in Appendix A.

The most pronounced fluctuations in our estimates of $\rho_{B,t}$ conform well with historical events. Specifically, we do observe a significant speed in the reduction of debt in the aftermath of both the 1971 Nixon shock and during the second mandate of the Clinton administration. We note that in our analysis, an administration that chooses not to increase government expenditures while collecting more taxes because of an economic boom (i.e., the IT boom in the US) is *de facto* more concerned about rapid debt reduction. On the other side, we see severe declines in the mean reversion of debt-to-output (run-ups in $\rho_{B,t}$) in the aftermath of both the Economic Recovery Tax Act approved during the 1982 recession and the Stimulus Package approved during the Great Recession.

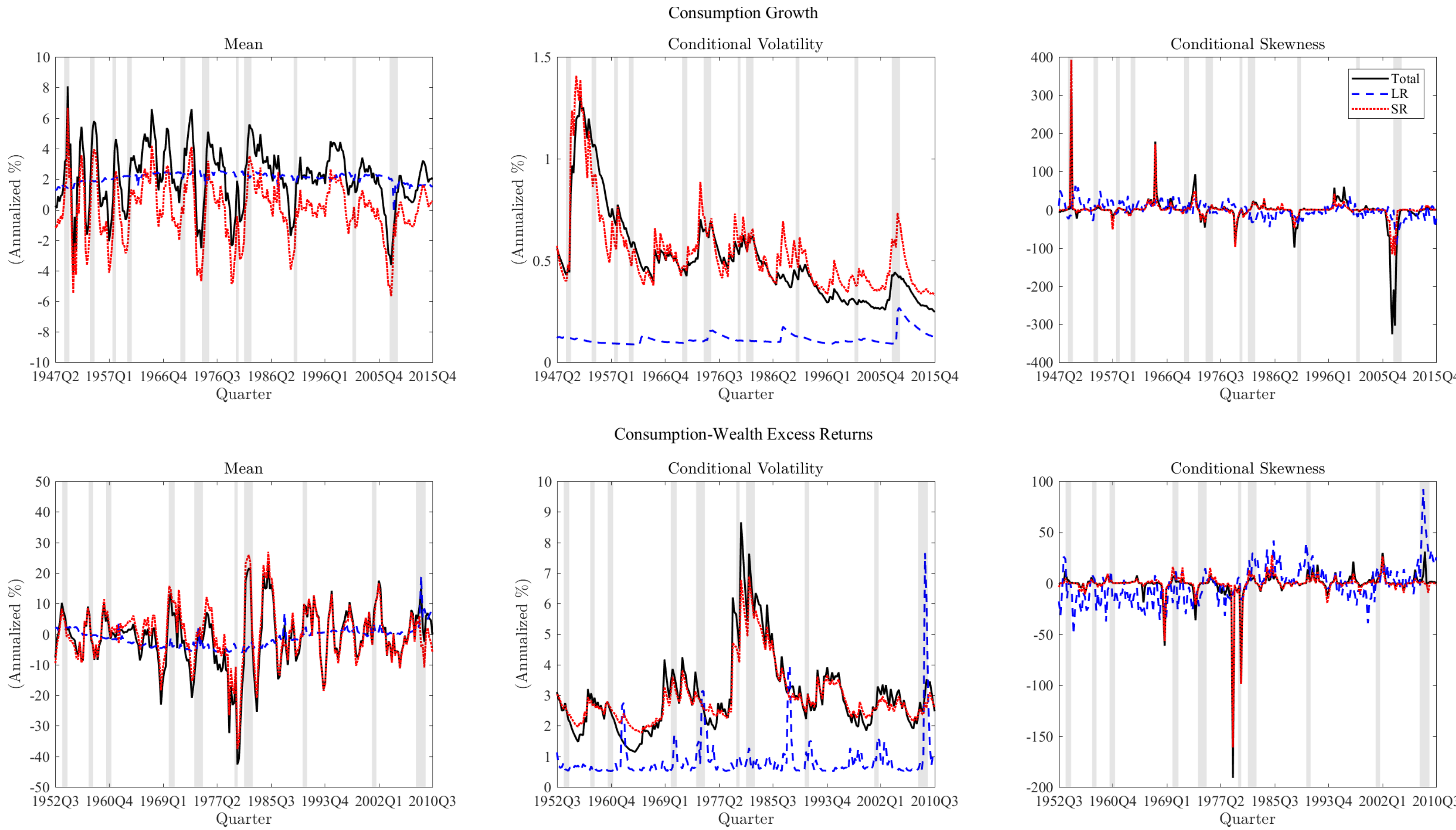


Fig. 2. Decomposed Moments of Consumption Growth and Consumption Claim Excess Returns

Notes: This figure shows quarterly conditional moments for one-year cumulative consumption growth (Δc_t) and consumption claim excess returns ($R^W_{ex,t}$). The long-run (LR) components are constructed from predictive regressions detailed in Appendix A and the short-run (SR) components are the fitted residuals from these predictive regressions. Quarterly data is from 1947:Q2–2016:Q4.

Our estimates are consistent with the idea that the US government tends to be less concerned about debt-to-output stabilization during economic slowdowns. Furthermore, the bottom panel of figure 1 shows that severe recessions also come with more uncertainty about the government's commitment to stabilize its debt. Indeed, when we modify equation (2) in order to allow for time-varying volatility in $\rho_{B,t}$ we find visible increases in uncertainty during recession episodes.[2]

We proceed by studying key moments of the distribution of both aggregate consumption growth and the returns of a claim to consumption (Lustig et al. (2013)). We use standard forecasting methods to disentangle the expected component from the unexpected shock to our variables of interest (see also Appendix A).

Let $y_{t+1\to t+J}$ be either the cumulative growth rate of consumption over J periods or the cumulative consumption excess return. In our analysis, we follow the language adopted in the long-run risk literature and refer to the conditional expectation of these variables as long-run (LR) components ($y^{LR}_{t+1\to t+J} := E_t[y_{t+1\to t+J}]$). The unexpected shock is denoted as a short-run (SR) component ($y^{SR}_{t+1\to t+J} := y_{t+1\to t+J} - y^{LR}_{t+1\to t+J}$). We report the level, conditional second moment, and the conditional skewness of each one of these components in figure 2. The top panels refer to consumption growth, whereas the bottom panels refer to the excess returns of a claim to consumption.

Our estimates for consumption growth are consistent with previous findings. We capture small but persistent fluctuations in the consumption growth long-run component, consistent with the time patterns estimated by Bansal et al. (2016). Consumption volatility is countercyclical and exhibits long-run moderation. The second moment of the long-run component of consumption is stable during booms, and it spikes significantly upward during recession episodes. Our skewness measure becomes strongly negative during the Great Recession, consistent with an increase in real downside risk.

Turning our attention to consumption excess returns, our methods capture the predictability and countercyclicality of time-varying volatility. Most of the dynamnics of the second moment are driven by short-run shocks, consistent with our findings about the growth of the consumption cashflow. Importantly, we also find that both the volatility and the skewness of expected returns

[2]This result contrasts the findings in Bryzgalova and Julliard (2019).

Table 1. $\rho_t(DGDP)$ **and Conditional Moments of Consumption Risk**

Horizons (J)	1	2	4	8	20
			Consumption Growth Distribution		
$E_t[\Delta c^{LR}_{t+J}]$	-0.47^{***}	-0.52^{***}	-0.68^{***}	-0.76^{***}	-0.73^{***}
	(0.14)	(0.14)	(0.12)	(0.16)	(0.19)
$\text{Var}_t[\Delta c_{t+J}]$	-0.53^{**}	-0.34^{**}	-0.58^{***}	-0.61^{***}	-0.67^{***}
	(0.26)	(0.15)	(0.22)	(0.18)	(0.19)
$\text{Var}_t[\Delta c^{LR}_{t+J}]$	0.24^{***}	0.26^{***}	0.49^{***}	0.36^{***}	0.36^{***}
	(0.07)	(0.08)	(0.16)	(0.09)	(0.10)
$\text{Skew}_t[\Delta c^{LR}_{t+J}]$	-0.26^{***}	-0.28^{***}	-0.30^{***}	-0.51^{***}	-0.46^{***}
	(0.07)	(0.07)	(0.07)	(0.11)	(0.07)
$\rho_t[\Delta c^{LR}_{t+1}]$	0.43^{**}				
	(0.18)				
			Consumption Claim Excess Returns Distribution		
$E_t[R^{W,LR}_{ex,t+J}]$	0.67^{***}	0.69^{***}	0.80^{***}	0.79^{***}	0.73^{***}
	(0.09)	(0.10)	(0.13)	(0.17)	(0.20)
$\text{Var}_t[R^{W}_{ex,t+J}]$	-0.29	-0.20	-0.26	-0.41^{*}	-0.49^{**}
	(0.21)	(0.22)	(0.24)	(0.21)	(0.23)
$\text{Var}_t[R^{W,LR}_{ex,t+J}]$	0.27^{***}	0.28^{***}	0.30^{***}	0.32^{***}	-0.03
	(0.08)	(0.09)	(0.09)	(0.09)	(0.12)
$\text{Skew}_t[R^{W,LR}_{ex,t+J}]$	0.31^{***}	0.32^{***}	0.44^{***}	0.58^{***}	0.53^{***}
	(0.07)	(0.07)	(0.07)	(0.11)	(0.17)
$\rho_t[R^{W,LR}_{ex,t+1}]$	0.58^{***}				
	(0.14)				

Notes: This table shows estimated coefficients from regressions of conditional moments for consumption growth (Δc_t) and consumption claim excess returns ($R^W_{ex,t}$) at various cumulative forward time horizons (J) on time-varying autocorrelation of debt-to-GDP ($\rho_t(DGDP)$). The long-run (LR) components are constructed from predictive regressions detailed in Appendix A, and the short-run (SR) components are implied fitted residuals. Quarterly data are from 1947:Q2–2016:Q4. Newey and West (1987) standard errors are in parentheses. One, two, and three asterisks denote significance at the 10%, 5%, and 1% levels, respectively.

spike upwards in periods of consumption growth distress. We note that, from a risk perspective, positive skewness in expected returns denotes periods of distress in capital markets because it implies the greater likelihood of states requiring higher ex-ante compensation for risk. This is particularly true if we focus on the Great Recession period.

Overall, we find that our estimation of the conditional moments of both consumption growth and excess returns is plausible and consistent with previous studies. This is an important result, as it validates our novel empirical contribution on the link between consumption distribution and debt-to-output convergence speed that we summarize in table 1.

Across different horizons, we find that a slower mean reversion in debt-to-output is followed

Table 2. $\rho_t(DGDP)$ **and Conditional Moments of GDP Risk**

Horizons (J)	1	2	4	8	20
			GDP Growth Distribution		
$E_t[\Delta y^{LR}_{t+J}]$	-0.46^{***}	-0.51^{***}	-0.69^{***}	-0.60^{**}	-0.54^{*}
	(0.09)	(0.09)	(0.16)	(0.27)	(0.29)
$\text{Var}_t[\Delta y_{t+J}]$	-0.50^{***}	-0.48^{**}	-0.42^{**}	-0.61^{***}	-0.66^{***}
	(0.18)	(0.22)	(0.20)	(0.20)	(0.18)
$\text{Var}_t[\Delta y^{LR}_{t+J}]$	0.48^{***}	0.22^{***}	0.46^{***}	0.44^{***}	0.38^{***}
	(0.17)	(0.06)	(0.17)	(0.16)	(0.11)
$\text{Skew}_t[\Delta y^{LR}_{t+J}]$	-0.26^{***}	-0.26^{***}	-0.28^{***}	-0.36	-0.35
	(0.06)	(0.06)	(0.06)	(0.25)	(0.23)
$\rho_t[\Delta y^{LR}_{t+1}]$	0.56^{**}				
	(0.22)				

Notes: This table shows estimated coefficients from regressions of conditional moments for GDP growth (Δy_t) at various cumulative forward time horizons (J) on time-varying autocorrelation of debt-to-GDP ($\rho_t(DGDP)$). The long-run (LR) components are constructed from predictive regressions detailed in Appendix A, and the short-run (SR) components are implied fitted residuals. Quarterly data are from 1947:Q2–2016:Q4. Newey and West (1987) standard errors are in parentheses. One, two, and three asterisks denote significance at the 10%, 5%, and 1% levels, respectively.

by (i.e., it forecasts) lower consumption volatility. This observation suggests that a less aggressive policy of debt consolidation can help stabilization. Consistent with the trade-off highlighted in Croce et al. (2012), however, we also observe slower future growth and more long-run consumption risk, as measured by the increase in both the persistence and the overall variance of the consumption long-run component.

In addition, the consumption long-run component inherits more negative skewness, a fact that goes beyond the insights of Croce et al. (2012). These facts apply also to output, as shown in table 2. Summarizing, current US fiscal data suggest that periods in which the government is less strict with debt-to-output mean reversion are followed by lower expected long-term growth, more long-run risk, and more long-run growth downside risk.

Simultaneously, these risk dynamics are visible also in wealth excess returns. As the autocorrelation of debt-to-output increases, the expected cost of equity increases and features both more variance and more positive skewness, implying that future distress periods may come with more severe downside risk in capital markets. In addition, the expected return becomes more persistent.

In Appendix B, we show that these results are robust to different ways of filtering the time-varying persistence of debt-to-output. In the next section, we show that these results apply also to other countries.

2.1 International Data

In this section, we consider a large cross section of 15 developed countries over the sample 1978–2014.[3] Macroeconomic data was sourced from the data set accompanying Alesina et al. (2019). Specifically, annual GDP by country is from OECD Economic Outlook n. 97, and country-level $DGDP$ is from the IMF Historical Public Debt Database.[4] Dividend yields and monthly returns for each country are from Ken French's Data Library, International Research Returns Data. These series are time-aggregated to an annual frequency to be consistent with our macroeconomic data.

In what follows, we study the role of debt-to-output persistence both on the dynamics of global variables aggregated across our countries and in a panel setting. We apply our previous empirical methods with three differences. First, we focus on GDP only for comparability reasons. Second, since our sample is annual, we compute moments over an horizon $J = 1, ..., 10$ years. Third, rolling autocorrelations of $DGDP$ are computed by using 15 years of annual data. Given these stricter data limitations, we focus only on the link between the persistence of debt-to-output and long-run conditional mean and variance of GDP growth and abstract away from third moments.

We start our analysis by constructing global measures of output growth, long-run output growth, and $DGDP$ ratios by computing the appropriate GDP-weighted averages across countries. We then estimate the following regressions on long-run moments of our global index per horizon J,[5]

$$
\begin{aligned}
y^{LR}_{w,t+1\to t+J} &= const^J + \beta^J_{w,E}\rho_{w,t}(DGDP) + \epsilon^J_{w,t}, \qquad (4)\\
Var_t(y^{LR}_{w,t+1\to t+J}) &= const^J + \beta^J_{w,V}\rho_{w,t}(DGDP) + \epsilon^J_{w,t},
\end{aligned}
$$

and report our results in table 3.

[3] Our data comprises: AUS, AUT, BEL, CAN, DEU, DNK, ESP, FIN, FRA, GBR, IRL, ITA, JPN, SWE, USA. Portugal (PRT) is not in this group due to inadequate equity market data.

