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# The role of automatic stabilizers in the U.S. business cycle\*

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## Abstract

Most countries have automatic rules in their tax-and-transfer systems that are partly intended to stabilize economic fluctuations. This paper measures how effective they are. We put forward a model that merges the standard incomplete-markets model of consumption and inequality with the new Keynesian model of nominal rigidities and business cycles, and that includes most of the main potential stabilizers in the U.S. data, as well as the theoretical channels by which they may work. We find that the conventional argument that stabilizing disposable income will stabilize aggregate demand plays a negligible role on the effectiveness of the stabilizers, whereas tax-and-transfer programs that affect inequality and social insurance can have a large effect on aggregate volatility. However, as currently designed, the set of stabilizers in place in the United States has barely had any effect on volatility. According to our model, expanding safety-net programs, like food stamps, has the largest potential to enhance the effectiveness of the stabilizers.

**JEL codes:** E32, E62, H30.

**Keywords:** Countercyclical fiscal policy; Heterogeneous agents; Fiscal multipliers.

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# 1 Introduction

The fiscal stabilizers are the rules in the law that make fiscal revenues and outlays relative to total income change with the business cycle. They are large, estimated by the Congressional Budget Office (2013) to account for \$386 of the \$1089 billion U.S. deficit in 2012, and much research has been devoted to measuring them using either microsimulations (e.g., Auerbach, 2009) or time-series aggregate regressions (e.g., Fedelino et al., 2005). Unlike the controversial topic of discretionary fiscal stimulus, these built-in responses of the tax-and-transfer system have been praised over time by many economists as well as policy institutions.<sup>1</sup> The IMF (Baunsgaard and Symansky, 2009; Spilimbergo et al., 2010) recommends that countries enhance the scope of these fiscal tools as a way to reduce macroeconomic volatility. In spite of this enthusiasm. Blanchard (2006) noted that: “very little work has been done on automatic stabilization [...] in the last 20 years” and Blanchard et al. (2010) argued that designing better automatic stabilizers was one of the most promising routes for better macroeconomic policy.

This paper asks the question: are the automatic stabilizers effective? More concretely, we propose a business-cycle model that captures the most important channels through which the automatic stabilizers may attenuate the business cycle, we calibrate it to U.S. data, and we use it to measure their quantitative importance. Our first and main contribution is a set of estimates of how much higher would the volatility of aggregate activity be if some or all of the fiscal stabilizers were removed.

Our second contribution is to investigate the theoretical channels by which the stabilizers may attenuate the business cycle and to quantify their relative importance. The literature suggests four main channels. The dominant mechanism, present in almost all policy discussions of the stabilizers, is the *disposable income* channel (Brown, 1955). If a fiscal instrument, like an income tax, reduces the fluctuations in disposable income, it will make consumption and investment more stable, thereby stabilizing aggregate demand. In the presence of nominal rigidities, this will stabilize the business cycle. A second channel for potential stabilization works through *marginal incentives* (Christiano, 1984). For example, with a progressive personal income tax, the tax rate facing workers rises in booms and falls in recessions, therefore encouraging intertemporal substitution of work effort away from booms and into recessions. Third, automatic stabilizers have a *redistribution* channel. Blinder (1975) argued that if

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<sup>1</sup>See Auerbach (2009) and Feldstein (2009) in the context of the 2007-09 recession, and Auerbach (2003) and Blinder (2006) more generally for contrasting views on the merit of countercyclical fiscal policy, but agreement on the importance of automatic stabilizers.

those that receive funds have higher propensities to spend them than those who give the funds, aggregate consumption and demand will rise with redistribution. Oh and Reis (2012) argued that if the receivers are at a corner solution with respect to their choice of hours to work, while the payers work more to offset their fall in income, aggregate labor supply will rise with redistribution. Related is the *social insurance* channel: these policies alter the risks households face with consequences for precautionary savings and the distribution of wealth (Floden, 2001; Alonso-Ortiz and Rogerson, 2010; Challe and Ragot, 2013). For instance, a generous safety net will reduce precautionary savings making it more likely that agents face liquidity constraints after an aggregate shock.

