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The welfare and distributional effects of fiscal volatility: A quantitative evaluation ☆

Rüdiger Bachmann [a], Jinhui H. Bai [b,c,*], Minjoon Lee [d], Fudong Zhang [e]

[a] University of Notre Dame, CEPR, CESifo and ifo, United States of America
[b] Washington State University, United States of America
[c] Peking University HSBC Business School, China
[d] Carleton University, Canada
[e] Tsinghua University, China

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ABSTRACT

This study explores the welfare and distributional effects of fiscal volatility using a neoclassical stochastic growth model with incomplete markets. In our model, households face uninsurable idiosyncratic risks in their labor income and discount factor processes, and we allow aggregate uncertainty to arise from both productivity and government purchases shocks. We calibrate our model to key features of the U.S. economy, before eliminating government purchases shocks. We then evaluate the distributional consequences of the elimination of fiscal volatility and find that, in our baseline case, welfare gains increase with private wealth holdings.

1. Introduction

One consequence of the financial crisis followed by political turmoil has been the perception of high volatility in government policies in both the U.S. and in Europe.[1] In this paper, we study, from the viewpoint of the household, the welfare

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* Corresponding author.
E-mail addresses: rbachmann@nd.edu (R. Bachmann), jinhui.bai@wsu.edu (J.H. Bai), minjoon.lee@carleton.ca (M. Lee), zhangfd@pbcsf.tsinghua.edu.cn (F. Zhang).

[1] This paper focuses on "fiscal volatility." However, in describing the related literature, we follow the widespread use in the recent literature and treat "fiscal uncertainty" and "fiscal volatility" as synonymous.

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costs of the volatility of government purchases, both in the aggregate and across different wealth holdings. We do so in a neoclassical model with incomplete markets and a richly specified government sector, where we eliminate the volatility of government purchases once and for all.

Most of the existing research on the consequences of fiscal volatility has focused on the aggregate effects of short-run volatility fluctuations on various macroeconomic variables. In one study, Baker et al. (2016) analyze Internet news and find a (causal) relationship between high policy uncertainty and subdued aggregate economic activity. In another study, based on a New Keynesian DSGE model, Fernández-Villaverde et al. (2015) find large contractionary effects of fiscal volatility on economic activity accompanied by inflationary pressure, especially when the nominal interest rate is at the zero lower bound. By contrast, we study the effects of permanently eliminating fiscal volatility on household welfare with a particular emphasis on distributional aspects.[2] In studying the welfare effect of permanent changes in fiscal policy, we take a similar approach to McKay and Reis (2016). They focus on permanent changes in the automatic stabilizer role of fiscal policy. Our study complements theirs through its focus on government purchases rather than transfers (see below for a more detailed discussion of the literature).

To quantify the welfare costs of fluctuations in government purchases for households, we follow the approach of Krusell and Smith (1998) and use an incomplete market model where heterogeneous households face uninsurable idiosyncratic risks in their labor income and discount factor processes. We then calibrate this model with U.S. data, in particular data on U.S. wealth inequality. Our model has aggregate uncertainty arising from both productivity and government purchases shocks. We thus specify government purchases shocks as the only fundamental source of fiscal volatility. In line with the data, we further assume that government purchases shocks are independent of aggregate productivity and employment conditions.[3] Government purchases enter the utility function of the households as separable goods.[4] We also employ an empirical aggregate tax revenue response rule, which includes government debt and is estimated from U.S. data.

Because the government partially funds its expenditures through taxation, purchases fluctuations generate volatile household-specific tax rates. To capture the distributional effects of fiscal shocks through taxation, we model key features of the progressive U.S. income tax system. Importantly, even though all the households face the same progressive tax schedule, depending on where they belong in the income distribution, their household-specific tax rate risks are differentially impacted by the aggregate fiscal risk. In U.S. data, we indeed find that higher tax revenues are associated with more progressive income taxes, rather than uniform shifts up in the tax schedule. This fact calls for capturing realistic household heterogeneity in our model.

To eliminate fiscal volatility, following Krusell and Smith (1999) and Krusell et al. (2009), we start from a stochastic steady state of the economy with both productivity and government purchases shocks, and remove the fiscal shocks at a given point in time by replacing them with their conditional expectations, while retaining the aggregate productivity process. We then compute the transition path towards the new stochastic steady state in full general equilibrium. Based on the quantitative solution for this transition path, we then compare the welfare of various household groups in the transition-path equilibrium to their welfare level with both aggregate shocks in place.

Our results show that the aggregate welfare costs from fiscal shocks are fairly small. The effect of removing fiscal volatility is equivalent to a 0.03% increase in the lifetime consumption on average. This is comparable to the welfare costs of business cycle fluctuations reported in Lucas (1987, 2003), as well as to those from a representative-agent version of our model, even though in our model aggregate (spending) fluctuations lead to differential impacts on household-specific tax rate risks in addition to the before-tax factor prices volatility, so that they, a priori, may lead to larger welfare costs than in Lucas (1987, 2003) (see Krusell et al., 2009).

By contrast, our results reveal interesting variations in the welfare costs of fiscal volatility along the wealth distribution. The welfare gains of eliminating fiscal volatility are increasing in household wealth according to the baseline specification, where the implementation of the progressive U.S. federal income tax system and the aggregate tax revenue response rule is modeled to best match the cyclicality of important moments of the U.S. tax system.

Since volatile tax rates pre-multiply labor income levels, they generate – loosely speaking – multiplicative after-tax labor income risk.[5] Just as with the additive labor endowment risk in early incomplete market models, this after-tax labor income risk leads households to self-insure through precautionary saving. Wealth-rich households can thus achieve a higher degree of self-insurance relative to wealth-poor households. Consequently, from a precautionary saving perspective, wealth-poor households should gain more when fiscal volatility is eliminated.

However, due to the multiplicative nature of the after-tax capital income risk, the tax-rate uncertainty induced by government purchases fluctuations also creates a rate-of-return risk to savings, which in turn, impacts the quality of capital and

[2] There are a few exceptions in an older literature with either no or rather limited heterogeneity: Bizer and Judd (1989), Chun (2001), and Skinner (1988).

[3] This might seem like an extreme assumption. It might be interesting to explore an alternative environment where government purchases are at least partly endogenously determined (see, e.g., Bachmann and Bai, 2013a,b). However, this assumption makes the implementation and interpretation of the thought experiment of eliminating fiscal volatility clean and transparent, and is akin to the original thought experiment about the elimination of business cycles in Lucas (1987, 2003).

[4] We consider other utility specifications with complementary and substitutable private-public good relationships, respectively, in extensions to the baseline calibration.

[5] This is cleanest in a linear tax system. However, even in a progressive tax system, the fluctuating average tax rates work like multiplicative after-tax income risk.

bonds as saving vehicles.[6] In a realistic incomplete asset market model where the after-tax return of all the financial assets is subject to tax rate uncertainty, wealth-rich households have much larger exposure to such a rate-of-return risk. As a result, from the rate-of-return risk perspective, wealth-rich households should gain more when fiscal volatility is eliminated.

Finally, the distributional effects of eliminating fiscal volatility can depend on its effect on the average factor prices.[7] The precautionary saving and rate-of-return risk effects lead to endogenous responses of the aggregate capital stock, changing both the pre-tax capital rate-of-return and real wages. In our baseline specification, the aggregate capital stock first declines and then increases after the elimination of fiscal volatility, causing a higher interest rate and lower wage rate in the early transition periods followed by a reversal later on.

Whether the combination of these three effects favors the wealth-rich or the wealth-poor households depends *in principle* – as we will show – on the details of the implementation of the progressive tax system and the aggregate tax revenue rule. Under the baseline specification, which is calibrated to best mimic the cyclical behavior of key moments of the U.S. tax system, the wealth-rich households are significantly exposed to the rate-of-return risk caused by tax-rate uncertainty, and they also benefit from changes in average factor prices. As a result, we find that the welfare gains are increasing in household wealth. The first contribution of the paper is thus to provide a calibration strategy that allows us to quantify the net effect of the precautionary saving, the rate-of-return risk, and the average factor price effects.