[4] For Ireland, our source is IMF WEO April 2015.

[5] In our sample, the global $DGDP$ ratio has a time-trend that we filter out.

Table 3. Global Long-Run Impact of $\rho(DGDP)$

Horizons (J)	2	4	6	8	10
			Long-Run Mean		
$\beta^J_{w,E}$	-0.04^{*}	-0.14^{**}	-0.28^{**}	-0.39^{**}	-0.56^{**}
	(0.02)	(0.04)	(0.07)	(0.11)	(0.21)
R^2	0.17	0.44	0.57	0.57	0.48
			Long-Run Volatility		
$\beta^J_{w,V}$	0.03^{*}	0.08	0.75^{***}	1.46^{***}	2.49^{***}
	(0.02)	(0.08)	(0.24)	(0.34)	(0.21)
R^2	0.15	0.07	0.44	0.65	0.95

Notes: This table shows estimated coefficients from the following regressions:

$$y^{LR}_{w,t+1\to t+J} = \beta^J_{w,0} + \beta^J_{w,E}\rho_{w,t}(DGDP) + \epsilon^J_{w,t}$$
$$Var_t(y^{LR}_{w,t+1\to t+J}) = \beta^J_{w,0} + \beta^J_{w,V}\rho_{w,t}(DGDP) + \epsilon^J_{w,t}$$

where $y^{LR}_{w,t+J}$ represents long-run J-years-ahead cumulative GDP growth for the global index and $Var_t(y^{LR}_{w,t+J})$ represents its respective conditional variance. $\rho_{w,t}(DGDP)$ is the time-varying auto-correlation of debt-to-GDP of the global index. The global index is constructed from 15 countries with annual data from 1978 to 2014. The point estimates for $\beta^J_{w,V}$ and their standard errors are multiplied by 100. Newey and West (1987) standard errors are in parentheses. One, two, and three asterisks denote significance at the 10%, 5%, and 1% levels, respectively.

Global data support our main findings on the first two moments of aggregate risk, that is, when debt-to-output becomes more sluggish, expected long-run output growth declines and long-run risk increases over the medium-run. In the case of long-run risk volatility, the results become statistically more significant over longer horizons since annual data smoothes time-variation in variance over shorter horizons.

We then turn our attention to a panel estimation approach. Specifically, we jointly estimate the impact of the persistence of $DGDP$ both across countries and across horizons with both time fixed effects and country-level fixed effects. In our specification,

$$y^{LR}_{i,t+1\to t+J} = \beta_0 + \tilde{\beta}^J_1\rho_{i,t}(DGDP) + \alpha_i + \delta_t + \epsilon_{i,t} \tag{5}$$
$$Var_t(y^{LR}_{i,t+1\to t+J}) = \beta_0 + \tilde{\beta}^J_1\rho_{i,t}(DGDP) + \alpha_i + \delta_t + \epsilon_{i,t},$$

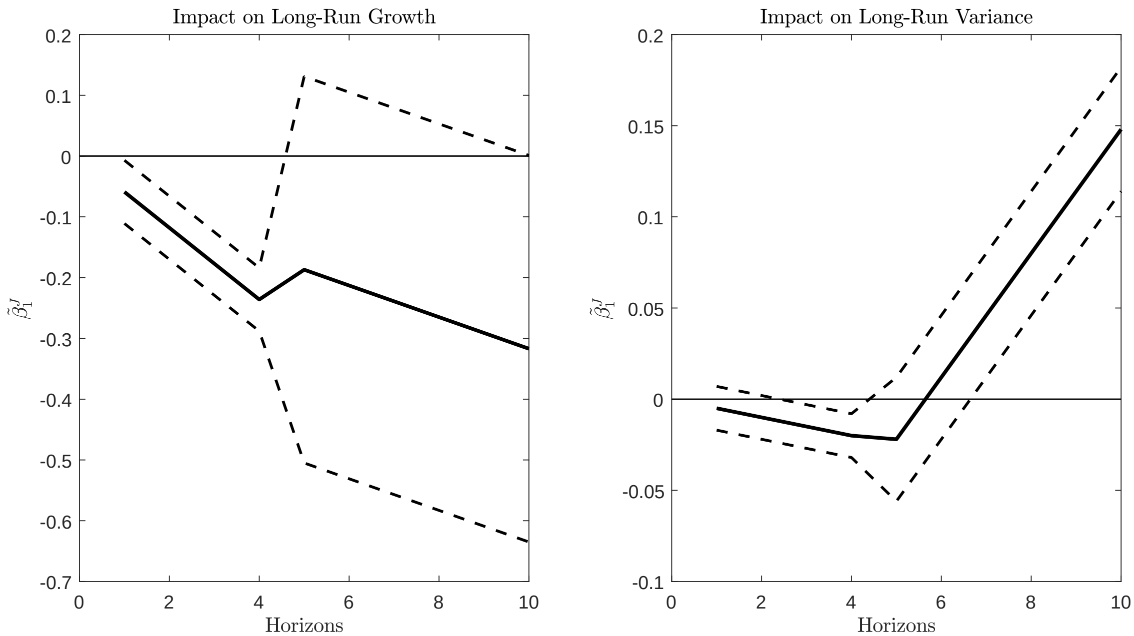


Fig. 3. $DGDP$ **Persistence and GDP Growth.**

Notes: This figures shows the composite coefficient $\tilde{\beta}_1^J$ estimated according to the system of equations (5)-(6). The left (right) panel refers to $E_t[\Delta y^{LR}_{t+J}]$ ($\text{Var}_t[\Delta y_{t+J}]$) for $J = 1, ..., 10$ on the horizontal axis. All estimates are ported in table B6. The entries for the figure are based on the specification with time fixed effect. Annual data for 15 countries is from 1978 to 2014. 95% confidence intervals (dashed lines) are based on the standard errors of $\tilde{\beta}_1^J$ conditional on $\tilde{\beta}_1^{J-1}$.

i indexes countries and $\tilde{\beta}_1^J$ is parameterized parsimoniously as follows

$$\tilde{\beta}_1^J = \begin{cases} \beta_1 \cdot J & 1 \leq J < 5 \\ \beta_2 + \beta_3 \cdot J & 5 \leq J \leq 10. \end{cases} \tag{6}$$

According to our specification, β_1^J is a linear function with respect to the horizon J. We choose $J = 4$ as threshold because our prior analysis with annual data shows that the effects on long-run volatility are stronger for $J > 4$. We report our estimates in table B6 (Appendix B) and their graphical representation in figure 3. According to our panel regressions, sluggish debt-to-output ratio is a leading indicator of lower growth at all horizons. For $J \leq 4$, this effect is statistically different from zero. Furthermore, sluggish debt-to-output anticipates higher long-run output risk, as determined by our conditional variance measure. This result is statistically significant for horizons longer than 4 years.

In the next section, we show that these results can be broadly replicated by a model featuring endogenous long-run growth and a government debt-to-output management policy with time-varying concern about debt stabilization.

3 Model

We use a stochastic version of the model of Romer (1990) in which the fiscal system affects all moments of the distribution of consumption growth, including its unconditional mean. Since our representative agent has recursive preferences, she cares about the intertemporal composition of consumption risk and is sensitive to both current and future taxation. Even though stylized, our model enables us to conduct a rich and detailed quantitative analysis of the link between growth risk and fiscal dynamics.

On the production side, the only source of sustained growth in the economy is the accumulation of patents that facilitate the production of a final consumption good. Patents are created through an innovation activity requiring investment in research and development (R&D) and can be stored. In this model, therefore, patents represent an endogenous stock of intangible capital. For simplicity, we abstract away from both tangible capital accumulation and capital taxation and allow the government to finance its expenditures only with a mix of debt and labor income taxes, as in Lucas and Stokey (1983).

In this class of models, the speed of patent accumulation (i.e., the growth rate of the economy) depends on the risk-adjusted present value of the additional cash-flow stream generated by the innovations. The fiscal system affects growth through two channels. First, by distorting the labor supply through taxation, fiscal policy affects future expected profits (the cash-flow channel). Second, 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 risk adjustments (the discount-rate channel). Asset pricing considerations are therefore required in order to understand the impact of a given tax system on the equilibrium growth rate of the economy.

Specifically, we show that smoothing distortional taxation using public debt affects the riskiness of patents' cash flows over both short and long horizons, thereby 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.

In what follows, we start by describing the household's problem, the production sector, and the government and fiscal policy. We then provide a description of the equilibrium link between asset prices and aggregate growth.

3.1 Household

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

$$U_t = \left[(1-\beta)u_t^{1-\frac{1}{\psi}} + \beta(\mathbb{E}_t U_{t+1}^{1-\gamma})^{\frac{1-\frac{1}{\psi}}{1-\gamma}}\right]^{\frac{1}{1-\frac{1}{\psi}}}, \tag{7}$$

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 (RRA) with respect to the bundle u_t, intertemporal elasticity of substitution (IES), and degree of complementarity between leisure and consumption, respectively.[6] Leisure is multiplied by A_t, our measure of standard of living, to guarantee balanced growth when $\nu \neq 1$.

When $\psi = \frac{1}{\gamma}$, these preferences collapse to the standard time-additive constant relative risk aversion (CRRA) case. When, instead, $\psi \neq \frac{1}{\gamma}$, the agent cares about the timing of the resolution of uncertainty, meaning that long-run growth news affects 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.

[6]Since labor is endogenous, γ is not a measure of consumption risk aversion.

In each period, the household chooses labor; consumption; equity shares, Z_{t+1}; and public debt holdings, B_t, to maximize utility according to the following budget constraint:

$$C_t + Q_t Z_{t+1} + B_t = (1-\tau_t) W_t L_t + (Q_t + D_t) Z_t + B_{t-1}(1 + r^f_{t-1}), \tag{8}$$

where D_t denotes aggregate dividends (to be specified in equation (25)), Q_t is the market value of an equity share, and r^f_t is the short-term risk-free rate. Wages, W_t, are taxed at a rate τ_t.

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

$$M_{t+1} = \beta \left(\frac{u_{t+1}}{u_t}\right)^{\frac{1}{\nu}-\frac{1}{\psi}} \left(\frac{C_{t+1}}{C_t}\right)^{-1/\nu} \left(\frac{U^{1-\gamma}_{t+1}}{\mathbb{E}_t[U^{1-\gamma}_{t+1}]}\right)^{\frac{1/\psi-\gamma}{1-\gamma}}, \tag{9}$$

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

$$\begin{aligned} Q_t &= \mathbb{E}_t[M_{t+1}(Q_{t+1} + D_{t+1})] \\ \frac{1}{1+r^f_t} &= \mathbb{E}_t[M_{t+1}]. \end{aligned}$$

In equilibrium, the representative agent holds the entire supply of both bonds and equities. The latter is normalized to be one: $Z_t = 1 \quad \forall t$. The intratemporal optimality condition on labor takes the following form:

$$\frac{1-\theta_c}{\theta_c} A_t^{(1-1/\nu)} \left(\frac{C_t}{1-L_t}\right)^{1/\nu} = (1-\tau_t) W_t \tag{10}$$

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

3.2 Production

The production process involves three sectors. The final consumption good is produced in a competitive sector using labor and a bundle of intermediate goods. Intermediate goods are produced by firms that have monopoly power and hence realize positive profits. Intermediate-good producers use these rents to acquire the right of production from innovators. Innovators create new patents through R&D investment and are subject to a free-entry condition.

Final-good firm. A representative and competitive firm produces the economy's single final output good, 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:

$$Y_t = \Omega_t L_t^{1-\alpha} \left[\int_0^{A_t} X_{it}^{\alpha} \, di \right], \tag{11}$$

where Ω_t denotes the 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.

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

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

where P_{it} is the price of intermediate good i at time t. Profit maximization thus implies

$$\begin{aligned} X_{it} &= L_t \left(\frac{\Omega_t \alpha}{P_{it}} \right)^{\frac{1}{1-\alpha}}, \\ W_t &= (1-\alpha) \frac{Y_t}{L_t}. \end{aligned} \tag{12}$$

Intermediate-good firms. Each intermediate good $i \in [0, A_t]$ is produced by a 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 fixed and equal to one. Taking the demand schedule of the final-good producer (equation (12)) as given, each firm chooses its price, P_{it}, to maximize the following operating 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 obtain

$$\begin{aligned} X_{it} &\equiv X_t = L_t(\Omega_t \alpha^2)^{\frac{1}{1-\alpha}}, \\ \Pi_{it} &\equiv \Pi_t = (\frac{1}{\alpha} - 1)X_t. \end{aligned} \tag{13}$$

In view of this symmetry, in what follows we drop the subscript i. Equations (11) and (13) allow us to express final output in the following compact form:

$$Y_t = \frac{1}{\alpha^2} A_t X_t = \frac{1}{\alpha^2} A_t L_t (\Omega_t \alpha^2)^{\frac{1}{1-\alpha}}. \tag{14}$$

Since both labor and productivity are stationary, equation (14) implies that the long-run growth rate of output is determined by the expansion of the variety of intermediate goods, A_t. This expansion stems from endogenous innovation conducted in the R&D sector, which we describe next.

Research and development. Innovators develop blueprints for new intermediate goods 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 the next period on, the new monopolists produce the new varieties and make profits. We assume that each existing variety becomes obsolete with probability $\delta \in (0, 1)$. In this case, its production is terminated. Given these assumptions, the cum-dividend value of an existing variety, V_{it}, is equal to the present value of all future expected profits and can be recursively expressed as follows:

$$V_t = \Pi_t + (1 - \delta) E_t [M_{t+1} V_{t+1}]. \tag{15}$$

Let $1/\vartheta_t$ be the cost of producing a new variety. The free-entry condition in the R&D sector implies that at the optimum

$$\frac{1}{\vartheta_t} = E_t \left[M_{t+1} V_{t+1} \right], \tag{16}$$

that is, the cost of producing a variety must equal the market value of the new patents. Equation (16) is central in this class of models because it implicitly pins down the optimal level of investment in R&D, S_t, and ultimately the growth rate of the economy.

Specifically, our stock of patents, A_t, evolves as follows:

$$A_{t+1} = \vartheta_t S_t + (1-\delta) A_t,^{7} \tag{17}$$

and hence

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

In the spirit of Jermann (1998), we assume that the innovation technology ϑ_t involves a congestion externality effect capturing decreasing returns to scale in the innovation sector,

$$\vartheta_t = \chi \left(\frac{S_t}{A_t} \right)^{\eta - 1} \qquad \eta \in (0,1), \tag{18}$$

where $\chi > 0$ is a scale parameter and $\eta \in [0,1]$ is the elasticity of new intermediate goods with respect to R&D. This specification captures 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 (16)–(18), we obtain the following optimality condition for investment in R&D:

$$\frac{1}{\chi} \left(\frac{S_t}{A_t} \right)^{1-\eta} = E_t \left[\sum_{j=0}^{\infty} M_{t+j|t} (1-\delta)^j \Pi_{t+j} \right], \tag{19}$$

where $M_{t+j|t} \equiv \prod_{s=1}^{j} M_{t+s}$ is the j-steps-ahead pricing kernel and $M_{t|t} \equiv 1$. Equation (19) suggests that the amount of innovation intensity in the economy, S_t/A_t, is directly related to the discounted

[7] This 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, equations (16) and (17) must be replaced by $A_{t+1} = (1-\delta)(\vartheta_t S_t + A_t)$ and $\frac{1}{\vartheta_t} = E_t \left[M_{t+1} (1-\delta) V_{t+1} \right]$, respectively. Our results are not sensitive to this modeling choice.

value of future profits. When agents expect profits above (below) steady state, they have an incentive to invest more (less) in R&D, ultimately boosting (reducing) long-run growth.