In addition to our baseline, we consider alternative implementations of how the progressive tax system and the aggregate tax revenue rule interplay. The distributional effects of fiscal volatility vary in these exercises, and thus, despite their counterfactual implications, help us uncover the mechanisms through which fiscal volatility influences economic welfare. A second contribution of the paper is thus to map out the relationship between tax instruments in a progressive tax system used to obtain the cyclical adjustment of the government budget and the distributional effects of fiscal volatility.

We also consider several alternative fiscal regimes: for example, a balanced budget regime with a progressive tax system, a linear tax system, and a lump-sum tax system, with the latter two again allowing for government debt. The welfare results under those three regimes are all in line with our baseline. In another variation, we show that when private and public consumption are complements, the overall welfare gains from eliminating government purchases fluctuations are higher, because a higher government purchases level leads to a higher marginal utility of private consumption when taxes are high (because government purchases are large). In addition, we extend our baseline model to allow for a positive fiscal impact multiplier consistent with the data and find similar distributional effects. Finally, motivated by recent policy discussions of the possible permanence of heightened fiscal volatility, we examine the welfare consequences of doubling the historical government purchases volatility level. Our results suggest that the welfare effects of fiscal volatility are symmetric between zero and twice the pre-crisis volatility of government purchases.

In addition to its substantive contributions, our study also makes a technical contribution to the literature. Specifically, we merge the algorithm for computing the *deterministic* transition path in heterogeneous-agent economies from Huggett (1997) and the algorithm for computing a *stochastic* recursive equilibrium in Krusell and Smith (1998) to show that an approximation of the wealth distribution and its law of motion by a finite number of moments can also be applied to a stochastic transition path analysis. Recall that after fiscal volatility is eliminated, our economy is still subject to aggregate productivity shocks. This solution method should prove useful for other quantitative studies of stochastic transition-path equilibria.

Related Literature

Besides the general link to the literature on incomplete markets and wealth inequality (see Heathcote et al., 2009 for an overview), our study is most closely related to three strands of literature.

First, our paper contributes to research on the welfare costs of aggregate fluctuations (see Lucas, 2003 for a comprehensive discussion). As in Krusell and Smith (1999), Mukoyama and Sahin (2006) and Krusell et al. (2009), we quantify the welfare and distributional consequences of eliminating macroeconomic fluctuations. Howeverto7 Tm 1 Tf 970 9.7s19 242.664 Tm of monetary or fiscal feedback rules (Bi et al., 2013, Davig and Leeper, 2011, and Richter and Throckmorton, 2015), or in the bargaining power parameter of search and matching models (Drautzburg et al., 2017). Our study complements this literature by focusing on the welfare and distributional effects of a permanent change in fiscal volatility.

Finally, our work contributes to the growing body of literature on macroeconomic policy in heterogeneous-agent environments (Auclert, 2019, Bachmann and Bai, 2013a, Bhandari et al., 2017b,a, 2018, We now specify the standard aggregate resource constraint:

$$C_t + K_{t+1} + G_t = Y_t + (1-\delta)K_t, \tag{2.4}$$

where C_t represents aggregate consumption, and δ the depreciation rate.

The markets in our model are perfectly competitive. Labor and capital services are traded on spot markets each period, at factor prices $r(K_t, L_t, z_t) = \alpha z_t K_t^{\alpha-1} L_t^{1-\alpha} - \delta$ and $w(K_t, L_t, z_t) = (1-\alpha) z_t K_t^{\alpha} L_t^{-\alpha}$. In addition, we assume that the households can trade one-period government bonds on the asset market in each period t. For computational tractability, we follow Heathcote (2005) and assume that government bonds pay the same rate-of-return as physical capital in all future states in $t+1$. Because of the assumed perfect substitutability between capital and bonds, each household has access to effectively only one asset in self-insuring against stochastic shocks. We use a to denote a household's total asset holdings, i.e., the sum of physical capital and government bonds.

2.2. Fiscal volatility and the government budget

Our model has three government spending components: government purchases, G_t, aggregate unemployment insurance payments, Tr_t, and aggregate debt repayments, $(1+r_t)B_t$. Government purchases are the only fundamental source of fiscal volatility. They follow an AR(1) process in logarithms:

$$\log(G_{t+1}) = \left(1-\rho_g\right)\overline{\log(G)} + \rho_g \log(G_t) + (1-\rho_g^2)^{\frac{1}{2}} \sigma_g \epsilon_{g,t+1}, \tag{2.5}$$

where ρ_g is a persistence parameter, $\overline{\log(G)}$ is the unconditional mean of $\log(G_t)$, $\epsilon_{g,t+1}$ is an innovation term which is normally distributed with mean zero and variance one, and σ_g is the unconditional standard deviation of $\log(G_t)$. Note that th[redacted]overnm[redacted]t purc[redacted]ses ~~process is~~ independent of

Following Castañeda et al. (2003), we specify the progressive income tax function as:

$$\tau^{y}(y_t) = \begin{cases} \tau_1 \left[y_t - \left(y_t^{-\tau_2} + \tau_3 \right)^{-\frac{1}{\tau_2}} \right] + \tau_0 y_t & \text{if } y_t > 0 \\ 0 & \text{if } y_t \leq 0, \end{cases} \tag{2.9}$$

where $(\tau_0, \tau_1, \tau_2, \tau_3)$ is a vector of tax coefficients and y_t is taxable household income; or $y_t = r_t a_t + w_t \varepsilon_t \tilde{l}$.[9] The first term in the above equation is based on Gouveia and Strauss' (1994) characterization of the effective federal income tax burden of U.S. households.[10] The federal income tax accounts for about 40% of

$$\tau_1 = \Theta(\Gamma, B, z, G). \tag{2.14}$$

The dynamic programming problem faced by a household can now be written as follows:

$$\begin{aligned}
V(a, \varepsilon, \tilde{\beta}, \Gamma, B, z, G; H_\Gamma, \Theta) = \max_{c,a'} \{ & u(c, G) + \tilde{\beta} E[V(a', \varepsilon', \tilde{\beta}', \Gamma', B', z', G'; H_\Gamma, \Theta) | \varepsilon, \tilde{\beta}, z, G]\} \\
\text{subject to: } (1 + \tau_c)c + a' = {} & a + y - \tau^y(y; \tau_1) + (1 - \varepsilon)\omega w(K, L, z)\tilde{l} \\
y = {} & r(K, L, z)a + w(K, L, z)\varepsilon\tilde{l}, \\
a' \geq {} & \underline{a}, \\
\Gamma' = {} & H_\Gamma(\Gamma, B, z, G, z'), \\
B' = {} & H_B(\Gamma, B, z, G), \\
\tau_1 = {} & \Theta(\Gamma, B, z, G),
\end{aligned}$$

where ε and $\tilde{\beta}$ follow the processes specified in Section 2.1, G follows the process specified in equation (2.5), and $\underline{a}$ is an exogenously set borrowing constraint. Finally, we can summarize the optimal saving decision for households in the following policy function:

$$a' = h(a, \varepsilon, \tilde{\beta}, \Gamma, B, z, G; H_\Gamma, \Theta). \tag{2.15}$$

Our recursive competitive equilibrium is then defined as: the law of motion H_Γ,[13] individual value and policy functions $\{V, h\}$, pricing functions $\{r, w\}$, and the Θ-function for the endogenous parameter τ_1,

Table 1
Summary of parameters.

Parameter	Value	Description	Source / Target
Taken from the literature			
$1/\rho$	1.00	Elasticity of substitution between c and G	Standard value
γ	1.00	Relative risk aversion	Standard value
α	0.36	Capital share	Standard value
δ	0.025	Depreciation rate	Standard value
$\tilde{l}$	0.3271	Hours of labor supply of employed	Normalization
(z_l, z_h)	(0.99, 1.01)	Support of aggr. productivity process	Krusell and Smith (1998)
$\Pi_{z,z'}$	See text	Transition matrix of aggr. productivity process	Krusell and Smith (1998)
(u_g, u_b)	(4%, 10%)	Possible unemployment rates	Krusell and Smith (1998)
$\Pi_{\varepsilon\varepsilon'\|zz'}$	See text	Transition matrix of employment process	Krusell and Smith (1998)
ω	0.10	Replacement rate	Krusell and Smith (1998)
τ_2	0.768	Parameter in the progressive tax function	Gouveia and Strauss (1994)
Estimated from the data			
τ_0	5.25%	Income tax parameter	
τ_c	8.14%	Consumption tax rate	
$\rho_{T,B}$	0.0173	Debt coefficient of fiscal rule	
$\rho_{T,Y}$	0.2820	Output coefficient of fiscal rule	
$\rho_{T,G}$	0.4835	Government purchases coefficient of fiscal rule	
$(G_l/G_m, G_h/G_m)$	(0.951, 1.049)	Size of the G-shock	
$\Pi_{G,G'}$	See text	Transition matrix of the G-process	
Calibrated in the model			
θ	0.7221	Weight on private consumption in utility	Lindahl-Samuelson condition
G_m	0.2318	Value of the middle grid of the G-process	Mean G/Y (20.86%)
$\underline{a}$	-4.15	Borrowing constraint	Negative wealth share (11%)
$\rho_{T,0}$	0.1007	Intercept of tax revenue rule	Average annualized B/Y (30%)
$\tilde{\beta}_m$	0.9919	Medium value of discount factor	Average annualized K/Y (2.5)
$\tilde{\beta}_h - \tilde{\beta}_m, \tilde{\beta}_m - \tilde{\beta}_l$	0.0046	Size of discount factor variation	Gini coeff. (0.79)
$\Pi_{\tilde{\beta},\tilde{\beta}'}$	See text	Transition matrix of discount factor	Top 1% wealth share (30%)
τ_3	1.776	Parameter in the progressive tax function	Mean of τ_1 (25.8%)

aggregate state (z'). There are thus four possible cases, (z_g, z_g), (z_g, z_b), (z_b, z_g), and (z_b, z_b), corresponding to the following employment status transition matrices[15]:

$$\begin{bmatrix} 0.33 & 0.67 \\ 0.03 & 0.97 \end{bmatrix}, \begin{bmatrix} 0.75 & 0.25 \\ 0.07 & 0.93 \end{bmatrix}, \begin{bmatrix} 0.25 & 0.75 \\ 0.02 & 0.98 \end{bmatrix}, \begin{bmatrix} 0.60 & 0.40 \\ 0.04 & 0.96 \end{bmatrix},$$

where the first row and column correspond to $\varepsilon = 0$ (unemployed).

We calibrate the borrowing constraint and the idiosyncratic time preference process to match key features of the overall wealth distribution in the U.S. The borrowing constraint is set to $\underline{a} = -4.15$ to match the fraction of U.S. households with negative wealth holdings, 11%.[16]

$\tilde{\beta}$ takes on values from a symmetric grid, ($\tilde{\beta}_l = 0.9873$, $\tilde{\beta}_m = 0.9919$, $\tilde{\beta}_h = 0.9965$). In the invariant distribution, 96.5% of the population is in the middle state, and 1.75% is distributed across either of the extreme points. The expected duration of the extreme discount factors is set at 50 years, to capture a dynastic element in the evolution of time preferences (Krusell and Smith, 1998). In addition, transitions occur only across adjacent values, where the transition probability from either extreme value to the middle grid is 1/200, and the transition probability from the middle grid to either extreme value is 7/77200. This Markov chain for $\tilde{\beta}$ allows our model to generate a long-run U.S. capital-output ratio of 2.5, and a Gini coefficient for the U.S. wealth distribution of 0.79. It also allows our model to match the wealth share of the top 1% (Krusell and Smith, 1998). An accurate calibration of this moment is important because, as we will show, the welfare effects of fiscal volatility for top wealth holders, characterized by high levels of buffer-stock savings and high capital income, can be quantitatively rather different from those for other households.

[15] The numbers are rounded to the second decimal point.

[16] We check that the total resources available to a household, taking into account unemployment insurance benefits and the borrowing limit, are never negative under this calibration. Under our baseline calibration, the average quarterly output turns out to be close to one (1.11), so the wealth levels can roughly be considered ratios to quarterly gross income per household. Therefore, households are allowed to borrow up to about the average annual gross income per household (1.1×4).

3.2. Fiscal parameters

3.2.1. Fiscal volatility and tax revenue rule

To estimate the parameters related to fiscal volatility and the aggregate tax revenue rule, we use U.S. quarterly data from the first quarter of 1960 to the last quarter of 2007. We restrict the data window up to 2007IV because, arguably, fiscal policy was special during and after the Great Recession and for calibration purposes we want to focus on "normal" times. Our model is stationary—that is, our paper is not about long-run trend or medium-run regime changes in the U.S. fiscal system[17]—so we use detrended data to empirically discipline the fiscal parameters. We provide the details of our fiscal parameter estimation in Appendix A. Here we briefly outline the general procedure.

For the government purchases process (equation (2.5)), we use the Rouwenhorst method (Rouwenhorst, 1995) to construct a three-state first-order Markov chain approximation to the AR(1) process of the linearly detrended $\log(G)$ series.[18] The middle grid point of the G-process, G_m, is calibrated using the average G/Y-ratio in the data; see Appendix A.1 for the details.

To determine the parameters of our tax revenue rule (equation (2.6)), we first estimate the federal revenue rule as in Bohn (1998) and Davig and Leeper (2011), and the state and local rule without debt. We then take the weighted average of the federal rule and the state and local rule to get the general government tax revenue function, the empirical counterpart of our model. We describe the details of this procedure in Appendix A.2.

TR in equation (2.6) is aggregate unemployment insurance payments. We set the unemployment insurance replacement rate, ω, to 10% of the current market wage income, in line with the data. From Stone and Chen (2014) we know that the overall replacement rate from unemployment insurance is about 46% of a worker's wage, and its average pre-2008 benefits duration is 15 weeks. This translates to about 53% of a worker's quarterly wage. In our case, since we spread the unemployment benefits through the agent's whole unemployment period and the average duration of unemployment in the model is about 2 quarters, this translates to about 27% of the quarterly wage level. Moreover, from Auray et al. (2019) we know that about 60% out of all the unemployed workers were eligible for unemployment benefits from 1989 to 2012, and that about 75% of those eligible for benefits actually collected them. Thus, we set our unemployment insurance payment to be 10% of the market wage.[19]

3.2.2. Tax instruments

Recall that to satisfy the tax revenue rule (equation (2.6)) we need to treat one of the tax parameters in the income tax function as an endogenous equilibrium object:

$$\tau_1 \left[y - \left(y^{-\tau_2} + \tau_3 \right)^{-\frac{1}{\tau_2}} \right] + \tau_0 y. \tag{3.1}$$

Which tax parameter we choose to be an endogenous variable then influences how the distribution of the tax burden across income changes over the business cycles. We thus run the model with each of τ_0, τ_1, τ_2, and τ_3 as the endogenous variable one by one, and examine the cyclicality of the tax system in each case. We then select the case where the cyclicalities of both the tax parameters and the (average) residual income elasticity (RIE, defined in equation (3.2)) of the

Table 2
Moments for tax instrument choice.