3.3 Government

Expenditure to be financed. The government faces an exogenous and stochastic expenditure stream, G_t, that evolves as follows:

$$\frac{G_t}{Y_t} = \frac{1}{1 + e^{-gy_t}}, \tag{20}$$

where

$$gy_t = (1-\rho)\overline{gy} + \rho_g gy_{t-1} + \epsilon_{G,t}, \quad \epsilon_{G,t} \sim N(0, \sigma_G^2).$$

This specification ensures that $G_t \in (0, Y_t) \quad \forall t$, and it enables us to replicate key features of the expenditure-to-output ratio observed in the US data. In most of our analysis, we focus only on the expenditure component of total public liabilities and abstract away from entitlements. We also abstract away from the volatility shocks documented by Fernandez-Villaverde et al. (2015).

Financing rules. In order to finance these expenditures, the government can use income tax, $T_t = \tau_t W_t L_t$, or public debt according to the following budget constraint:

$$B_t = (1 + r_{f,t-1})B_{t-1} + G_t - T_t. \tag{21}$$

The government's fiscal stance accommodates taxation and deficit financing through simple, implementable, and plausible fiscal rules, in the spirit of Favero and Monacelli (2005), Schmitt-Grohe and Uribe (2007), and Leeper et al. (2010). In this paper, we focus on a tax rule that allows for tax smoothing and lets the government adjust its fiscal stance according to prevailing macroeconomic conditions. More specifically, we specify the government's policy in terms of a debt-management rule, with tax rates implied by the budget constraint, as follows:

$$\frac{B_t}{Y_t} = \rho_{B,t}\frac{B_{t-1}}{Y_{t-1}} + \epsilon_t^B, \tag{22}$$

$$\epsilon_t^B = A_\omega \epsilon_t + A_G \epsilon_{G,t} + A_\phi \epsilon_{\phi,t}, \tag{23}$$

where A_ω and A_G are constant parameters that determine both the intensity and cyclicality of the government response to productivity and expenditure shocks, respectively, and $\epsilon_{\phi,t} \sim i.i.d.N(0, \sigma_\phi^2)$ is a pure policy shock that is relevant in bringing the model closer to the data. The parameter μ_B captures the long-run level of debt, whereas $\rho_{B,t}$ is a time-varying measure of the speed of repayment of debt: the higher the value of ρ_B, the slower the repayment of debt relative to output. Specifically, as in our empirical investigation we assume that

$$\rho_{B,t} = \rho_B(1 - \rho_{\rho,B}) + \rho_{\rho,B} \cdot \rho_{B,t-1} + A_\rho \epsilon_t,$$

in which $\rho_B \in (0, 1)$ so that the debt-to-GDP ratio is stationary in the long run.

This parsimonious specification has two main advantages. First, the condition $\rho_B < 1$ guarantees that the debt-to-output ratio remains stationary, consistent with the evidence in Bohn (1998). Second, this specification replicates key empirical properties of the US debt-to-output ratio, including the mild cyclicality of the speed of repayment, which is captured by setting $A_\rho < 0$.

3.4 Market Clearing

We complete the description of our model by discussing our market clearing conditions. In the labor market, the following holds:

$$\frac{1-\theta_c}{\theta_c}\left(\frac{C_t}{A_t(1-L_t)}\right)^{1/\nu} = (1-\tau_t)\frac{(1-\alpha)Y_t}{A_t L_t}. \tag{24}$$

The market clearing condition for the final good is given by

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

implying that final output is used for consumption, R&D investment, production of intermediate goods, and public expenditure.

Given the multisector structure of the model, various assumptions on the constituents of the stock market can be adopted. We assume that the stock market is a claim to the net payout from 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:

$$D_t = \Pi_t A_t - S_t. \tag{25}$$

3.5 Growth, Asset Prices, and Risk Distribution

Combining equations (16)–(19), we obtain the following expression for growth rate in the economy:

$$\begin{aligned} \frac{A_{t+1}}{A_t} &= 1 + \delta + \chi^{\frac{1}{1-\eta}} E_t \left[M_{t+1} V_{t+1} \right]^{\frac{\eta}{1-\eta}} \qquad (26) \\ &= 1 + \delta + \chi^{\frac{1}{1-\eta}} E_t \left[\sum_{j=1}^{\infty} M_{t+j|t} (1-\delta)^{j-1} \left(\frac{1}{\alpha} - 1 \right) \left(\Omega_{t+j} \alpha^2 \right)^{\frac{1}{1-\alpha}} L_{t+j} \right]^{\frac{\eta}{1-\eta}}. \end{aligned}$$

The relevance of equation (26) is twofold, as it enables us to highlight 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 monotonic 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 profit risk matters for the determination of the value of a patent. When the agent has recursive preferences, however, optimal growth depends also on the endogenous amount of volatility in expected long-run profits. A characterization of the entire intertemporal distribution of risk is required.

Second, since profits are proportional to labor, and labor supply is sensitive to the tax rate (equation (24)), a fiscal system with sluggish debt repayment ultimately introduces long-lasting fluctuations in future profits. Depending on the dynamic properties of current and future taxes, tax smoothing can depress or enhance long-term growth and ultimately wealth and welfare.

Our study shows that in an economy calibrated to match key asset pricing facts, short-run-oriented tax smoothing comes at the cost of reduced long-run growth, whereas long-run-oriented tax smoothing can produce benefits. This tension is at the core of our welfare analysis.

3.6 Calibration

We report our benchmark calibration along with the implied main statistics of our model in table 4. RRA, IES, and the subjective discount factor are set to target the low historical average of the risk-free rate and the consumption claim risk premium estimated by Lustig et al. (2013). Targeting 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. The parameters ν and θ_c control the labor supply and are chosen to yield a steady-state share of hours worked of 1/3 and a steady-state Frisch elasticity of 0.7, respectively. These values are standard in the literature.

Turning to technology parameters, the constant α captures the relative weight of labor and intermediate goods in the production of final goods, and, by equation (13), controls the markup and hence profits in the economy. We choose this parameter to match the empirical share of profits in aggregate income. The parameter η, the elasticity of new intermediate goods with respect to R&D, is within the range of the panel and cross-sectional estimates of Griliches (1990). We set $1-\delta$ to 0.97, which corresponds to an annual depreciation rate of R&D capital of about 14%, the value assumed by the Bureau of Labor Statistics in its R&D stock calculations. The scale parameter χ is chosen to match the average growth rate of the US economy. We calibrate our productivity parameters to be consistent with our estimates on the volatility and autocorrelation of US consumption growth.

All of the fiscal policy parameters can be estimated directly in the data. We detail our estimations in Appendix C and choose parameter values consistent with our confidence intervals. Under our benchmark calibration, both the average tax rate and its volatility are consistent with the data.

Our results, therefore, are not driven by implausible tax rate dynamics. Importantly, we set $|A_\rho|$ to the lower bound of our empirical confidence interval, that is, to a very conservative value. In the next sections, we run sensitivity analysis with respect to A_ρ and show that our results are enhanced when we choose stronger values for this parameter.

In Appendix D, we provide more details on both our solution methods and our computation of welfare.

3.7 Results, Policy, and Welfare

Simulations. We simulate our model and report the results in table 5. The results are qualitatively, and in many cases quantitatively, consistent with our empirical findings. Specifically, in an economy with endogenous growth and time-varying concern for debt-to-output convergence, when the government allows debt-to-GDP to be very sluggish, expected growth declines and short-run stabilization is obtained at the cost of increasing long-run uncertainty.

Interestingly, the model also reproduces the rise of negative skewness in long-run growth. From a mathematical point of view, this is due to the strong nonlinearities of our economic environment. On an intuitive level, this result arises from the interplay of two observations: future tax rate uncertainty increases with debt-to-output, and the concern for debt stabilization is counter cyclical.

The increase in future tax uncertainty with increases in the ratio of outstanding debt to GDP is a well-known result in economies with random productivity shocks. Put simply, since the tax base is uncertain, the future tax rate required to consolidate debt is uncertain as well. The gap in the future tax rate across good and bad productivity states widens when the current outstanding liabilities of the government are higher.

Since our benchmark policy prescribes that in bad times the government decides to both run more pronounced deficits and let future debt-to-output stabilization be slower, future downside periods are also associated with less leeway in future fiscal capacity. That is, future negative productivity shocks are associated with even more severe tax rate increases. In the language of Segal et al. (2015), this means that our benchmark fiscal policy endogenously makes bad tax

Table 4. Calibration and Main Statistics

Panel A: Parameters

Description	Symbol	Value
Preference parameters		
Discount factor (%)	β	99.6
Intertemporal elasticity of substitution	ψ	1.38
Risk aversion	γ	4.00
Consumption-labor elasticity	ν	0.70
Utility share of consumption (%)	θ_c	9.21
Technology parameters		
Elasticity of substitution between intermediate goods	α	0.70
Elasticity of new varieties wrt R&D investment	η	0.82
Survival rate of intermediate goods	$1-\delta$	0.97
Scale parameter for R&D externalities	χ	0.52
Standard deviation of technology shock (%)	σ	0.50
Autocorrelation of productivity	ρ	0.96
Government expenditure parameters		
Log-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	0.80
Financing policy parameters		
Average autocorrelation of debt-output	ρ_B	0.98
Response to productivity news	A_z	-0.4
Response to expenditure news	A_G	0.50
Standard deviation of debt-output shocks	σ_ϕ	0.01
Persistence of autocorrelation of debt-output	$\rho_{\rho,B}$	0.92
Response of autocorrorelation of debt-output to productivity news	A_ρ	-0.1

Panel B: Moments

	Data		Model		Data		Model
Description	Estimate	SE		Description	Estimate	SE	
$E(\Delta c)$	2.09	0.25	2.08	$E(L/3)$	40.63	0.13	34.02
$\sigma(\Delta c)$	1.63	0.18	1.92	$E(\tau)$ (%)	32.93	0.99	33.50
$ACF_1(\Delta c)$	0.09	0.16	0.26	$\sigma(\tau)$ (%)	7.56	0.64	9.51
$\sigma(m)$ (%)			20.66	$E(r_f)$	1.01	0.12	2.44
$E(r^C)$	3.57	1.16	3.52				

Notes: This table reports the benchmark quarterly calibration of our model along with the main moments of interest. All moments are annualized and multiplied by 100, except the first-order autocorrelation of consumption growth, $ACF_1(\Delta c)$. The log discount factor is denoted by m, and τ is the labor tax rate. r^C and r_f are the return of the consumption claim and the risk-free bond, respectively. $E(L/3)$ is the fraction of hours worked. The entries for the data moments are based on (i) aggregate data provided in the NIPA tables, for the sample 1947:Q1–2016:Q4, and (ii) the estimates in Lustig et al. (2013).

Table 5. Consumption, Wealth, and Aggregate Risk

Horizons (J)	1	2	4	8	20
			Consumption Growth Distribution		
$E_t[\Delta c^{LR}_{t+J}]$	−0.87	−0.92	−0.92	−0.93	−0.91
$\text{Var}_t[\Delta c_{t+J}]$	−0.03	−0.02	−0.03	−0.05	−0.02
$\text{Var}_t[\Delta c^{LR}_{t+J}]$	0.06	0.14	0.05	0.05	0.05
$\text{Skew}_t[\Delta c^{LR}_{t+J}]$	−0.70	−0.72	−0.75	−0.74	−0.71
$\rho_t[\Delta c^{LR}_{t+1}]$	0.02				
			Consumption Claim Excess Returns Distribution		
$E_t[R^{W,LR}_{ex,t+J}]$	0.59	0.57	0.55	0.50	0.36
$\text{Var}_t[R^{W}_{ex,t+J}]$	−0.05	−0.06	−0.07	−0.07	−0.05
$\text{Var}_t[R^{W,LR}_{ex,t+J}]$	0.00	0.09	0.04	0.04	0.03
$\text{Skew}_t[R^{W,LR}_{ex,t+J}]$	0.47	0.45	0.43	0.39	0.29
$\rho_t[R^{W,LR}_{ex,t+1}]$	0.07				

Notes: All figures are obtained from a long-sample simulation of our model, calibrated as in table 4. The coefficients reported are computed by applying the empirical methods detailed in section 2 and Appendix A on the simulated data. The top (bottom) portion of this table shows estimated coefficients from regressions of conditional moments for consumption growth (Δc_t) and consumption claim excess returns ($R^W_{ex,t}$) at various cumulative forward time horizons (J) on time-varying autocorrelation of debt-to-GDP ($\rho_t(DGDP)$). The long-run (LR) components are constructed from predictive regressions detailed in Appendix A.

rate volatility more pronounced than good tax rate volatility. Equivalently, there is more adverse conditional skewness. In what follows we clarify that these statements apply to consumption growth because, firstly, they affect the risk properties of the monopolist rents that motivate innovation and long-run growth. Furthermore, these patterns are also reflected in a consistent manner in the consumption returns. As in the data, when the autocorrelation of debt-to-output increases, risk premia increase and exhibit more volatility and more adverse skewness.

The role of preferences. To further highlight the relevance of the aforementioned results, we repeat the analysis, this time focusing on a version of our model with CRRA preferences ($\psi = 1/\gamma = 0.25$). This is a setting in which patent valuation is not directly sensitive to news-shocks risk. In table 6, we show that our model without recursive preferences fails to reproduce the key consumption distribution properties that we have highlighted so far. Thus, our results are not driven solely by our endogenous growth production structure, but rather by its interplay with a rich asset pricing setting in which all moments of the consumption distribution matter.

Table 6. Model: $\rho_t(DGDP)$ and Conditional Moments of Risk with CRRA

Horizons (J)	1	2	4	8	20
			Consumption Growth Distribution		
$E_t[\Delta c^{LR}_{t+J}]$	-0.09	0.03	0.25	0.53	0.75
$\mathrm{Var}_t[\Delta c_{t+J}]$	0.03	0.04	0.00	0.02	0.02
$\mathrm{Var}_t[\Delta c^{LR}_{t+J}]$	-0.02	-0.02	-0.01	0.00	0.00
$\mathrm{Skew}_t[\Delta c^{LR}_{t+J}]$	-0.07	0.03	0.20	0.42	0.57
$\rho_t[\Delta c^{LR}_{t+1}]$	-0.01				

Notes: All figures are obtained from a long-sample simulation of our model, calibrated as in table 4, with the additional restriction $\psi = 1/\gamma$. The coefficients reported are computed by applying the empirical methods detailed in section 2 and Appendix A to the simulated data. This table shows estimated coefficients from regressions of conditional moments for consumption growth (Δc_t) at various cumulative forward time horizons (J) on time-varying autocorrelation of debt-to-GDP ($\rho_t(DGDP)$). The long-run (LR) components are constructed from predictive regressions detailed in Appendix A.