A: Data (1966 - 1989)	ρ(RIE, Y)	ρ(RIE, T-Tr)	$\rho(\tau_0$,T-Tr)	$\rho(\tau_1$,T-Tr)	$\rho(\tau_2$,T-Tr)	$\rho(\tau_3$,T-Tr)
	-0.3353	-0.3652	-0.1865	0.3235	-0.2184	-0.0344
B: Model simulation	ρ(RIE, Y)	ρ(RIE, T-Tr)	$\rho(\tau_0$,T-Tr)	$\rho(\tau_1$,T-Tr)	$\rho(\tau_2$,T-Tr)	$\rho(\tau_3$,T-Tr)
τ_0-adjustment	-0.2978	-0.3108	0.3986	-	-	-
	(0.2689)	(0.2675)	(0.3056)	-	-	-
τ_1-adjustment	-0.2900	-0.3803	-	0.2999	-	-
	(0.3187)	(0.3077)	-	(0.2788)	-	-
τ_2-adjustment	0.2887	0.3744	-	-	-0.3333	-
	(0.2105)	(0.1951)	-	-	(0.2320)	-
τ_3-adjustment	0.1615	0.2478	-	-	-	0.3261
	(0.2886)	(0.2880)	-	-	-	(0.2199)

Notes: In Panel A, Y and $T - Tr$ are HP-filtered (with a smoothing parameter of 6.25) real log series of output and tax revenue net of transfers, respectively. τ_0, τ_1, τ_2 and τ_3 are linearly-detrended tax parameters, where τ_0 is estimated by the authors (see Appendix A.3) and τ_1, τ_2 and τ_3 are from Gouveia and Strauss (1999). RIE is the quadratic-detrended residual income elasticity from Gouveia and Strauss (1999). In Panel B, all variables are defined and filtered the same way as those in Panel A. The reported numbers are the average values from 2,000 independent simulations of the same length as the data (24 years), where quarterly data are converted to annual data to match the data frequency in Panel A. We show the standard deviations across these simulations in parentheses.

negatively with output and tax revenue net of transfers; see the first two columns of Panel A, Table 2. And the first two columns of Panel B, Table 2, show that our model can obtain the right cyclicality of RIE only when we use either τ_0 or τ_1 as the tax instrument to cyclically adjust the government budget. The intuition for this result is: to have a negative correlation between the RIE and tax revenue (a positive correlation between tax progressivity and tax revenue), the tax burden on income-rich individuals from the federal income tax must increase with tax revenue. This means, given the specification of our federal income tax function, that τ_1 has to adjust instead of τ_2 or τ_3, because adjustments in τ_1 lead to differential changes in individual marginal tax rates proportional to the existing progressive rates. In contrast, adjustments in τ_2 or τ_3 affect the poor- and medium-income households more than the high income group, since they leave the highest marginal tax rate unaffected.[21]

To make the further choice between τ_0- and τ_1-adjustments, we examine how τ_0 and τ_1 themselves are correlated with tax revenue net of transfers.[22] The third and fourth columns of Table 2 report these two correlations in the data (Panel A), negative for τ_0 and positive for τ_1, whereas the model implies positive correlations for both cases (Panel B), and hence τ_1 appears to be the driver for the empirical cyclicality of RIE. Therefore, we choose τ_1 as the endogenous equilibrium object in the baseline model. We thus show that time series data on the progressivity of the U.S. tax system are informative of which tax instruments are likely to be used for cyclical government budget adjustment. It is top marginal tax rates, which is also consistent with evidence documented in Mertens and Montiel Olea (2018). They report the time series of the average marginal tax rates of various income groups in the U.S. We calculate the difference in the average marginal tax rates between the top 1% and bottom 90% income groups as a measure of the progressivity of the income tax schedule. We find that this measure is positively correlated with output and tax revenue net of transfers, consistent with Table 2 (columns 1 and 2, Panel A; recall that the RIE is inversely related to tax progressivity).[23]

We then calibrate the remaining tax parameters in the progressive part of the income tax function based on the values estimated by Gouveia and Strauss (1994) for U.S. data from 1989 (see Castañeda et al., 2003 and Conesa and Krüger, 2006), the last year in their sample and close to the midpoint of the sample period in this paper. Note that equation (3.1) is linearly homogeneous in y, if τ_3 is readjusted appropriately. Therefore, we 3

Table 3
Wealth distribution.

	% of wealth held by top					Fraction with wealth < 0	Gini coefficient
	1%	5%	10%	20%	30%		
Model	31%	59%	71%	80%	86%	10%	0.78
K&S	24%	54%	72%	87%	91%	11%	0.81
Data	30%	51%	64%	79%	88%	11%	0.79

Notes: The wealth distribution in the data is taken from Krusell and Smith (1998). Household wealth in our model is the sum of physical capital and government bonds.

Table 4
Business cycle moments.

A: Data (1960 I - 2007 IV)	Y	T-Tr	G	(T-Tr/Y)	(G/Y)	(B/Y)
Standard deviation	0.0149	0.0543	0.0134	0.0123	0.0083	0.0772
Autocorrelation	0.8616	0.8134	0.7823	0.9045	0.9573	0.9945
Corr(Y,X)	1	0.7242	0.0992	0.4791	-0.3826	-0.0472
Corr(G,X)	0.0992	0.0352	1	0.0345	0.4806	-0.0281

B: Model simulation	Y	T-Tr	G	(T-Tr/Y)	(G/Y)	(B/Y)
Standard deviation	0.0235	0.0414	0.0123	0.0063	0.0086	0.0403
	(0.0018)	(0.0043)	(0.0025)	(0.0009)	(0.0012)	(0.0151)
Autocorrelation	0.5840	0.5870	0.6978	0.8183	0.8252	0.9732
	(0.0561)	(0.0558)	(0.0582)	(0.0575)	(0.0546)	(0.0341)
Corr(Y,X)	1	0.9892	-0.0012	0.6941	-0.6436	-0.1822
	(0)	(0.0043)	(0.1294)	(0.1053)	(0.0939)	(0.1685)
Corr(G,X)	-0.0012	0.1316	1	0.2499	0.3805	-0.0089
	(0.1294)	(0.1296)	(0)	(0.1121)	(0.1079)	(0.0577)

Notes: In Panel A, $Y, T - Tr$ and G are HP-filtered (with a smoothing parameter of 1600) real log series of output, tax revenue net of transfers and government purchases, respectively. $(T - Tr)/Y$, G/Y and B/Y are linearly detrended output ratios of tax revenue net of transfers, government purchases and federal government debt, respectively. The data sources are documented in Appendix A.2. In Panel B, all variables are defined and filtered the same way as those in Panel A. The reported numbers are the average values from 1,000 independent simulations of the same length as the data (192 quarters). We show the standard deviations across these simulations in parentheses.

For the consumption tax rate and the linear part of the income tax function, we follow standard procedures and calculate the time series of the corresponding tax rates from the quarterly NIPA data (see, e.g., Fernández-Villaverde et al., 2015 and Mendoza et al., 1994). We then take the time-series average values to obtain the following tax rates: $\tau_c = 8.14\%$ and $\tau_0 = 5.25\%$; see Appendix A.3 for the details.

3.3. The wealth distribution and business cycle moments

In this section, we examine the wealth distribution and the business cycle moments, focusing on the fiscal variables, generated by our calibrated model. For our model to be a suitable laboratory for the experiment of eliminating fiscal volatility, and for producing reliable quantitative answers to our welfare and distributional questions, it should broadly match these aspects of the data.

Table 3 compares the long-run wealth distribution generated by our model with both the data and the model results in Krusell and by this feature of the model, we conduct a robustness check where we recalibrate the aggregate productivity process so that the model matches the output volatility in the data. The results remain unchanged.

4. Computation

4.1. Stochastic steady state

To compute the model's equilibrium with two aggregate shocks, we use the approximate aggregation technique proposed by Krusell and Smith (1998).[26] This technique assumes that households act as if only a limited set of moments of the wealth distribution matters for predicting the future of the economy, and that the aggregate result of their actions is consistent with their perceptions of how the economy evolves. However, in contrast to Krusell and Smith (1998), we find that higher moments of the wealth distribution are necessary in our model with progressive taxation. That is, the accurate description of our economy's evolution requires a combination of average

Therefore, our counterfactual economy features aggregate productivity shocks both during and after the transition. This creates a new technical challenge in addition to those present in previous transition path analyses of heterogeneous-agent economies (e.g., Huggett, 1997). While these studies model a deterministic aggregate economy along the transition path, our stochastic setting with aggregate uncertainty produces an exponentially higher number of possible aggregate paths as the transition period lengthens. This feature precludes computation of the equilibrium for all possible realizations of aggregate shocks.