Counterfactual analysis. In order to better understand the relevance of time-varying concerns for the speed of debt stabilization, we compare our benchmark model to one in which there is a commitment to a fixed half-life of debt-to-output. Specifically, in figure 4 we show how expected growth, long-run risk, and welfare all change as we progressively bring the parameter A_ρ to zero.

As the government commits to less uncertainty on the persistence of debt-to-output, long-term tax pressure uncertainty declines making both long-run profits risk ($StD(E_t[\pi_{t+1}])$) and long-run consumption risk ($StD(E_t[\Delta c_{t+1}])$) less pronounced. Since the agent prices long-run risk, a reduction in long-term growth swings reduces the required cost of capital for innovative investments and helps average long-term growth, according to equation (26). As a result, welfare increases. In Appendix G, we report both unconditional and conditional moments of interest for a calibration featuring a stronger value for A_ρ and show that our results become stronger.

In figure 5(a), we assess the welfare implications of a financing policy with a full commitment to a fixed speed of repayment of public debt, ρ_B, for different targeted values of this parameter. Consistent with our previous result, when ρ_B is set to the value specified in the benchmark calibration we obtain an improvement in welfare. When the commitment is to a slower speed of debt repayment (i.e., the values of ρ_B are higher), welfare declines and can become negative. This is related to the fact that as ρ_B increases our financing policy stabilizes short-run consumption fluctuations (as in Croce et al. (2012)) at the cost of increasing long-run risk in the economy and

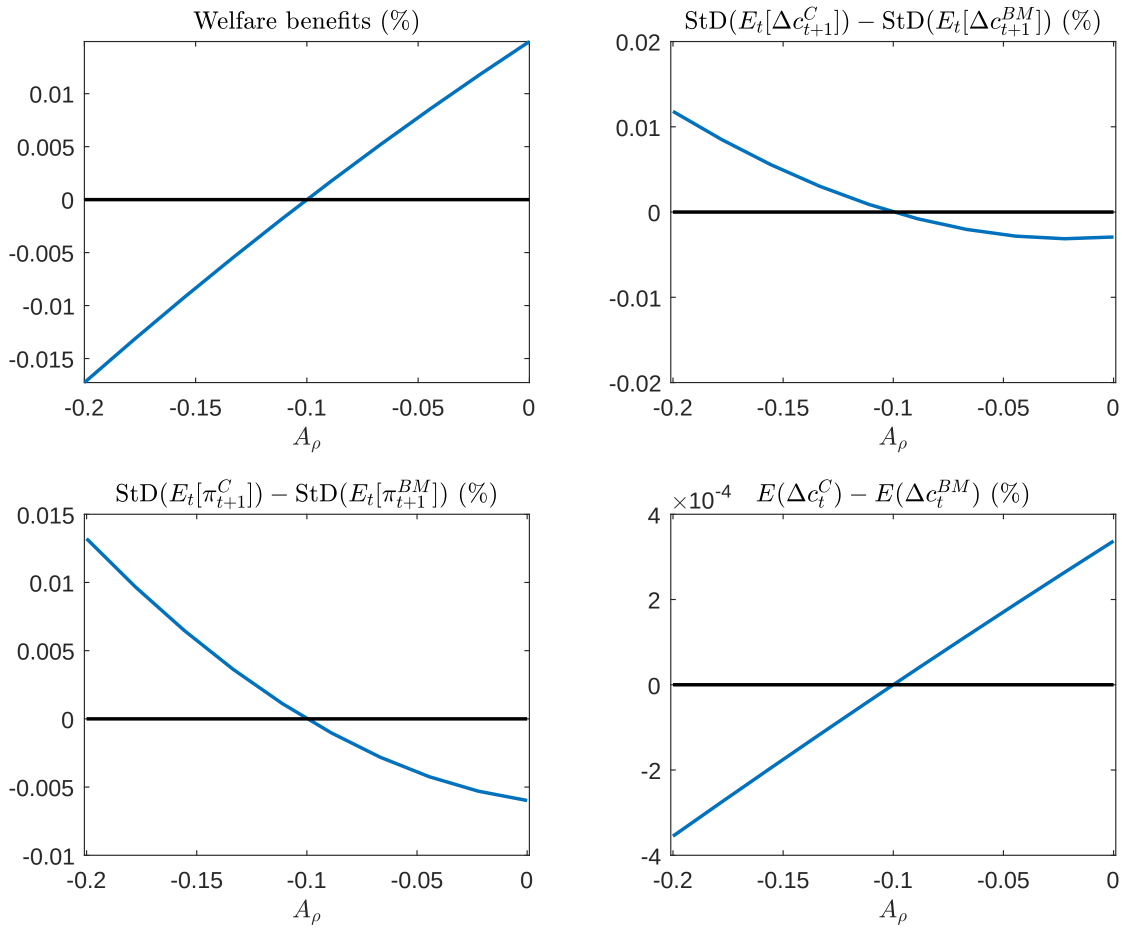
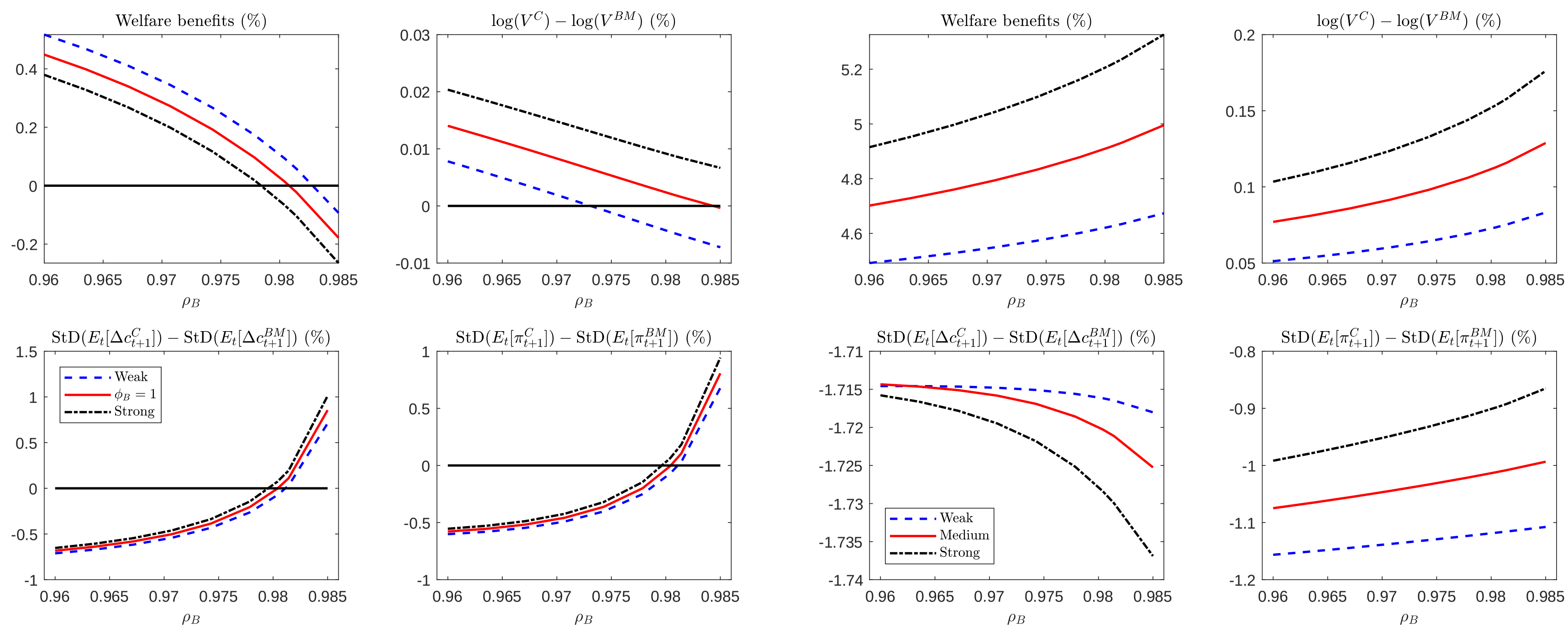


Fig. 4. The Role of A_ρ

Notes: This figure compares the change in key moments from our model as we vary A_ρ (i.e., the extent of lack of commitment to a fixed half-life of debt-to-output). BM refers to our benchmark calibration. C refers to the model calibrated with a different A_ρ.

decreasing the value of new innovations. We provide further details about this point in Appendix E.

This exercise teaches us two lessons. First, full government commitment to a fixed repayment speed is not enough to guarantee welfare benefits. Unless the government avoids sluggish debt-to-output dynamics, this policy can be welfare inferior. Second, the policy that we have estimated from US data falls within the class denoted by Croce et al. (2012) as aimed at stabilizing short-run fluctuations. In what follows, we push our analysis a step forward by focusing on a different way to approach stabilization. Specifically, we study the effects of a financing policy aimed at stabilizing



(a) Short-Run-Oriented Policy (b) Long-Run-Oriented Policy

Fig. 5. Fiscal Policies, Welfare, Risk, and Patent Value

Notes: Each panel shows how welfare, patent value, long-run profit risk, and long-run consumption growth risk change as we vary the unconditional mean-reversion speed of debt-to-output (ρ_B). In panel (a), results are obtained under our benchmark policy, where the parameters A_z, A_G, and σ_ϕ are rescaled by a factor $\phi_B = 0.99$ ($\phi_B = 1.01$) in order to have a weaker (stronger) cyclicality. In panel (b), we use the long-run-oriented policy described in equation (27). Weak, medium, and strong cyclical policies are generated by calibrating ϕ_B to 0.35%, 0.55% and 0.75%, respectively. All the other parameters are calibrated to the values used in table 4. The horizontal axis corresponds to different autocorrelation levels, ρ_B, of the debt-to-output ratio, B/Y; the higher the autocorrelation, the lower the speed of repayment.

future expected profit growth,

$$\frac{B_t}{Y_t} = \rho_B \cdot \frac{B_{t-1}}{Y_{t-1}} + \phi_B(E_t(\pi_{t+1}) - \pi_{ss}), \tag{27}$$

with a full commitment to the persistence of debt-to-output. Since in our economy there is a positive link between expected profits and patent values, the government rule is now designed to stabilize the stock market, as opposed to the labor market.

In this setting, the government increases current taxation (reduces current debt) when expected profits are below average. Specifically, if profits are expected to grow at a rate below average, the government counterbalances these negative long-run profit expectations with lower future tax rates. In order to remain solvent, the government has to increase taxation in the short run.

We illustrate the implications of this policy for both welfare and the distribution of consumption and profits in figure 5(b). In contrast to short-run stabilization, long-term stabilization produces welfare benefits. On the one hand, this policy is costly because it increases short-run volatility. On the other hand, our simple policy in equation (27) enables the government to reduce long-run risk in both consumption and profits. Since long-term stabilization enhances the market value of patents, the average growth is greater as well. Under our benchmark calibration, higher growth and lower long-term risk outweigh the increase in short-term risk and produce welfare benefits.

Importantly, even when we set the parameter ϕ_B to the highest value in our range, the unconditional moments produced in our counterfactual scenario remain close to both the ones in our benchmark model and the data (see table 7). Aside from reducing the countercyclicality of the labor tax rate, our counterfactual policy does not imply any implausible change in aggregate consumption.[8]

The relevance of these results is twofold. First, we show that the observed government financing policy may be costly. Second, our counterfactual experiment shows that the financing of public debt with a mix of taxes and deficit can be beneficial, provided that it is aimed at long-term stabilization. We provide further insights on the link between this policy and the term-structure

[8]The contemporaneous correlation with consumption growth becomes less negative by 20 basis points.

Table 7. Unconditional Moments and Long-Run Stabilization

	Data	Benchmark Model	Counterfactual Policy
$E(\Delta c)$	2.09	2.08	2.16
$\sigma(\Delta c)$	1.63	1.92	1.93
$ACF_1(\Delta c)$	0.09	0.26	0.31
$E(L/3)$	40.63	34.02	34.01
$E(\tau)$ (%)	32.29	33.50	33.50
$\sigma(\tau)$ (%)	7.56	9.51	2.30
$E(r_f)$	1.01	2.44	2.81
$\sigma(m)$ (%)		20.66	19.52
$E(r^C)$	3.57	3.52	3.50
$E(\log(U/A))$		151.10	156.31

Notes: All moments are annualized and multiplied by 100, except the first-order autocorrelation of consumption growth, $ACF_1(\Delta c)$. The log discount factor is denoted by m, and τ is the labor tax rate. r^C and r_f are the return of the consumption claim and the risk-free bond, respectively. $E(L/3)$ is the fraction of hours worked. The entries for the data moments are based on (i) aggregate data provided in the NIPA tables, for the sample 1947:Q1–2016:Q4, and (ii) the estimates in Lustig et al. (2013). The counterfactual policy is based on the fiscal policy detailed in equation (27) and promotes long-run stabilization ($\phi_B = 0.75\%$).

of discount rates in Appendix F.

3.8 Corporate and Labor Taxes.

In this section, we modify our benchmark fiscal policy by introducing a mix of both labor and corporate taxes in order to quantify the costs of taxing corporate cash-flows as opposed to labor income. Specifically, we redefine the problem of the monopolistic firms in the intermediate-good sector as follows,

$$(1-\tau_t^c)\Pi_{it} \equiv \max_{P_{it}}(1-\tau_t^c)(P_{it}X_{it}-X_{it}), \tag{28}$$

where τ_t^c is the corporate tax rate at time t. Even though this formulation does not alter the optimality condition of the monopolist producers that we derived under our benchmark model, it changes the net cash flows that determine the equilibrium value of patents:

$$V_t \;=\; (1-\tau_t^c)\Pi_t + (1-\delta)E_t\left[M_{t+1}V_{t+1}\right]. \tag{29}$$

The government also taxes the capital income produced by the final-good producer,

$$\max_{L_t, X_{it}} (1-\tau_t^c)\left[Y_t - W_t L_t - \int_0^{A_t} P_{it} X_{it} di\right], \tag{30}$$

so that the total corporate tax base is

$$(\text{corporate tax base})_t = Y_t - W_t L_t - A_t X_t = GDP_t - W_t L_t. \tag{31}$$

Let $T_t^c = \tau_t^c \cdot (\text{corporate tax base})_t$ be the total corporate income tax flow. We pin down the corporate tax rate by imposing

$$T_t^c = \kappa T_t^l, \tag{32}$$

where κ is a parameter that determines the relative size of the corporate tax flow relative to the labor income tax. In order to complete the model, the total tax flow is defined as:

$$T_t = T_t^c + T_t^l, \tag{33}$$

where $T_t^l = \tau_t^l \cdot W_t L_t$. All other equations of our benchmark model remain unchanged. Given these conditions, the introduction of capital taxation is revenue-neutral, that is, as we increase κ labor tax pressure declines keeping everything else constant.

In figure 6, we keep our benchmark calibration and let our additional parameter (κ) range from zero to 10%. Since we are not recalibrating the other parameters, $\kappa = 10\%$ is the highest level for which we still obtain reasonable steady state values. The main take away of this figure is that substituting labor income taxation with capital income taxation generates severe welfare losses because it depresses the average value of patents and hence R&D investment intensity and growth.