To address this challenge, we extend the approximate aggregation technique to the transition-path setting: that is, we postulate that time-dependent prediction functions govern the evolution of the economy on the transition path, through the following set of laws of motions:

$$\Gamma_{t+1} = H^{trans}_{\Gamma,t}\big(\Gamma_t, B_t, z_t\big), \tag{4.5}$$

$$\tau_{1,t} = \Theta^{trans}_{t}\big(\Gamma_t, B_t, z_t\big), \tag{4.6}$$

where t denotes an arbitrary period along the transition path. At the end of the transition path, the laws of motions converge to those in our one-shock equilibrium. Consequently, solving for the transition-path equilibrium is equivalent to finding the appropriate approximations for (4.5) and (4.6), such that the realized evolution of the economy is consistent with the postulated evolution; see Online Appendix B.3 for the details of the algorithm. We find that the same functional forms we use for the stochastic steady state economy yield accurate predictions also for the transition-path equilibrium. That is, for every period on the transition path, we achieve a similar forecast accuracy as in the stochastic steady state two-shock economy; see Online Appendix B.4 for the details.

5. Results

Following Lucas (1987), we measure the welfare costs of fiscal volatility as the proportional change in a household's life-time consumption (Consumption Equivalent Variation or λ), such that:

$$E_1\Big[\sum_{t=1}^{\infty}\beta_t u((1+\lambda)c_t, G_t)\Big] = E_1\Big[\sum_{t=1}^{\infty}\beta_t u(\tilde{c}_t, \tilde{G}_t)\Big], \tag{5.1}$$

where c_t is consumption in the baseline economy with G_t-fluctuations, while $\tilde{c}_t$ is consumption in the counterfactual economy with a deterministic $\tilde{G}_t$-process.

5.1. Baseline results

To obtain our baseline results, we first calculate welfare gains conditional on wealth, employment status and time preference for every sample economy in the transition-path computation,[29] using the value functions from our two-shock and transition-path equilibria.[30] We then average these across the sample economies, including all possible values of G_1, the government purchases level when fiscal volatility is eliminated. The results, presented in Table 5, can thus be interpreted as the *ex-ante* expected welfare gains from eliminating fiscal volatility.

The results in Table 5 show that the aggregate welfare gain, i.e., the average welfare change across the whole population, is about 0.03%, comparable in size to the results in Lucas (1987). We further find that the welfare gains increase with wealth and patience while employment status does not affect the welfare changes. In the next sub-section, we examine the mechanisms affecting the welfare gains along the wealth dimension.

5.2. The mechanisms

Our analyses show that the increasing-with-wealth welfare gain pattern is the result of three interacting channels: a direct utility channel, an income risk channel, and an average factor price channel. The direct utility channel isolates the utility gains resulting from household risk aversion with respect to government purchases fluctuations. In the income risk channel, two types of fiscal risk arising from tax rate fluctuations coexist: an after-tax-wage risk and an after-tax-rate-of-return risk. These risks have different distributional effects through the precautionary saving behavior of households and the risk exposure of households' resources. Finally, the average factor price channel reflects changes in average factor prices along the transition path.

In the following sub-sections, we discuss each channel in turn. We can exactly and quantitatively separate the direct utility channel from the other two. Although an exact quantitative separation of the income risk channel from the average factor price channel is not feasible as they are intertwined in the economy, we can illustrate the distinct ways of how they work.

[29] To start the transition-path simulation, we draw a large set (16,000) of independent joint distributions over $(a, \varepsilon, \tilde{\beta})$ from the simulation of the two-shock equilibrium; see Online Appendix B.3 for the details.

[30] The right side of (5.1) is the value function from the transition-path equilibrium. Given the log-log utility assumption in the baseline calibration, the left side of (5.1) can be expressed using the value function from the two-shock equilibrium and λ; see Online Appendix B.5 for the details of the derivation.

Table 5
Expected welfare gains λ (%).

	Wealth Group								
	All	<1%	1-5%	5-25%	25-50%	50-75%	75-95%	95-99%	>99%
All	0.0293	0.0289	0.0295	0.0296	0.0293	0.0290	0.0287	0.0313	0.0371
$\varepsilon = 1$	0.0293	0.0288	0.0294	0.0296	0.0293	0.0290	0.0287	0.0313	0.0371
$\varepsilon = 0$	0.0294	0.0291	0.0297	0.0297	0.0294	0.0291	0.0287	0.0312	0.0371
$\tilde{\beta} = \tilde{\beta}_l$	0.0277	0.0278	0.0277	0.0276	0.0275	0.0274	0.0268	0.0272	0.0314
$\tilde{\beta} = \tilde{\beta}_m$	0.0292	0.0300	0.0299	0.0296	0.0293	0.0290	0.0285	0.0302	0.0356
$\tilde{\beta} = \tilde{\beta}_h$	0.0360	0.0329	0.0327	0.0326	0.0326	0.0326	0.0336	0.0377	0.0440

Notes: The wealth groups are presented in ascending order from left to right. The welfare number for a particular combination of ε (or $\tilde{\beta}$) and a wealth group is calculated as follows: we first draw a large set (16,000) of independent joint distributions over $(a, \varepsilon, \tilde{\beta})$ from the simulation of the two-shock equilibrium. These distributions are used to start the computation of the transition-path equilibria. For each sample economy, we then find all the individuals that fall into a particular wealth×employment status or wealth×preference category, and calculate their welfare gain according to equation (5.1). We then take the average over the individuals in a particular category to find the welfare numbers for a given sample economy. To arrive at the numbers in this table, we finally take the average across all the 16,000 samples.

Table 6
Expected welfare gains from private consumption changes, λ_c (%).

	Wealth Group								
	All	<1%	1-5%	5-25%	25-50%	50-75%	75-95%	95-99%	>99%
All	0.0082	0.0081	0.0085	0.0085	0.0082	0.0079	0.0076	0.0101	0.0159
$\varepsilon = 1$	0.0082	0.0081	0.0085	0.0085	0.0082	0.0079	0.0076	0.0101	0.0159
$\varepsilon = 0$	0.0083	0.0083	0.0087	0.0086	0.0083	0.0080	0.0076	0.0101	0.0159
$\tilde{\beta} = \tilde{\beta}_l$	0.0072	0.0073	0.0073	0.0072	0.0071	0.0069	0.0064	0.0068	0.0110
$\tilde{\beta} = \tilde{\beta}_m$	0.0082	0.0089	0.0088	0.0085	0.0082	0.0079	0.0074	0.0091	0.0145
$\tilde{\beta} = \tilde{\beta}_h$	0.0142	0.0111	0.0109	0.0108	0.0108	0.0108	0.0118	0.0159	0.0222

Notes: The welfare numbers in this table are calculated as those in Table 5, using (5.3) instead of (5.1).

5.2.1. The direct utility channel

Since a household's utility over G is strictly concave, eliminating fluctuations in G leads to a direct increase in expected lifetime utility. To isolate this direct utility gain, we first compute a λ_c such that:

$$E_1[\sum_{t=1}^{\infty} \beta_t u((1+\lambda_c)c_t, G_t)] = E_1[\sum_{t=1}^{\infty} \beta_t u(\tilde{c}_t, G_t)], \tag{5.2}$$

where c_t, $\tilde{c}_t$, and G_t are defined in the same way as before. Note that, λ_c is by definition insulated from any utility change caused by direct changes in the G-process, since the stochastic G-process now enters both sides of equation (5.2). Therefore, λ_c represents welfare changes that result solely from changes in private consumption profiles. The difference between λ and λ_c thus characterizes the direct utility channel.

Furthermore, with a separable flow utility function, λ_c can be computed using the following simpler equation:

$$E_1[\sum_{t=1}^{\infty} \beta_t log((1+\lambda_c)c_t)] = E_1[\sum_{t=1}^{\infty} \beta_t log(\tilde{c}_t)]. \tag{5.3}$$

The results, presented in Table 6, show positive, albeit smaller welfare changes when fiscal volatility is eliminated (after the gain from the direct utility channel is subtracted). Thus, we conclude that the direct utility channel is quantitatively important for the overall level of welfare changes, but, distributionally, the other two channels are the ones that matter.