In figure 7, we reassess the benefits from commitment as we increase κ and vary ρ_B, that is, the share of capital tax revenue and the average half life of debt-to-output, respectively. We note that capital taxation reduces the welfare benefits of commitment. This is because, for a given ρ_B, higher capital taxation pressure tends to both diminish the value of innovation and mitigate the reduction of long-run risk in consumption and after-tax profits prompted by commitment. All of

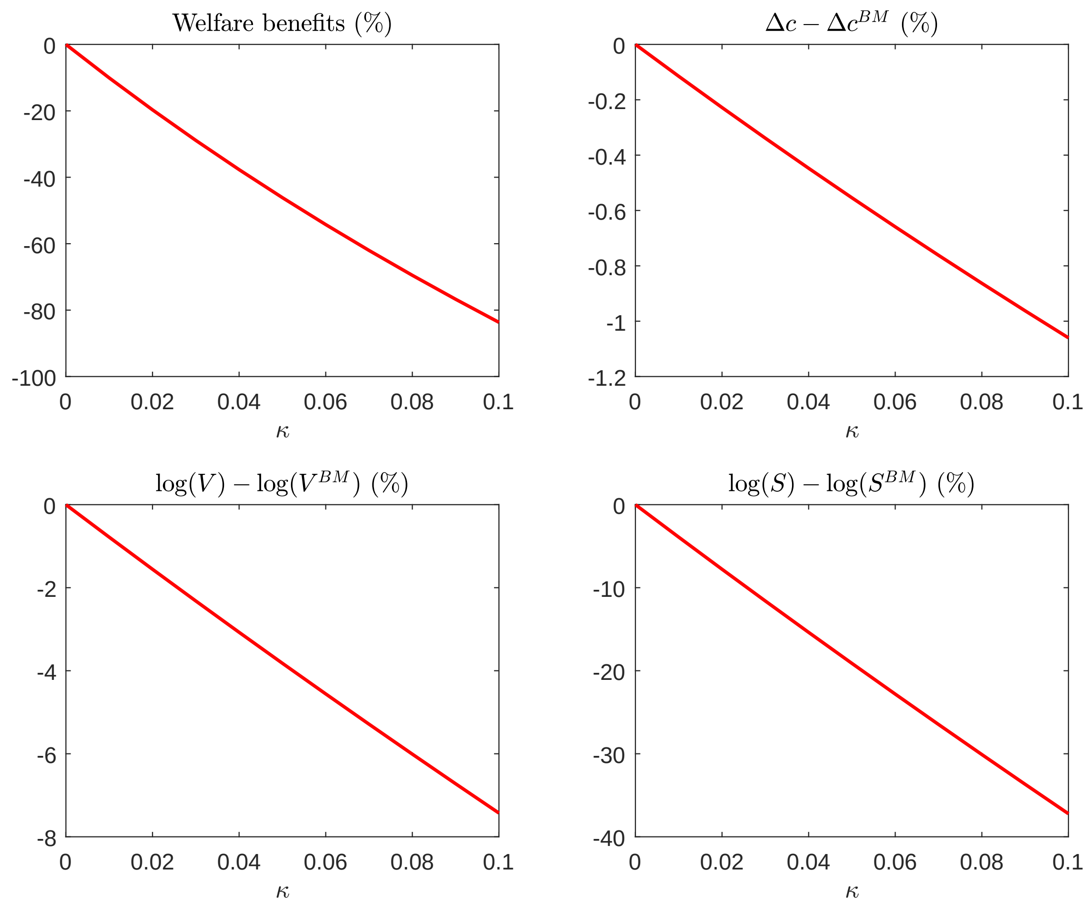


Fig. 6. Welfare Costs of Corporate Taxation

Notes: This figure shows the welfare benefits, the average change in growth, the average percent change in patent value, and the average percent change in R&D investment as we increase the share of corporate tax income (κ). The model features equations (28)–(33) and corresponds to our benchmark specification for $\kappa = 0$.

these effects contribute to a reduction in welfare relative to the case of no capital taxation ($\kappa = 0$).

So far, we have perturbed our benchmark calibration keeping $\kappa = 0$ as our reference point. In what follows, we set $\kappa = 0.34$ to be consistent with US data and recalibrate $\chi = 0.5868$ to maintain average growth to about 2% per year. All other parameters stay the same. In table 8, we show that after this recalibration all of the main unconditional moments of interest remain unchanged. An exception refers to the volatility of the labor tax rate, which declines because of the additional capital income tax margin.

In figure 8, we revisit the role of A_ρ in our recalibrated model. Specifically, we reproduce the top two panels of figure 4 for comparability (solid line), and repeat the same exercise for our

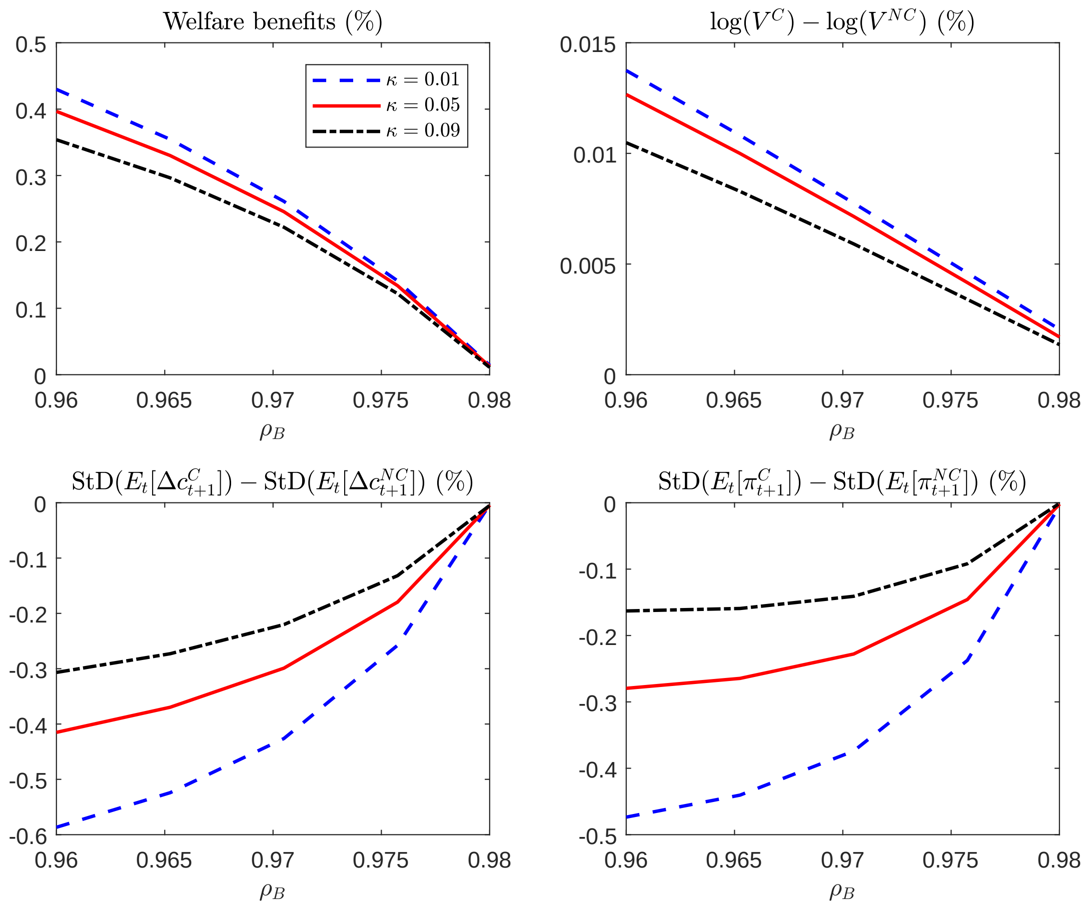


Fig. 7. Commitment and Corporate Profit Tax

Notes: This figure compares the change in key moments from our model with ($A_\rho = 0$) and without ($A_\rho = -0.10$) commitment as we vary ρ_B, i.e., the average half life of debt-to-output. C (NC) refers to our benchmark calibration with (without) commitment. Different lines refer to different levels of corporate taxation, as determined by κ. Our model features the equations (28)–(33).

recalibrated model with capital taxation (dashed line). When we compute welfare benefits and long-run consumption risk variations in the new setting, we do so relative to the benchmark calibration in which we set $\kappa = 0.34$, $\chi = 0.5868$, and $A_\rho = -0.10$. Since in both cases the benchmark value for A_ρ is set to -0.10, by construction the two lines depicted in figure 8 cross the horizontal axis in correspondence of this value. By doing so, we abstract away from the disruptive effects of the increased levels of capital taxation already documented in figure 6 and 7 across the two settings.

Interestingly, adding the capital tax margin reduces the sensitivity of long-run consumption risk to the impact of the lack of commitment when there is a fixed half-life of debt-to-output.

Table 8. Summary Statistics with $\kappa = .34$ and $\chi = 0.5868$

	Data	BM	Including corp. tax
$E(\Delta c)$	2.09	2.08	2.08
$\sigma(\Delta c)$	1.63	1.92	1.91
$ACF_1(\Delta c)$	0.09	0.26	0.29
$E(L/3)$	40.63	34.02	33.41
$E(\tau)$ (%)	32.29	33.50	25.00
$\sigma(\tau)$ (%)	7.56	9.26	5.95
$E(r_f)$	1.01	2.44	2.72
$\sigma(m)$ (%)		20.33	19.28
$E(r^C)$	3.57	3.52	3.51

Notes: All moments are annualized and multiplied by 100, except the first-order autocorrelation of consumption growth, $ACF_1(\Delta c)$. The log discount factor is denoted by m, and τ is the labor tax rate. r^C and r_f are the return of the consumption claim and the risk-free bond, respectively. $E(L/3)$ is the fraction of hours worked. The entries for the data moments are based on (i) aggregate data provided in the NIPA tables, for the sample 1947:Q1–2016:Q4, and (ii) the estimates in Lustig et al. (2013). The rightmost column refers to the model augmented with equations (28)–(33) and $\kappa = .34$ and $\chi = 0.5868$.

As before, increased commitment (i.e., less negative A_ρ) produces welfare benefits, but to a lesser extent than in the case in which government expenditure is financed only with labor income tax. Conversely, when the lack of commitment increases (i.e., A_ρ becomes more negative), the rise of long-run consumption risk is less severe and the associated welfare loss is less severe. This result suggests that lack of commitment to a fixed speed of debt-to-output repayment is particularly concerning when it affects labor income taxes. In a setting in which labor taxes are less volatile both unconditionally and conditionally because they are cushioned by capital income taxation, welfare is less sensitive to changes in the debt-to-output half life.

Importantly, this is a statement about the relative sensitivity of welfare to A_ρ, but not about the average level of welfare with capital taxation. As already shown in figures 6 and 7, capital taxation affects significantly the average level of patent value and hence R&D intensity and growth in a detrimental way. In Appendix G, we report additional moments of interest for this model configuration and we show that they conform well with the data.

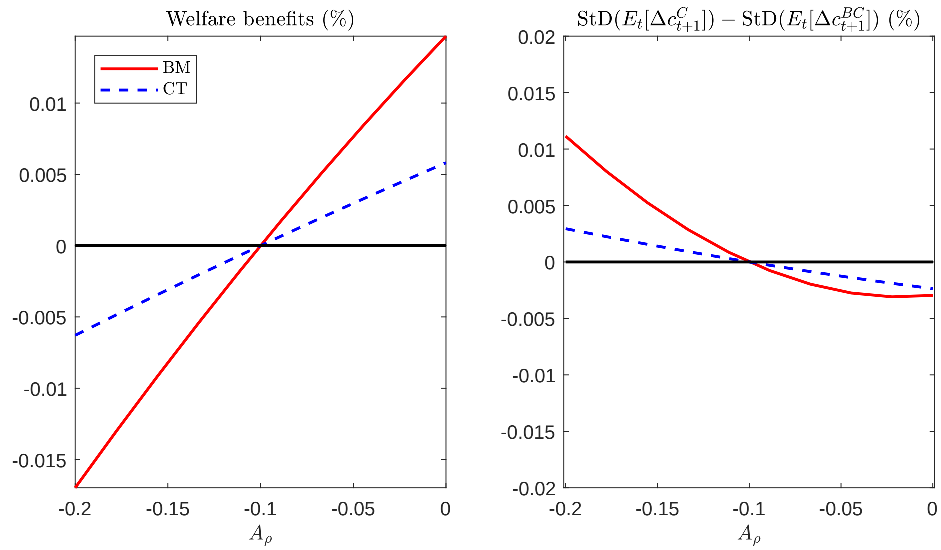


Fig. 8. The Role of A_ρ with Corporate Taxation

Notes: This figure compares the change in key moments from our model as we vary A_ρ (i.e., the extent of lack of commitment to a fixed half-life of debt-to-output). *BM* refers to our benchmark model. *CT* refers to model including corporate taxation with $\chi = 0.5868$ and $\kappa = .34$. All other parameters are calibrated as in the benchmark calibration. For each of these models, *BC* refers to its own benchmark calibration (i.e., $A_\rho = -0.1$), and *C* refers to the model calibrated with a different A_ρ.

4 Conclusion

Recent fiscal interventions have raised concerns about public debt, future fiscal pressure, and long-run economic growth both in the US and in many other large economies. Governments have shown less concern for prompt public debt consolidation and a lack of commitment to future debt-to-output management. Very often these policies are considered growth oriented, but whether this view is correct is still an open question both empirically and in theory.

Using US data, we estimate time variation in the speed of the mean reversion of debt-to-output. This is an econometrically convenient way to quantify policy regime changes. Specifically, in this study we examine changes in the half-life (i.e., sluggishness) of outstanding debt-to-output. In the data, we find that when debt-to-output becomes more sluggish, the distribution of consumption risk worsens, meaning that (i) expected long-term growth declines, and (ii) long-run risk increases and it exhibits more negative skewness, that is, long-term growth downside risk. Results (i) and

(ii) also apply to a broader cross section of 15 developed countries. Simultaneously, the expected return to the consumption claim increases and features more adverse skewness.

These empirical findings are a rational equilibrium outcome in a model in which (i) the representative agent cares about long-run risks; (ii) growth is endogenously supported by investments in innovation; and (iii) the government follows a fiscal policy rule consistent with US data. Through the lens of our macrofinance model, we find that countercyclical tax policies promoting short-run stabilization substantially increase long-run uncertainty, causing a costly decline in innovation incentives and growth. These negative effects are aggravated when the government is not committed to a specific debt-to-output mean reversion. In contrast, tax smoothing policies aimed at stabilizing long-term growth with commitment can significantly increase growth and welfare, even though short-run consumption risk remains substantial.

Our analysis thus identifies a novel and significant tension both in the data and in theory between short-run stabilization, “pro-growth” budget expansions, and realized long-run growth. This tension is driven by risk considerations quantified through the lens of a general equilibrium asset pricing model with endogenous growth. Given the magnitude of our welfare results, we regard long-term fiscal risk as a first-order determinant of fiscal policy design. Since our study abstracts away from various channels through which fiscal stabilization may generate significant welfare benefits, future research should focus on the net welfare effects of fiscal intervention.