In addition to the direct utility channel, fluctuations in government purchases can contribute to the welfare of households through affecting factor prices (pre-tax labor and capital income) and individual income tax rates, both of which determine households' after-tax income. The government purchases process can directly

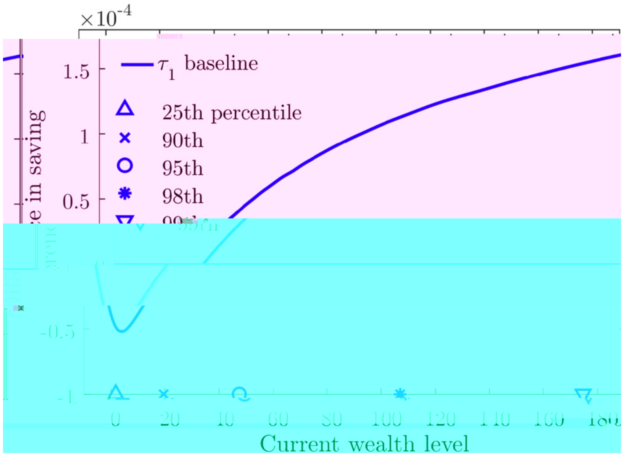


Fig. 1. Policy function comparison - saving.

Notes: This figure shows the difference between the first-period policy function for saving from the transition equilibrium (with $G_1 = G_m$) and that from the two-shock equilibrium (with $G_1 = G_m$), evaluated at $z = z_g$, $\varepsilon = 1$, $\tilde{\beta} = \tilde{\beta}_m$, and the long-run averages of $(K, B, Gini)$ conditional on $G_1 = G_m$ and $z = z_g$. Note that, under our baseline calibration, the average quarterly output turns out to be close to one (1.11). Hence, the wealth levels can roughly be interpreted as ratios to quarterly gross income per household.

the aggregate productivity and fiscal risk. Heterogeneous exposures to tax rate risks may then in turn also shape the general equilibrium effect. Whether this actually matters for average welfare is ex-ante an open question. We also computed a representative-agent version of the model and found that the λ_c welfare gains from eliminating government purchases fluctuations are 0.0075, that is, somewhat smaller than in the heterogeneous agent case but not substantially so.

In the following two subsections, we separately consider the volatility and the level effects on households' after-tax income from fluctuations in government purchases. We denote the volatility effect as the *income risk channel*, and the level effect as the *average factor price channel*.

5.2.2. The income risk channel

Fluctuations in government purchases lead to more volatile after-tax income through both tax rates and factor prices. The distributional welfare implications of eliminating this after-tax income risk are, however, not straightforward. This is because the two components of after-tax income risk, labor income risk and rate-of-return risk (or capital income risk), have opposite distributional effects.

On the one hand, the effect of eliminating after-tax labor income uncertainty depends on a household's (heterogeneous) degree of self-insurance against labor income risks. As in other Bewley-type incomplete market economies, our households engage in precautionary saving. Wealthier households can better insure themselves against after-tax labor income risk. As a result, wealth-poor households should benefit more from the elimination of this uncertainty. Hereafter, we tax

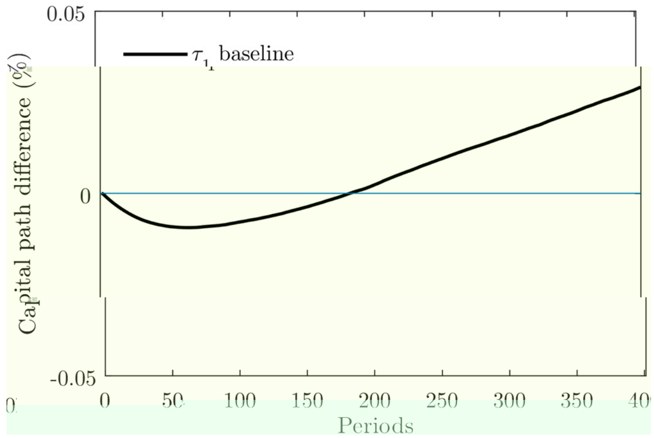


Fig. 2. Expected aggregate capital path comparison.
Notes: This figure shows the percentage difference between the expected aggregate capital path in the transition-path equilibrium and the two-shock equilibrium. We use the same 16,000 sample economies and the same sequences of z-shocks (for both the transition and the two-shock aggregate capital paths) as in the transition-path computation and then take the average. The G-shock sequences in the two-shock simulations are constructed in such a way that the cross-sectional joint distribution of (z, G)-shocks in each period is close to the invariant joint distribution.

In short, the income risk channel is an amalgam of the aforementioned two competing effects. As will be made clear in Section 6.1, through alternative counterfactual tax adjustment mechanisms,

Table 7
Expected welfare gains from private consumption, λ_c (%), conditional on G_1.

	Wealth Group								
	All	<1%	1-5%	5-25%	25-50%	50-75%	75-95%	95-99%	>99%
$G_1 = G_l$									
All	0.0135	0.0141	0.0144	0.0142	0.0138	0.0133	0.0124	0.0130	0.0179
$\varepsilon = 1$	0.0135	0.0141	0.0144	0.0142	0.0138	0.0133	0.0124	0.0130	0.0179
$\varepsilon = 0$	0.0137	0.0143	0.0146	0.0144	0.0139	0.0134	0.0124	0.0130	0.0178
$\tilde{\beta} = \tilde{\beta}_l$	0.0131	0.0134	0.0133	0.0131	0.0128	0.0125	0.0111	0.0096	0.0126
$\tilde{\beta} = \tilde{\beta}_m$	0.0134	0.0149	0.0147	0.0142	0.0138	0.0133	0.0122	0.0120	0.0163
$\tilde{\beta} = \tilde{\beta}_h$	0.0185	0.0176	0.0172	0.0169	0.0167	0.0166	0.0166	0.0194	0.0248
$G_1 = G_m$									
All	0.0085	0.0084	0.0088	0.0088	0.0085	0.0082	0.0078	0.0102	0.0160
$\varepsilon = 1$	0.0085	0.0084	0.0088	0.0088	0.0085	0.0082	0.0078	0.0102	0.0160
$\varepsilon = 0$	0.0086	0.0085	0.0089	0.0089	0.0086	0.0083	0.0078	0.0102	0.0160
$\tilde{\beta} = \tilde{\beta}_l$	0.0075	0.0076	0.0076	0.0075	0.0073	0.0072	0.0066	0.0070	0.0111
$\tilde{\beta} = \tilde{\beta}_m$	0.0084	0.0092	0.0091	0.0088	0.0085	0.0082	0.0076	0.0093	0.0146
$\tilde{\beta} = \tilde{\beta}_h$	0.0143	0.0112	0.0111	0.0110	0.0110	0.0110	0.0119	0.0160	0.0223
$G_1 = G_h$									
All	0.0025	0.0015	0.0020	0.0023	0.0022	0.0021	0.0023	0.0068	0.0137
$\varepsilon = 1$	0.0025	0.0015	0.0020	0.0023	0.0022	0.0021	0.0023	0.0068	0.0137
$\varepsilon = 0$	0.0025	0.0017	0.0022	0.0023	0.0022	0.0021	0.0023	0.0068	0.0137
$\tilde{\beta} = \tilde{\beta}_l$	0.0008	0.0007	0.0007	0.0008	0.0008	0.0009	0.0012	0.0036	0.0091
$\tilde{\beta} = \tilde{\beta}_m$	0.0024	0.0024	0.0024	0.0023	0.0022	0.0021	0.0021	0.0059	0.0124
$\tilde{\beta} = \tilde{\beta}_h$	0.0097	0.0042	0.0043	0.0044	0.0045	0.0047	0.0066	0.0123	0.0195

Notes: The welfare numbers in this table are calculated as in Table 6, but separately for $G_1 = G_l, G_m, G_h$, using 8,000 simulations for $G_1 = G_m$ and 4,000 simulations each for $G_1 = G_l, G_h$.