On a broader level, our analysis conveys the need to introduce risk considerations into the current fiscal policy debate. Rather than focusing exclusively on average tax pressure and short-run growth gains, fiscal authorities should be concerned with the timing of and the uncertainty surrounding their fiscal policy.

Further research should consider the impact of policy uncertainty and learning (Pastor and Veronesi 2012, 2013) on asset prices and growth. It will be important to examine to what extent the government has incentives to resort to monetization of debt as a fiscal policy instrument (Diercks 2013) when growth is endogenous and prices are sticky (Kung 2015).

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Appendix A. Econometric Methods

Data sources. Most of our empirical results are based on data provided in the NIPA tables, for the sample 1947:Q1–2016:Q4. Quarterly consumption growth is constructed from real per capita nondurables and services expenditure. Government-spending-to-GDP ($Govt/GDP$) comprises current government expenditures. GDP is real gross domestic product per the Bureau of Economic Analysis (BEA) (Series ID: GDPC96).

Debt-to-GDP ($DGDP$) is defined as gross public debt divided by lagged real gross domestic product from the BEA (Series ID: GDPC96). The gross public debt series is concatenated from two different sources. For the period 1947:Q1–1965:Q4 we use "Total gross public debt" from the monthly statement of the public debt files maintained by the US Treasury,

https://www.treasurydirect.gov/govt/reports/pd/mspd/mspd.htm,

and from 1966:Q1–2016:Q4 we use the "Federal Debt: Total Public Debt" (GFDEBTN) series from the Federal Reserve Bank of St. Louis.

Total factor productivity (TFP) comes from the Federal Reserve Bank of San Francisco and John Fernald's quarterly TFP series. We use the business-sector TFP ($dtfp$) variable as our measure of TFP. Labor tax rate data are from the NBER's US Federal Marginal Income Tax Rates data (http://users.nber.org/ taxsim/conrate/), which are annual data from 1960–2016. Data on labor hours worked are from the series "Average Weekly Hours of Production and Nonsupervisory Employees: Manufacturing" (AWHMAN) from the Federal Reserve Bank of St. Louis.

The wealth-consumption ratio returns were graciously provided by Lustig et al. (2013).

Estimating $\rho_{B,t}$. We estimate the speed of repayment of debt-to-output, $\rho_{B,t}$, in several ways in order to assess the reliability of our results across methods. We start by adopting a quasi-maximum-likelihood approach in order to estimate the following system of equations:

$$DGDP_t = a + \rho_{B,t} DGDP_{t-1} + \epsilon_t \tag{A.1}$$

$$\rho_{B,t} = b + \rho_{\rho,B} \cdot \rho_{B,t-1} + v_t \tag{A.2}$$

We estimate these equations either by leaving $\rho_{\rho,B}$ unrestricted (SSM-AR(1)), or by setting this parameter at a predetermined value for sensitivity analysis purposes. We also consider the extreme case, $\rho_{\rho,B} = 1$ (SSM-RW(1)). We define these estimates respectively as $\hat{\rho}_t(DGDP)^{AR}$ and $\hat{\rho}_t(DGDP)^{RW}$.

As an alternative to the parametric approach described above, we also estimate rolling-window AR(1) models on $DGDP$ for various window lengths. This estimation framework inherently contains a large degree of model uncertainty around the choice of window size; therefore, we adopt a forecast combination mindset and use equally weighted averages of the autocorrelation estimates across a grid of window sizes. We look at an equally spaced grid of window sizes from 10 to 50 quarters, implying that the maximum window size represents approximately 20% of our sample size. We define this estimate as $\hat{\rho}_t(DGDP)^{RollWind}$.

As a way to aggregate these different estimates, we also construct a model ensemble using equally weighted averages across the nonparametric and parametric estimates:

$$\hat{\rho}_t(DGDP)^{Combo} = \frac{1}{2}\hat{\rho}_t(DGDP)^{RollWind} + \frac{1}{2}\left(\frac{1}{2}\hat{\rho}_t(DGDP)^{AR} + \frac{1}{2}\hat{\rho}_t(DGDP)^{RW}\right). \tag{A.3}$$

In figure 9, we depict $\hat{\rho}_t(DGDP)^{Combo}$ along with its bootstrapped 95% confidence interval.

Construction of long- and short-run conditional moments. Let y represent either real per capita consumption growth or the consumption claim excess return series. We construct cumulative growth rates over different quarterly horizons as follows:

$$y_{t+1\to t+J} = \sum_{j=1}^{J} y_{t+j} \quad \text{for} \quad J \in \{1, 2, 4, 8, 20\}.$$

Fig. 9. Autocorrelation of Debt-to-Output

Notes: This figure shows our estimate of $\hat{\rho}_t(DGDP)^{Combo}$ (solid line) along with the associated 95% bootstrap confidence interval.

Across different horizons, we estimate the conditional expectation functions through a regression approach that uses the market price-dividend ratio (PD_t), a proxy for market volatiliy (MV_t), and Debt/DGDP ($DGDP_t$) as forecasting variables:

$$y_{t+1\to t+J} = \underbrace{\beta_0 + \beta_1 PD_t + \beta_2 MV_t + \beta_3 DGDP_t}_{y^{LR}_{t+1\to t+J}} + \underbrace{\epsilon_{t+J}}_{y^{SR}_{t+1\to t+J}}, \tag{A.4}$$

and denote the long-run and short-run components of y at horizon J as $y^{LR}_{t+1\to t+J}$ and $y^{SR}_{t+1\to t+J}$, respectively.

Conditional variances are estimated using a GJR-GARCH(1,1) model for each horizon. We construct conditional variances for both the overall series, $\text{Var}_t(y_{t+1\to t+J})$, and the their long-run components, $\text{Var}_t(y^{LR}_{t+1\to t+J}) \equiv \text{Var}_t[\hat{E}_{t+1}(y_{t+2\to t+1+J})]$.

The conditional skewness for the long-run component, as well as the overall series, are defined as follows:

$$\text{Skew}_t\left(y^{LR}_{t+1\to t+J}\right) \equiv E_t\left[\left(\frac{y^{LR}_{t+2\to t+1+J} - E_{t+1}[y^{LR}_{t+2\to t+1+J}]}{\text{Var}_t(y^{LR}_{t+1\to t+J})}\right)^3\right] \tag{A.5}$$

$$\text{Skew}_t\left(y^{SR}_{t+1\to t+J}\right) \equiv E_t\left[\left(\frac{y^{SR}_{t+1\to t+J} - E_t[\hat{\epsilon}_{t+J}]}{Var_t(y^{SR}_{t+1\to t+J})}\right)^3\right] \tag{A.6}$$

$$\text{Skew}_t\left(y_{t+1\to t+J}\right) \equiv E_t\left[\left(\frac{y_{t+1\to t+J} - E_t[y_{t+1\to t+J}]}{\text{Var}_t(y_{t+1\to t+J})}\right)^3\right]. \tag{A.7}$$

We also estimate the conditional autocorrelation of the long-run component $y^{LR}_{t+1\to t+J}$, $\rho_t(y^{LR}_{t+1\to t+J})$, using a rolling-window method with 40 quarters.

Equations of interest. Given the methods described above, we study the impact of $\rho_t(DGDP)$ on the conditional distribution of $y_{t+1\to t+J}$ and its long-run component by estimating the following system of equations:

$$y_{t+1\to t+J} = \gamma_0 + \gamma_1 \cdot \rho_t(DGDP) + v_{t+J} \tag{A.8}$$

$$y^{LR}_{t+1\to t+J} = \gamma^{LR}_0 + \gamma^{LR}_1 \cdot \rho_t(DGDP) + v^{LR}_{t+J} \tag{A.9}$$

$$\text{Var}_t(y_{t+1\to t+J}) = \gamma_{0,V} + \gamma_{1,V} \cdot \rho_t(DGDP) + v_{t+J,V} \tag{A.10}$$

$$\text{Var}_t(y^{LR}_{t+1\to t+J}) = \gamma^{LR}_{0,V} + \gamma^{LR}_{1,V} \cdot \rho_t(DGDP) + v^{LR}_{t+J,V} \tag{A.11}$$

$$\text{Skew}_t(y_{t+1\to t+J}) = \gamma_{0,S} + \gamma_{1,S} \cdot \rho_t(DGDP) + v_{t+J,S} \tag{A.12}$$

$$\text{Skew}_t(y^{LR}_{t+1\to t+J}) = \gamma^{LR}_{0,S} + \gamma^{LR}_{1,S} \cdot \rho_t(DGDP) + v^{LR}_{t+J,S}. \tag{A.13}$$

Appendix B. Robustness

In table B1, we report the results for the case in which $\rho_t(DGDP)$ is estimated with its persistence fixed to 0.9, that is, by fixing $\rho_{\rho,B} = 0.9$ in equation (A.2) when estimating the persistence.

Table B1. Impact of $\rho_t(DGDP)$ on conditional moments (I)

Horizons (J)	1	2	4	8	20
			Consumption growth		
$E_t[\Delta c^{LR}_{t+J}]$	-0.46^{***}	-0.53^{***}	-0.70^{***}	-0.72^{***}	-0.69^{***}
	(0.10)	(0.08)	(0.07)	(0.15)	(0.18)
$\text{Var}_t[\Delta c_{t+J}]$	-0.28^{*}	-0.26^{**}	-0.46^{***}	-0.50^{**}	-0.44^{*}
	(0.16)	(0.13)	(0.18)	(0.21)	(0.23)
$\text{Var}_t[\Delta c^{LR}_{t+J}]$	0.50^{***}	0.31^{***}	0.49^{***}	0.30^{***}	0.43^{***}
	(0.13)	(0.08)	(0.14)	(0.08)	(0.10)
$\text{Skew}_t[\Delta c^{LR}_{t+J}]$	-0.27^{***}	-0.28^{***}	-0.29^{***}	-0.44^{***}	-0.48^{***}
	(0.06)	(0.06)	(0.06)	(0.07)	(0.09)
$\rho_t[\Delta c^{LR}_{t+1}]$	0.26^{*}				
	(0.15)				
			Consumption claim excess returns		
$E_t[R^{W,LR}_{ex,t+J}]$	0.67^{***}	0.68^{***}	0.76^{***}	0.72^{***}	0.62^{**}
	(0.08)	(0.10)	(0.15)	(0.20)	(0.24)
$\text{Var}_t[R^{W}_{ex,t+J}]$	-0.04	0.04	-0.05	-0.18	-0.19
	(0.22)	(0.22)	(0.25)	(0.24)	(0.27)
$\text{Var}_t[R^{W,LR}_{ex,t+J}]$	0.31^{***}	0.31^{***}	0.33^{***}	0.35^{***}	0.01
	(0.08)	(0.09)	(0.09)	(0.09)	(0.10)
$\text{Skew}_t[R^{W,LR}_{ex,t+J}]$	0.33^{***}	0.33^{***}	0.45^{***}	0.58^{***}	0.53^{***}
	(0.07)	(0.07)	(0.06)	(0.11)	(0.18)
$\rho_t[R^{W,LR}_{ex,t+1}]$	0.33^{*}				
	(0.17)				

Notes: This table shows estimated coefficients from regressions of conditional moments for consumption growth (Δc_t) and consumption-wealth excess returns ($R^{W}_{ex,t}$) at various cumulative horizons on $\rho_t(DGDP)$, the time-varying autocorrelation of debt-to-GDP. See Appendix A for details on variable constructions. Quarterly data are from 1947:Q2–2016:Q4. Newey and West (1987) standard errors are in parentheses. One, two, and three asterisks denote significance at the 10%, 5%, and 1% levels, respectively.

In table B2, we report the results for the case in which $\rho_t(DGDP)$ is estimated with its persistence fixed to 0.95, that is, by fixing $\rho_{\rho,B} = 0.95$ in equation (A.2) when estimating the persistence.

Table B2. Impact of $\rho_t(DGDP)$ on conditional moments(II)

Horizons (J)	1	2	4	8	20
			Consumption growth		
$E_t[\Delta c^{LR}_{t+J}]$	-0.36^{***}	-0.46^{***}	-0.72^{***}	-0.91^{***}	-0.89^{***}
	(0.12)	(0.11)	(0.10)	(0.09)	(0.10)
$\text{Var}_t[\Delta c_{t+J}]$	-0.44^{***}	-0.39^{***}	-0.58^{***}	-0.66^{***}	-0.63^{***}
	(0.11)	(0.09)	(0.13)	(0.14)	(0.17)
$\text{Var}_t[\Delta c^{LR}_{t+J}]$	0.43^{***}	0.21^{**}	0.42^{**}	0.20^{**}	0.33^{***}
	(0.16)	(0.08)	(0.17)	(0.08)	(0.11)
$\text{Skew}_t[\Delta c^{LR}_{t+J}]$	-0.17^{***}	-0.18^{***}	-0.19^{***}	-0.57^{***}	-0.64^{***}
	(0.05)	(0.06)	(0.06)	(0.10)	(0.10)
$\rho_t[\Delta c^{LR}_{t+1}]$	0.33^{*}				
	(0.18)				
			Consumption claim excess returns		
$E_t[R^{W,LR}_{ex,t+J}]$	0.67^{***}	0.70^{***}	0.86^{***}	0.89^{***}	0.86^{***}
	(0.07)	(0.08)	(0.08)	(0.12)	(0.15)
$\text{Var}_t[R^{W}_{ex,t+J}]$	-0.24	-0.19	-0.25	-0.39^{*}	-0.43^{*}
	(0.21)	(0.21)	(0.25)	(0.22)	(0.26)
$\text{Var}_t[R^{W,LR}_{ex,t+J}]$	0.22^{**}	0.22^{**}	0.24^{**}	0.25^{**}	-0.05
	(0.09)	(0.10)	(0.10)	(0.10)	(0.09)
$\text{Skew}_t[R^{W,LR}_{ex,t+J}]$	0.24^{***}	0.25^{***}	0.39^{***}	0.61^{***}	0.67^{***}
	(0.07)	(0.07)	(0.07)	(0.08)	(0.12)
$\rho_t[R^{W,LR}_{ex,t+1}]$	0.34^{*}				
	(0.19)				

Notes: This table shows estimated coefficients from regressions of conditional moments for consumption growth (Δc_t) and consumption-wealth excess returns ($R^{W}_{ex,t}$) at various cumulative horizons on $\rho_t(DGDP)$, the time-varying autocorrelation of debt-to-GDP. See Appendix A for details on variable constructions. Quarterly data are from 1947:Q2–2016:Q4. Newey and West (1987) standard errors are in parentheses. One, two, and three asterisks denote significance at the 10%, 5%, and 1% levels, respectively.

In table B3, we report the results for the case in which $\rho_t(DGDP)$ is estimated with its persistence fixed to 0.98, that is, by fixing $\rho_{\rho,B} = 0.98$ in equation (A.2) when estimating the persistence.

Table B3. Impact of $\rho_t(DGDP)$ on conditional moments (III)

Horizons (J)	1	2	4	8	20
			Consumption growth		
$E_t[\Delta c^{LR}_{t+J}]$	-0.27^{**}	-0.37^{***}	-0.67^{***}	-0.94^{***}	-0.94^{***}
	(0.11)	(0.11)	(0.11)	(0.08)	(0.08)
$\text{Var}_t[\Delta c_{t+J}]$	-0.51^{***}	-0.44^{***}	-0.60^{***}	-0.71^{***}	-0.69^{***}
	(0.08)	(0.06)	(0.11)	(0.11)	(0.13)
$\text{Var}_t[\Delta c^{LR}_{t+J}]$	0.34^{**}	0.12	0.34^{**}	0.12^{*}	0.24^{**}
	(0.16)	(0.08)	(0.17)	(0.07)	(0.10)
$\text{Skew}_t[\Delta c^{LR}_{t+J}]$	-0.09^{**}	-0.10^{**}	-0.11^{**}	-0.60^{***}	-0.68^{***}
	(0.04)	(0.05)	(0.05)	(0.12)	(0.11)
$\rho_t[\Delta c^{LR}_{t+1}]$	0.34^{*}				
	(0.19)				
			Consumption claim excess returns		
$E_t[R^{W,LR}_{ex,t+J}]$	-0.27^{**}	-0.37^{***}	-0.67^{***}	-0.94^{***}	-0.94^{***}
	(0.11)	(0.11)	(0.11)	(0.08)	(0.08)
$\text{Var}_t[R^{W}_{ex,t+J}]$	-0.51^{***}	-0.44^{***}	-0.60^{***}	-0.71^{***}	-0.69^{***}
	(0.08)	(0.06)	(0.11)	(0.11)	(0.13)
$\text{Var}_t[R^{W,LR}_{ex,t+J}]$	0.34^{**}	0.12	0.34^{**}	0.12^{*}	0.24^{**}
	(0.16)	(0.08)	(0.17)	(0.07)	(0.10)
$\text{Skew}_t[R^{W,LR}_{ex,t+J}]$	-0.09^{**}	-0.10^{**}	-0.11^{**}	-0.60^{***}	-0.68^{***}
	(0.04)	(0.05)	(0.05)	(0.12)	(0.11)
$\rho_t[R^{W,LR}_{ex,t+1}]$	0.34^{*}				
	(0.19)				

Notes: This table shows estimated coefficients from regressions of conditional moments for consumption growth (Δc_t) and consumption-wealth excess returns ($R^W_{ex,t}$) at various cumulative horizons on $\rho_t(DGDP)$, the time-varying autocorrelation of debt-to-GDP. See Appendix A for details on variable constructions. Quarterly data are from 1947:Q2–2016:Q4. Newey and West (1987) standard errors are in parentheses. One, two, and three asterisks denote significance at the 10%, 5%, and 1% levels, respectively.

In table B4, we report the results for the case in which $\rho_t(DGDP)$ is estimated using rolling-window regressions.

Table B4. Impact of $\rho_t(DGDP)$ on conditional moments (IV)

Horizons (J)	1	2	4	8	20
			Consumption growth		
$E_t[\Delta c^{LR}_{t+J}]$	-0.34^{***}	-0.35^{***}	-0.36^{***}	-0.32^{*}	-0.31
	(0.11)	(0.11)	(0.12)	(0.18)	(0.19)
$\text{Var}_t[\Delta c_{t+J}]$	-0.04	-0.04	-0.10	-0.23	-0.35^{*}
	(0.24)	(0.17)	(0.22)	(0.19)	(0.21)
$\text{Var}_t[\Delta c^{LR}_{t+J}]$	0.31^{***}	0.33^{***}	0.42^{***}	0.40^{***}	0.40^{***}
	(0.07)	(0.08)	(0.12)	(0.08)	(0.09)
$\text{Skew}_t[\Delta c^{LR}_{t+J}]$	-0.31^{***}	-0.32^{***}	-0.32^{***}	-0.20^{**}	-0.18^{**}
	(0.07)	(0.06)	(0.06)	(0.09)	(0.08)
$\rho_t[\Delta c^{LR}_{t+1}]$	0.29				
	(0.23)				
			Consumption claim excess returns		
$E_t[R^{W,LR}_{ex,t+J}]$	0.52^{***}	0.51^{***}	0.51^{***}	0.42^{**}	0.22
	(0.12)	(0.13)	(0.16)	(0.18)	(0.21)
$\text{Var}_t[R^{W}_{ex,t+J}]$	-0.11	0.03	-0.05	-0.17	-0.22
	(0.21)	(0.21)	(0.23)	(0.23)	(0.25)
$\text{Var}_t[R^{W,LR}_{ex,t+J}]$	0.33^{***}	0.33^{***}	0.35^{***}	0.37^{***}	0.06
	(0.08)	(0.08)	(0.08)	(0.07)	(0.13)
$\text{Skew}_t[R^{W,LR}_{ex,t+J}]$	0.35^{***}	0.36^{***}	0.41^{***}	0.36^{***}	0.12
	(0.07)	(0.07)	(0.08)	(0.13)	(0.19)
$\rho_t[R^{W,LR}_{ex,t+1}]$	0.57^{***}				
	(0.13)				

Notes: This table shows estimated coefficients from regressions of conditional moments for consumption growth (Δc_t) and consumption-wealth excess returns ($R^{W}_{ex,t}$) at various cumulative horizons on $\rho_t(DGDP)$, the time-varying autocorrelation of debt-to-GDP. See Appendix A for details on variable constructions. Quarterly data are from 1947:Q2–2016:Q4. Newey and West (1987) standard errors are in parentheses. One, two, and three asterisks denote significance at the 10%, 5%, and 1% levels, respectively.

In table B5, we report the results for the case in which $\rho_t(DGDP)$ is estimated under the assumption that it follows a random walk.

Table B5. Impact of $\rho_t(DGDP)$ on conditional moments (V)

Horizons (J)	1	2	4	8	20
			Consumption growth		
$E_t[\Delta c^{LR}_{t+J}]$	-0.27^{***}	-0.38^{***}	-0.67^{***}	-0.94^{***}	-0.92^{***}
	(0.11)	(0.12)	(0.11)	(0.08)	(0.10)
$\text{Var}_t[\Delta c_{t+J}]$	-0.51^{***}	-0.44^{***}	-0.59^{***}	-0.70^{***}	-0.64^{***}
	(0.08)	(0.06)	(0.11)	(0.11)	(0.14)
$\text{Var}_t[\Delta c^{LR}_{t+J}]$	0.24^{**}	0.09^{*}	0.34^{**}	0.11^{*}	0.31^{**}
	(0.13)	(0.06)	(0.17)	(0.07)	(0.16)
$\text{Skew}_t[\Delta c^{LR}_{t+J}]$	-0.09^{**}	-0.10^{**}	-0.11^{***}	-0.63^{***}	-0.71^{***}
	(0.04)	(0.05)	(0.04)	(0.12)	(0.10)
$\rho_t[\Delta c^{LR}_{t+1}]$	0.34^{**}				
	(0.19)				
			Consumption claim excess returns		
$E_t[R^{W,LR}_{ex,t+J}]$	0.60^{***}	0.64^{***}	0.83^{***}	0.91^{***}	0.94^{***}
	(0.07)	(0.07)	(0.06)	(0.07)	(0.08)
$\text{Var}_t[R^{W}_{ex,t+J}]$	-0.36^{**}	-0.33^{**}	-0.37^{*}	-0.50^{***}	-0.60^{***}
	(0.20)	(0.19)	(0.23)	(0.20)	(0.21)
$\text{Var}_t[R^{W,LR}_{ex,t+J}]$	0.13^{**}	0.14^{**}	0.15^{**}	0.16^{**}	-0.05
	(0.07)	(0.08)	(0.08)	(0.08)	(0.09)
$\text{Skew}_t[R^{W,LR}_{ex,t+J}]$	0.16^{***}	0.17^{***}	0.31^{***}	0.59^{***}	0.73^{***}
	(0.04)	(0.04)	(0.05)	(0.06)	(0.08)
$\rho_t[R^{W,LR}_{ex,t+1}]$	0.33^{**}				
	(0.20)				

Notes: This table shows estimated coefficients from regressions of conditional moments for consumption growth (Δc_t) and consumption-wealth excess returns ($R^{W}_{ex,t}$) at various cumulative horizons on $\rho_t(DGDP)$, the time-varying autocorrelation of debt-to-GDP. See Appendix A for details on variable constructions. Quarterly data are from 1947:Q2–2016:Q4. Newey and West (1987) standard errors are in parentheses. Hypothesis tests are associated with the null that the signs are inconsistent with those predicted by our model. One, two, and three asterisks denote significance at the 10%, 5%, and 1% levels, respectively.

In table B6, we report our panel regression results based on the system of equations (5)-(6).

Table B6. International Panel Regressions

	$E_t[\Delta y^{LR}_{t+J}]$		$\text{Var}_t[\Delta y_{t+J}]$	
β_1	-0.057^{**}	-0.059^{**}	-0.007^{**}	-0.005
	(0.025)	(0.026)	(0.004)	(0.006)
β_2	-0.112	-0.057	-0.198^{**}	-0.192^{**}
	(0.807)	(0.842)	(0.107)	(0.111)
β_3	-0.015	-0.026	0.034^{**}	0.034^{**}
	(0.159)	(0.159)	(0.017)	(0.017)
Time FE	No	Yes	No	Yes
Adj R^2	0.008	0.057	0.006	0.025

Notes: This table shows estimated coefficients from the system of equations (5)-(6). "Time FE" indicates whether the model includes time fixed effects or not. Annual data is for 15 countries from 1978-2014. Newey and West (1987) standard errors are in parentheses. Hypothesis tests are associated with the null that the signs are inconsistent with those predicted by our model. One, two, and three asterisks denote significance at the 10%, 5%, and 1% levels, respectively.

Appendix C. Auxiliary Regressions for Calibration

The following estimations are used to calibrate the government's debt policy functions in the model:

$$DGDP_t = \underset{(0.0022)}{0.0009} + \underset{(0.0036)}{\overset{***}{0.9985}} DGDP_{t-1} + \hat{\epsilon}_t^{DGDP} \tag{C1}$$

$$GY_t = \underset{(0.0022)}{\overset{*}{0.0042}} + \underset{(0.0076)}{\overset{***}{0.9870}} GY_{t-1} + \hat{\epsilon}_t^{GY} \tag{C2}$$

$$TFP_t = \underset{(0.0005)}{\overset{***}{0.0025}} + \underset{(0.0593)}{\overset{***}{0.1829}} TFP_{t-1} + \hat{\epsilon}_t^{TFP} \tag{C3}$$

$$\hat{\epsilon}_t^{DGDP} = \underset{(0.0007)}{0.0000} + \underset{(0.1358)}{\overset{***}{0.5075}} \hat{\epsilon}_t^{GY} + \underset{(0.0833)}{\overset{***}{-0.4542}} \hat{\epsilon}_t^{TFP} + \hat{v}_t, \tag{C4}$$

where numbers in parentheses are heteroscedasticity-adjusted standard errors, and implied p-values of 1%, 5%, and 10% are denoted by ***, **, and *, respectively.

The estimated volatilities of the residuals are

$$\hat{\sigma}(\epsilon_t^{DGDP}) = 0.0126 \tag{C5}$$

$$\hat{\sigma}(\epsilon_t^{GY}) = 0.0053 \tag{C6}$$

$$\hat{\sigma}(\epsilon_t^{TFP}) = 0.0086 \tag{C7}$$

$$\hat{\sigma}(v_t) = 0.0114. \tag{C8}$$

We then use the following equations to calibrate the dynamics of the autocorrelation of $DGDP$, where we estimate a restricted model such that the unconditional autocorrelation of $DGDP$ aligns with the unconditional AR(1) estimated in equation (C1). In particular, we estimate

$$\rho_t(DGDP) = e_0 + e_1 \rho_{t-1}(DGDP) + e_2 \hat{\epsilon}_t^{TFP} + u_t$$
$$\text{s.t. } \frac{e_0}{(1-e_1)} = a_1,$$

where a_1 is the persistence in (C1).

The estimated version follows:

$$\rho_t(DGDP) = \underset{(0.02)}{0.03} + \underset{(0.022)}{\overset{***}{0.96}}\rho_{t-1}(DGDP) - \underset{(0.30)}{\overset{**}{0.61}}\hat{\epsilon}_t^{TFP} + \hat{u}_t,$$

where $\hat{\sigma}(u_t) = 0.019$.

C.1. Simulation-based Estimates

Given our estimated model for $DGDP$ in Appendix C, we can simulate artificial data and compare our estimated time-varying persistence of $DGDP$ with the true simulated series. This exercise is important because it establishes the link between our empirical and theoretical analysis and it justifies our empirical procedure.

Specifically, in table C1 we report the correlations between the true persistence, $\rho_t(DGDP)$, and the filtered one, $\hat{\rho}_t(DGDP)$, across different estimation methods. We report our results for both a long-sample simulation and repetitions of small samples whose length is equal to the one in our data set.

In both long and short samples, our rolling window procedure produces a less precise proxy for the actual process $\rho_{B,t}$. In contrast, when we parameterize $\rho_{B,t}$ either as a stationary AR(1) or as a random walk, the quality of our inference increases sharply. In our long sample, our correlations rise to very high levels greater or equal to 80%. Across repetitions of small sample, $Avg[corr(\hat{\rho}_{B,t}, \rho_{B,t})]$ is lower than in long sample, but it remains above 60%.

In small sample, our model ensemble (Combo) delivers a satisfactory correlation of 50%. Since our estimators are consistent, in long sample this correlation becomes as large as 80%, a very high level.

In figure C1 we plot the various series from our long sample simulation. This plot shows that our empirical estimators are consistent and hence they produce filtered series very close to the actual simulated process.

Table C1. Filtered vs Actual Persistence Process: $corr(\hat{\rho}_{B,t}, \rho_{B,t})$

	$\hat{\rho}^{Combo}_{B,t}$	$\hat{\rho}^{AR}_{B,t}$	$\hat{\rho}^{RW}_{B,t}$	$\hat{\rho}^{RollWind}_{B,t}$	$\hat{\rho}^{FixedAR}_{B,t}$
Long sample	0.8	0.9	0.9	0.3	0.9
Short sample repetitions	0.5	0.7	0.6	0.4	0.7

Notes: This table shows correlations between actual and filtered time-varying persistence for $DGDP$. The long sample simulation features 5000 quarterly observations. In the case of short sample repetitions, we report averages across 100 samples with 280 quarters (our sample length in the empirical analysis). The model is calibrated using the estimates reported in Appendix C.