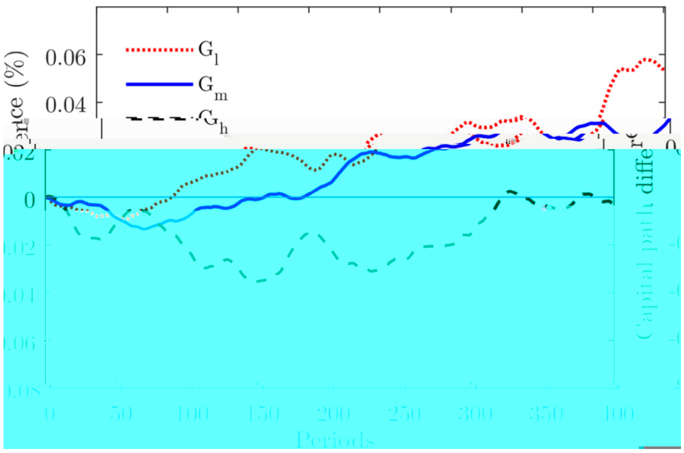


Fig. 3. Expected aggregate capital path comparison, conditional on G_1.
Notes: This figure shows the percentage difference between the expected aggregate capital path in the transition-path equilibrium and the two-shock equilibrium conditional on G_1. We use the same 16,000 sample economies and the same sequences of z-shocks (for both the transition and the two-shock aggregate capital paths) as in the transition-path computation and then average by G_1: 8,000 simulations for $G_1 = G_m$, and 4,000 simulations each for $G_1 = G_l, G_h$. Note that, due to our conditioning on G_1 and the subsequent smaller sample sizes, the expected aggregate capital paths in Fig. 3 are more volatile compared to those in Fig. 2.

6. Alternative specifications and additional experiments

In this section, we examine the welfare and distributional consequences of eliminating fiscal volatility under the following alternative model specifications: different adjustments to the progressive tax function, other fiscal regimes, different flow utility functions, and alternative TFP and labor income processes. In addition, we examine our

Table 8
Expected welfare gains from private consumption, λ_c (%), under different cases.

	Wealth Group								
	All	<1%	1-5%	5-25%	25-50%	50-75%	75-95%	95-99%	>99%
Baseline	0.0082	0.0081	0.0085	0.0085	0.0082	0.0079	0.0076	0.0101	0.0159
Different Tax Function Adjustment									
Adjusting τ_0	0.0084	0.0083	0.0086	0.0087	0.0084	0.0082	0.0077	0.0091	0.0135
Adjusting τ_2	0.0088	0.0093	0.0095	0.0095	0.0093	0.0091	0.0080	0.0051	0.0065
Adjusting τ_3	0.0087	0.0095	0.0097	0.0096	0.0093	0.0090	0.0078	0.0028	0.0030
Other Fiscal Regimes									
Balanced Budget	0.0112	0.0109	0.0109	0.0108	0.0107	0.0107	0.0110	0.0159	0.0242
Linear Tax	0.0072	0.0067	0.0068	0.0070	0.0070	0.0070	0.0071	0.0103	0.0163
Lump-sum Tax	0.0073	0.0070	0.0070	0.0070	0.0069	0.0068	0.0071	0.0129	0.0204
Linear Capital Tax	0.0051	0.0057	0.0057	0.0057	0.0056	0.0051	0.0043	0.0028	0.0041
Benabou Tax Function	0.0071	0.0072	0.0076	0.0076	0.0073	0.0070	0.0064	0.0072	0.0102
Non-separable Utility Function									
Substitute	0.0008	0.0015	0.0028	0.0028	0.0003	0.0020	-0.0017	-0.0019	0.0014
Complement	0.0278	0.0258	0.0281	0.0284	0.0236	0.0305	0.0285	0.0322	0.0294
Alternative TFP and labor income processes									
Constant TFP	0.0089	0.0084	0.0089	0.0090	0.0087	0.0085	0.0084	0.0119	0.0191
Demand Externality	0.0090	0.0090	0.0095	0.0095	0.0092	0.0089	0.0084	0.0093	0.0127
Richer Income Process	0.0054	0.0058	0.0059	0.0059	0.0057	0.0052	0.0046	0.0050	0.0107
Superstar Income	0.0062	0.0069	0.0069	0.0069	0.0066	0.0060	0.0053	0.0049	0.0086
Higher UI rate	0.0081	0.0077	0.0088	0.0082	0.0080	0.0078	0.0075	0.0105	0.0169
Additional Experiments									
Double Volatility	-0.0070	-0.0070	-0.0074	-0.0073	-0.0070	-0.0067	-0.0063	-0.0089	-0.0148
Sudden Change	0.0108	0.0125	0.0123	0.0118	0.0111	0.0104	0.0092	0.0100	0.0158

6.1. Alternative specifications

Tax function adjustments Recall that, in our baseline specification, the top marginal rate of the progressive income tax (τ_1) is determined endogenously to satisfy the government's tax revenue response rule (equation (2.6)), while the linear tax rate (τ_0) and the tax function parameters τ_2 and τ_3 in the progressive tax function are fixed. Although we have argued that a fluctuating τ_1 can best represent the cyclicality of the progressivity of the U.S. tax system, here we consider the following three alternative adjustments in the tax function: adjusting τ_0, the linear part in the income tax function, and adjusting τ_2 and τ_3, the tax parameters that govern the progressivity of the tax system.

The average and distributional welfare results from the case with τ_0-adjustment turn out to be quite similar to those from the baseline (row 2 of Table 8). To understand this outcome, we first note that the

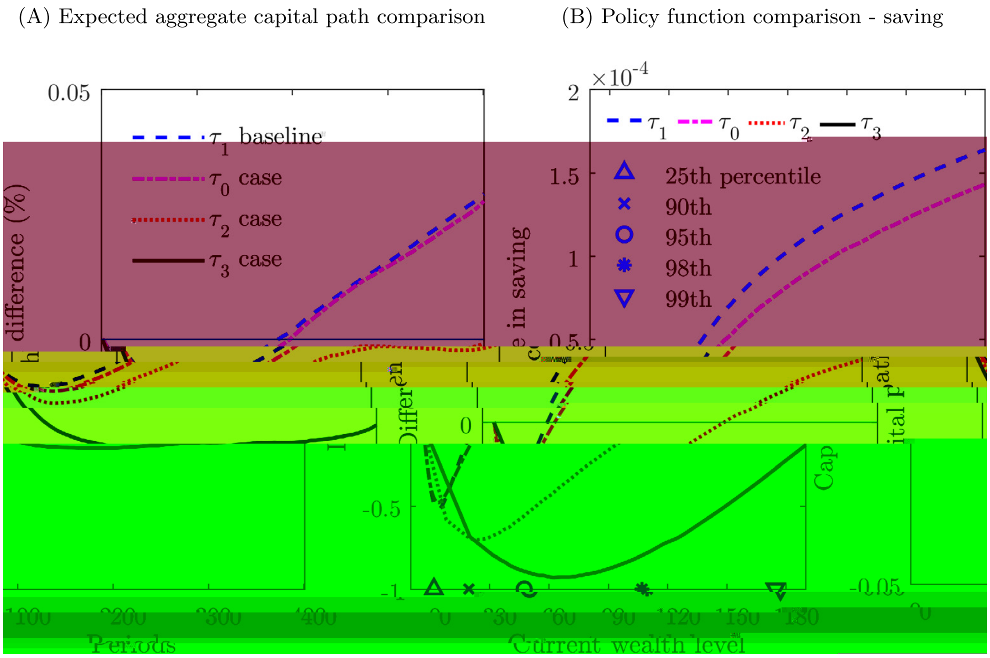
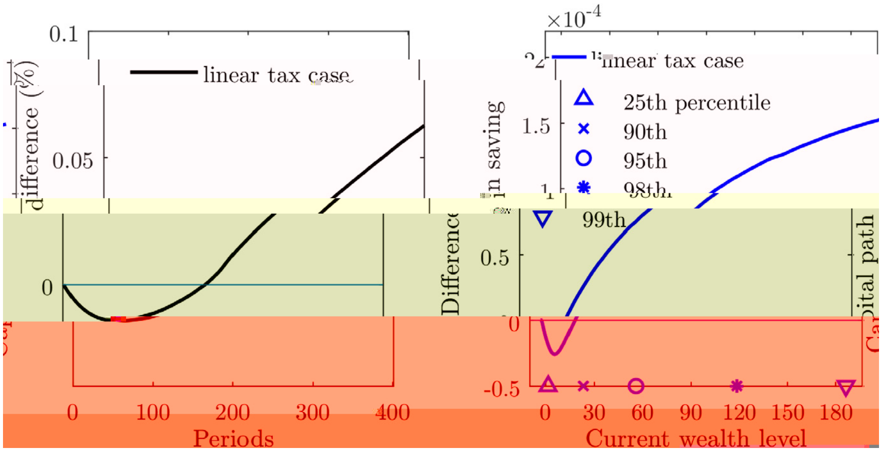


Fig. 4. Comparing various tax adjustment cases with the baseline.

Notes: Panel (A) compares the percentage difference

(A) Expected aggregate capital path co



returns and wages in this case we also have a less powerful income risk channel): the higher return makes capital more attractive as a saving vehicle after the elimination of volatility (see Panel B of Fig. 6), leading to benefits for the wealth-rich.

In our baseline model, we subject both labor and capital income to the same progressive tax function on total income. We view this as a good first pass because, at the

e eore-5.9(s49e4tc)14i2com:r and e4.2rmy choices (flexible prices in combination with inelastic labor supply). Following Krueger et al. (2016), we implement a model specification with a demand externality where output is an increasing function of the sum of private and public consumption. To be specific, we assume the following aggregate production function:

$$Y_t = z_t(C_t + G_t)^{\Omega} K_t^{\alpha} L_t^{1-\alpha}, \tag{6.2}$$

where $\Omega > 0$ determines the strength of the effect of demand on output. We calibrate Ω to be 0.43, which gives us a fiscal multiplier on impact around 0.5, a value within the range reported in Ramey (2011).[38] The welfare numbers in row 13 of Table 8 show that the welfare gains in the economy with a positive fiscal multiplier are similar to those from the baseline model. This is because the positive fiscal multiplier has two offsetting effects. On the one hand, a positive multiplier amplifies the impact of government purchases shocks on economic volatility, which by itself would lead to higher welfare gains from eliminating fiscal volatility. On the other hand, the positive multiplier acts as partial insurance to the same shocks by increasing the effective TFP when tax rates are higher.[39] Moreover, our distributional result that welfare gains are increasing in wealth continues to hold.

Our baseline specification, to ease the computational burden, also does not allow for any labor income heterogeneity conditional on being employed. However, a realistically richer income process might matter for our welfare results. It can affect the implications of the progressive tax system as well as the degree of precautionary saving motive. Moreover, it provides an additional channel through which wealth inequality is generated in the model (Krueger et al., 2016). To examine whether this feature affects our welfare results, we introduce individual-specific productivity shocks as in McKay and Reis (2016). The idiosyncratic productivity process is assumed to be independent from any other processes and determines the labor earnings for employed households.[40] The welfare numbers in row 14 of Table 8 indicate that the richer labor income dynamics does not change the main message of the baseline model. The average welfare change is slightly smaller than that in the baseline case, but the wealth-rich still benefit more from the fiscal volatility elimination.

The richer income process case above still relies on heterogeneous discount factors to generate realistic wealth inequality; one might wonder whether our results would stay the same if the wealth distribution were purely driven by precautionary savings. To examine this question, we consider a

Table 9
Conditional expected welfare gains from private consumption, λ_c (%), sudden change.

$G_1 = G_l$	Wealth Group								
	All	<1%	1-5%	5-25%	25-50%	50-75%	75-95%	95-99%	>99%
All	-0.3749	-0.5121	-0.4826	-0.4469	-0.4198	-0.3922	-0.3030	0.0078	0.2184
$\varepsilon = 1$	-0.3748	-0.5134	-0.4833	-0.4471	-0.4200	-0.3924	-0.3036	0.0074	0.2182
$\varepsilon = 0$	-0.3762	-0.5054	-0.4764	-0.4455	-0.4179	-0.3897	-0.2952	0.0132	0.2212
$\tilde{\beta} = \tilde{\beta}_l$	-0.4978	-0.5347	-0.5213	-0.4932	-0.4636	-0.4369	-0.3232	-0.0537	0.1555
$\tilde{\beta} = \tilde{\beta}_m$	-0.3786	-0.4904	-0.4732	-0.4465	-0.4198	-0.3924	-0.3090	-0.0032	0.2056
$\tilde{\beta} = \tilde{\beta}_h$	-0.0521	-0.4158	-0.3934	-0.3644	-0.3380	-0.3097	-0.1665	0.0754	0.2759
$G_1 = G_h$	Wealth Group								
	All	<1%	1-5%	5-25%	25-50%	50-75%	75-95%	95-99%	>99%

Appendix A. Estimation of the fiscal parameters

For the calibration, we use quarterly data from 1960I to 2007IV.

A.1. Government purchases process

We first construct a real government purchases (G) series by deflating the "Government consumption expenditures and gross investment" series (from NIPA table 3.9.5, line 1) with the GDP deflator (from NIPA table 1.1.9, line 1). We then estimate an AR(1) process for the linearly detrended real log(G) series. The estimated AR(1) coefficient is 0.9603 and the standard deviation of the innovation term is 0.0096. We use the Rouwenhorst method (see Rouwenhorst (1995)) to approximate this zero-mean AR(1) process with a three-state Markov Chain. This gives us a transition probability matrix, and a grid in the form $(-m, 0, m)$, where m represents the percentage deviation from the middle grid point. The middle grid point of the G-process, G_m, is then calibrated

Table 10
Estimated coefficients of the fiscal rule.

	constant	B_t/Y_t	$log(Y_t/\bar{Y}_t)$	G_t/Y_t
Federal	-0.009	0.017	0.321	0.146
	(0.001)	(0.003)	(0.032)	(0.096)
State and local	0.001	–	-0.039	0.771
	(0.001)	–	(0.015)	(0.063)

A.2.2. The composite fiscal rule

The composite fiscal rule used in our model is given by:

$$\begin{aligned}\frac{T_t - Tr_t}{Y_t} &= \rho_{T,0} + \rho_{T,B}\frac{B_t}{Y_t} + \rho_{T,Y} log(\frac{Y_t}{\bar{Y}_t}) + \rho_{T,G}\frac{G_t}{Y_t} \\ &= \rho_{T,0} + \rho^F_{T,B}\frac{B_t}{Y_t} + (\rho^F_{T,Y} + \rho^{SL}_{T,Y}) log(\frac{Y_t}{\bar{Y}_t}) + (\gamma^F \rho^F_{T,G} + (1-\gamma^F)\rho^{SL}_{T,G})\frac{G_t}{Y_t},\end{aligned} \tag{A.3}$$

where γ^F is calibrated as the average share of federal government purchases within total government purchases: 0.46. This yields the following fiscal rule parameters:

$$\rho_{T,B} = 0.017, \quad \rho_{T,Y} = 0.282, \quad \rho_{T,G} = 0.484.$$

We use $\rho_{T,0}$ to match the average debt-to-GDP ratio in the data: 30%.

A.3. Consumption and income tax parameters

For the consumption tax function and the linear part of the income tax function, we use the average tax rate calculated from the data.

To be specific, the average tax rate on consumption is defined as:

$$\tau_c = \frac{TPI - PRT}{PCE - (TPI - PRT)}, \tag{A.4}$$

where the numerator is taxes on production and imports (TPI, NIPA table 3.1, line 4) minus state and local property taxes (PRT, NIPA table 3.3, line 8). The denominator is personal consumption expenditures (PCE, NIPA table 1.1.5, line 2) net of the numerator. We calculate the average $\tau_{c,t}$ over our sample period as our τ_c parameter: 8.14%.

For income taxes, we use the state level tax revenue to approximate the linear part:

$$\tau_0 = \frac{PIT + CT + PRT}{\text{Taxable Income}}, \tag{A.5}$$

where PIT (NIPA table 3.3, line 4) is state income tax, CT (NIPA table 3.3, line 10) is state tax on corporate income, and PRT (NIPA table 3.3, line 8) is state property taxes. Note that we exclude the social insurance contribution in the numerator since we do not have social security expenditures in the model. The denominator is GDP minus consumption of fixed capital (NIPA table 1.7.5, line 6), since our model has a depreciation allowance for capital income. Averaging $\tau_{0,t}$ from 1960I to 2007IV yields $\tau_0 = 5.25\%$.

Appendix B. Supplementary material

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.red.2020.04.001.

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