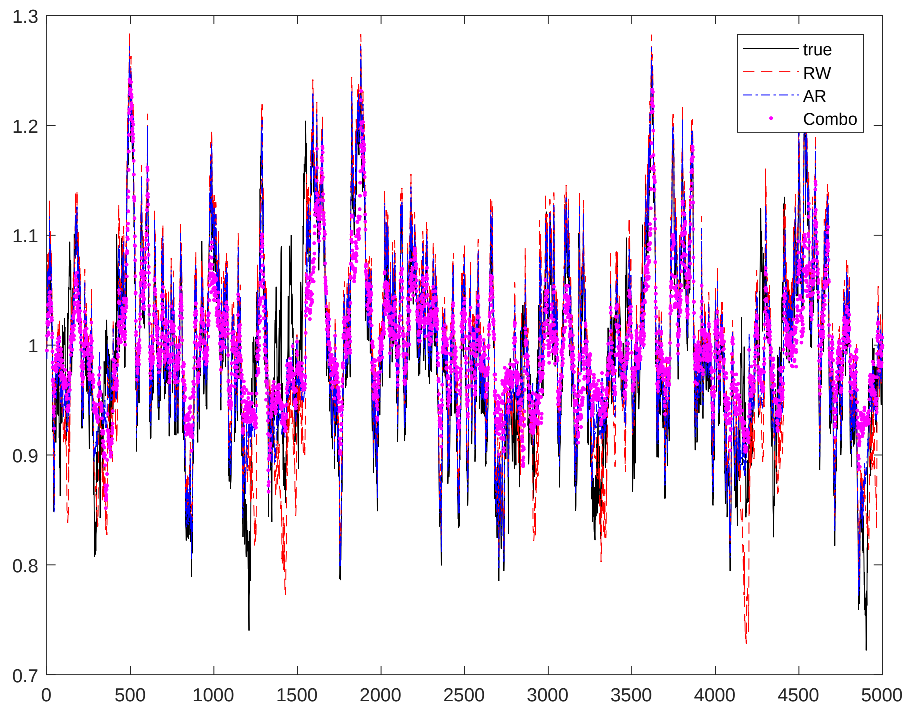

Fig. C1. Actual vs Filtered $\rho_{B,t}$

Notes: This figure plots both the actual and the filtered $DGDP$ persistence processes along a long sample simulation.

Appendix D. Solution Method and Welfare Costs

Solution method and computations. We solve the model in `dynare++4.2.1` using a fourth-order approximation. The policies are centered about a fixed point that takes into account the effects of volatility on decision rules. In the **.mat** file generated by `dynare++`, the vector with the fixed 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, $\{u^1\}$ and $\{u^2\}$. We express welfare costs as the additional fraction λ of the lifetime consumption bundle required to make the representative agent indifferent between $\{u^1\}$ and $\{u^2\}$:

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

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

$$\frac{U_0(\{u^1\})}{u_0^1} \cdot u_0^1 = \frac{U_0(\{u^2\})}{u_0^2} \cdot u_0^2 \cdot (1+\lambda).$$

This shows that the welfare costs depend on both 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 patents, $A_0^i \quad i \in \{1,2\}$, in contrast, is exogenous:

$$\frac{U_0(\{u^1\})}{u_0^1} \cdot \frac{u_0^1}{A_0^1} \cdot A_0^1 = \frac{U_0(\{u^2\})}{u_0^2} \cdot \frac{u_0^2}{A_0^2} \cdot A_0^2 \cdot (1+\lambda).$$

We compare economies with different tax regimes but the same initial condition for the stock of patents: $A_0^1 = A_0^2$. After taking logs, evaluating utility- and consumption-productivity ratios at their unconditional mean, and imposing $A_0^1 = A_0^2$, we obtain the following expression:

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

where the bar denotes the unconditional average, which is computed using the `dyn_ss` variable in `dynare++`.

Appendix E. Counterfactual Analysis

Stabilizing Consumption. The fiscal policy functions that we estimate from the data are similar to ones designed to stabilize short-run consumption fluctuations. Here we make this point more formal by focusing on a modified version of our model in which we have

$$\frac{B_t}{Y_t} = \rho_{B,t} \cdot \frac{B_{t-1}}{Y_{t-1}} + \phi_B(\Delta c_{ss} - \Delta c_t)$$
$$\rho_{B,t} = \rho_B(1 - \rho_{\rho,B}) + \rho_{\rho,B}\rho_{B,t-1} + A_\rho \epsilon_t,$$

and $\phi_B > 0$ so that the government increases public debt when consumption growth is subdued.

Figure E1 shows patterns for both welfare and patents value qualitatively similar to the ones in figure 5(a). These results are consistent with Croce et al. (2012) as they have been the first one to document that short-run stabilization can often be achieved only by allowing more long-run tax rate uncertainty. In an economy in which long-run uncertainty is priced, this trade off is relevant for welfare.

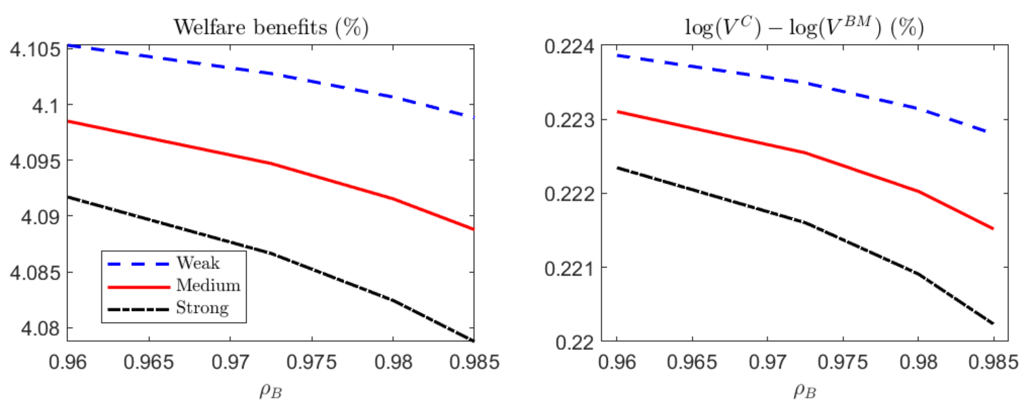

Fig. E1. Consumption Stabilization with No Commitment policy

Notes: C refers to the consumption stabilization policy with no commitment described below:

$$\frac{B_t}{Y_t} = \rho_{B,t} \cdot \frac{B_{t-1}}{Y_{t-1}} + \phi_B(\Delta c_{ss} - \Delta c_t)$$
$$\rho_{B,t} = \rho_B(1 - \rho_{\rho,B}) + \rho_{\rho,B}\rho_{B,t-1} + A_\rho \epsilon_t.$$

This economy is calibrated for different level of average speed of repayment ρ_B as shown in the x-axis. Weak, medium, and strong cyclical policies are generated by calibrating ϕ_B to 0.2%, 0.3% and 0.4%, respectively. BM refers to our benchmark model and calibration.

Appendix F. Term Structure Insights

To better illustrate how our long-term-oriented tax policy affects profit risk premia across different horizons, in figure F1 we depict the variation of the whole term structure of profit excess returns across the long-term-oriented and the benchmark fiscal policies (for a detailed analysis of the term structure of equities see, among others, Binsbergen et al. (2012), Binsbergen et al. (2013), Binsbergen and Koijen (2016), and Binsbergen and Koijen (2017)). Specifically, let $P^{\pi,C}_{n,t}$ ($P^{\pi,BM}_{n,t}$) denote the time t value of profits realized at time $t+n$ under our long-run-oriented (benchmark) fiscal policy. The one-period excess return of a zero-coupon claim to profits with maturity n is

$$R^{\pi,j}_{n,t} = E_t[P^{\pi,j}_{n-1,t+1}/P^{\pi,j}_{n,t}] - r^f_t, \quad j \in \{C, BM\}.$$

Under recursive preferences, the fiscal system becomes a vehicle by which to significantly alter the shape of the term structure of profits. Specifically, under our long-run-oriented policy, the value-weighted return of a strip of dividends paid over a maturity of up to 42 periods (about 10 years) is riskier than under the benchmark policy. This increase in short-term risk, however, comes with the benefit of significantly reduced risk over the long horizon. Since our representative agent is very patient and averse to long-run risk, the reduction in long-term risk premia compounded over the infinite horizon dominates and enhances patent values and growth.

More broadly, this analysis demonstrates that government financing policies, along with their associated sources of uncertainty, are important determinants of the distribution of consumption and profits fluctuations. Financing policies that increase long-term uncertainty may disrupt innovation and growth and be welfare inferior even though they are effective at stabilizing the economy in the short run.

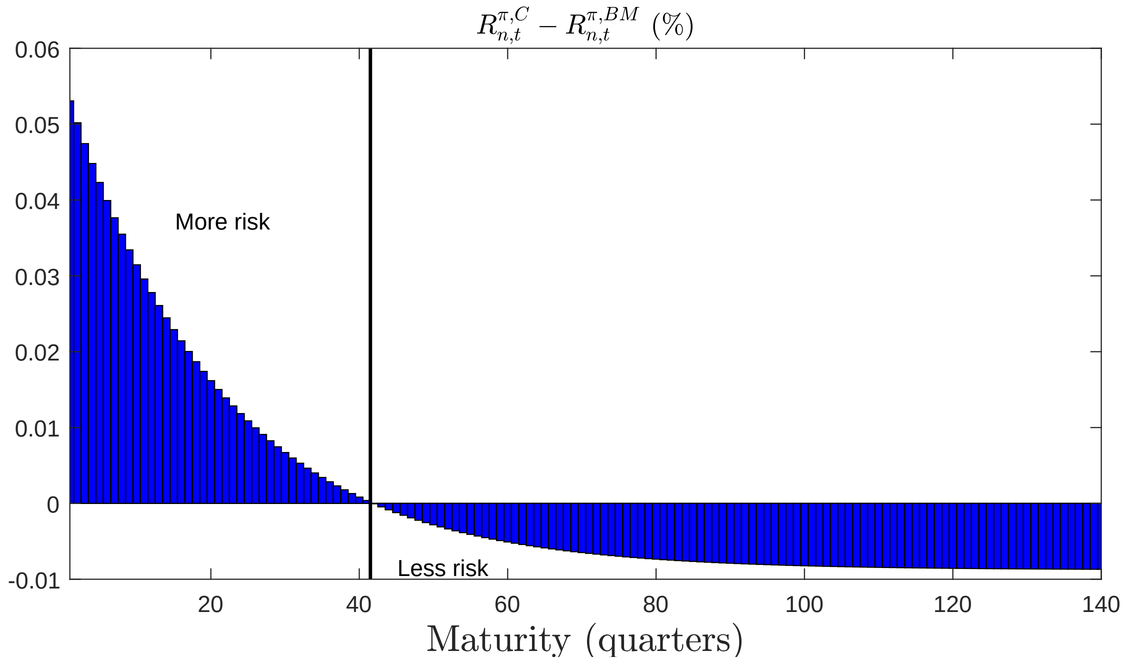

Fig. F1. Fiscal Policies and Term Structure of Profits

Notes: This figure depicts the difference in the term structure of profit average excess returns across our long-run-oriented policy defined in equation (27) (C) and our benchmark policy (BM). Let $P^{\pi,C}_{n,t}$ ($P^{\pi,BM}_{n,t}$) denote the time t value of profits realized at time $t+n$ under our long-run-oriented (benchmark) fiscal policy. The one-period excess return of a zero-coupon claim to profits with maturity n is defined as:

$$R^{\pi,j}_{n,t} = E_t[P^{\pi,j}_{n-1,t+1}/P^{\pi,j}_{n,t}] - r^f_t, \quad j \in \{C, BM\}.$$

Excess returns are annualized and in percentages.

Appendix G. Additional Simulation Results

In table G1, we report both unconditional and conditional moments for both consumption and the consumption-claim excess returns. We consider both our benchmark configuration without corporate taxation and the configuration suggested by the referee. In all cases, our general findings are confirmed: a more sluggish debt-to-output ratio is a leading indicator of lower long-run growth, higher consumption long-run risk, and more severe downside risk in long-run consumption growth. Simultaneously, the consumption claim risk premium increases and features more adverse (positive) skewness. In many cases, the coefficients implied by our model configurations are also quantitatively consistent with our empirical confidence intervals.

In the model, this is true both when we consider the actual simulated conditional persistence of debt-to-output ($\rho_{B,t}$), and when we estimate it from simulated data as we do in the true empirical data ($\hat{\rho}_{B,t}$). For parsimony, we report only the results for $J = 8$, but similar considerations apply to the other horizons that we have considered.

Table G1. The Role of $A_\rho = -1.4$

Moment	Data		No Corp. Tax	with Corp. Tax
	Estimate	SE		
Panel A: Unconditional moments				
$E(\Delta c)$	2.09	0.25	2.04	2.08
$\sigma(\Delta c)$	1.63	0.18	1.93	1.87
$ACF_1(\Delta c)$	0.09	0.16	0.24	0.29
$E(L/3)$	40.63	0.13	34.01	33.41
$E(\tau)$ (%)	32.93	0.99	33.5	25
$\sigma(\tau)$ (%)	7.56	0.64	11.29	6.3
$E(r_f)$	1.01	0.12	2.44	2.72
$\sigma(m)$ (%)			21.96	19.4
$E(r^C)$	3.57	1.16	3.51	3.51
Panel B: Conditional moments with $\rho_{B,t}$ ($J = 8$)				
$E_t[\Delta c^{LR}_{t+J}]$	-0.76	0.16	-0.93	-0.92
$\text{Var}_t[\Delta c^{LR}_{t+J}]$	0.36	0.09	0.07	0.01
$\text{Skew}_t[\Delta c^{LR}_{t+J}]$	-0.51	0.11	-0.74	-0.70
$E_t[R^{W,LR}_{ex,t+J}]$	0.79	0.17	0.80	0.58
$\text{Var}_t[R^{W,LR}_{ex,t+J}]$	0.32	0.09	0.08	0.02
$\text{Skew}_t[R^{W,LR}_{ex,t+J}]$	0.58	0.11	0.58	0.39
Panel C: Conditional moments with estimated $\hat{\rho}_{B,t}$ ($J = 8$)				
$E_t[\Delta c^{LR}_{t+J}]$	-0.76	0.16	-0.24	-0.14
$\text{Var}_t[\Delta c^{LR}_{t+J}]$	0.36	0.09	0.02	0.01
$\text{Skew}_t[\Delta c^{LR}_{t+J}]$	-0.51	0.11	-0.25	-0.14
$E_t[R^{W,LR}_{ex,t+J}]$	0.79	0.17	0.25	0.16
$\text{Var}_t[R^{W,LR}_{ex,t+J}]$	0.32	0.09	0.05	0.03
$\text{Skew}_t[R^{W,LR}_{ex,t+J}]$	0.58	0.11	0.32	0.19

Notes: In panel A, all moments are annualized and multiplied by 100, except the first-order autocorrelation of consumption growth, $ACF_1(\Delta c)$. The log discount factor is denoted by m, and τ is the labor tax rate. r^C and r_f are the return of the consumption claim and the risk-free bond, respectively. $E(L/3)$ is the fraction of hours worked. The entries for the data moments are based on (i) aggregate data provided in the NIPA tables, for the sample 1947:Q1–2016:Q4, and (ii) the estimates in Lustig et al. (2013). In panel B and C, we report estimated coefficients from regressions of conditional moments for consumption growth (Δc_t) and consumption claim excess returns ($R^W_{ex,t}$) for the cumulative forward time horizon of 8 quarters ($J = 8$) on time-varying autocorrelation of debt-to-GDP ($\rho_t(DGDP)$). The long-run (LR) components are constructed from predictive regressions detailed in Appendix A. Standard errors are computed as in Newey and West (1987). In panel B, the entries from the model are based on the actual $\rho_{B,t}$ simulates series. In panel C, we use the model-implied $\hat{\rho}_{B,t}$, which is obtained by estimating $\rho_t(DGDP)$ from simulated data by employing the same procedure adopted for the true data. The column 'No Corp. Tax' ('With Corp. Tax') refers to the benchmark model (extended model in section 3.8) with $A_\rho = -1.4$.