Our third contribution is methodological. We believe our model is the first to merge the standard incomplete-markets model surveyed in Heathcote et al. (2009) with the standard sticky-price model of business cycles in Woodford (2003). Building on work by Reiter (2010, 2009), we show how to numerically solve for the ergodic distribution of the endogenous aggregate variables in a model where the distribution of wealth is a state variable and prices are sticky. This allows us to compute second moments for the economy, and to investigate counterfactuals in which some or all of the stabilizers are not present. We hope that future work will build on this contribution to study the interaction between inequality, business cycles and macroeconomic policy in the presence of nominal rigidities.

We do not calculate optimal policy in our model, partly because this is computationally infeasible at this point, and partly because that is not the spirit of our exercise. Our calculations are instead in the tradition of Summers (1981) and Auerbach and Kotlikoff (1987). Like them, we propose a model that fits the US data and then change the tax-and-transfer system within the model to make positive counterfactual predictions on the business cycle. We also calculate the effect on welfare using different metrics, but acknowledging that many of the stabilizers involve a great deal of redistribution, so any measure of social welfare will rely on controversial assumptions about how to weigh different individuals.

### *Literature Review*

This paper is part of a revival of interest in fiscal policy in macroeconomics.<sup>2</sup> Most of this literature has focussed on fiscal multipliers that measure the response of aggregate variables to discretionary shocks to policy. Instead, we measure the effect of fiscal rules on the ergodic variance of aggregate variables. This leads us to also devote more attention to taxes and government transfers, whereas the previous literature has tended to focus on government

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<sup>2</sup>For a survey, see the symposium in the *Journal of Economic Literature*, with contributions by Parker (2011), Ramey (2011) and Taylor (2011).

purchases.<sup>3</sup>

Focussing on stabilizers, there is an older literature discussing their effectiveness (e.g., Musgrave and Miller, 1948), but little work using modern intertemporal models. Christiano (1984) and Cohen and Follette (2000) use a consumption-smoothing model, Gali (1994) uses a simple RBC model, Andrés and Doménech (2006) use a new Keynesian model, and Hairault et al. (1997) use a few small-scale DSGEs. However, they typically consider the effect of a single automatic stabilizer, the income tax, whereas we comprehensively evaluate several of them to provide a quantitative assessment of the stabilizers as a group. Christiano and Harrison (1999), Guo and Lansing (1998) and Dromel and Pintus (2008) ask whether progressive income taxes change the region of determinacy of equilibrium, whereas we use a model with a unique equilibrium, and focus on the impact of a wider set of stabilizers on the volatility of endogenous variables at this equilibrium. Jones (2002) calculates the effect of estimated fiscal rules on the business cycle using a representative-agent model, whereas we focus on the rules that make up for automatic stabilization and find that heterogeneity is crucial to understand their effects. Finally, some work (van den Noord, 2000; Barrell and Pina, 2004; Veld et al., 2013) uses large macro simulation models to conduct exercises in the same spirit as ours, but their models are often too complicated to isolate the different channels of stabilization and they typically assume representative agents, shutting off the redistribution and social insurance channels that we will find to be important.

Huntley and Michelangeli (2011) and Kaplan and Violante (2012) are closer to us in the use of optimizing models with heterogeneous agents to study fiscal policy. However, they estimate multipliers to discretionary tax rebates, whereas we estimate the systematic impact on the ergodic variance of the automatic features of the fiscal code. Heathcote (2005) analyzes an economy that is hit by tax shocks and shows that aggregate consumption responds more strongly when markets are incomplete due to the redistribution mechanism. We study instead how the fiscal structure alters the response of the economy to non-fiscal shocks. Floden (2001), Alonso-Ortiz and Rogerson (2010), Horvath and Nolan (2011), and Berriel and Zilberman (2011) focus on the effects of tax and transfer programs on average output, employment, and welfare in a steady state without aggregate shocks. Instead, we focus on business-cycle volatility, so we have aggregate shocks and measure variances.

Methodologically, we are part of a recent literature using incomplete-market models with

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<sup>3</sup>In the United States in 2011, total government purchases were 2.7 trillion dollars. Government transfers amounted to almost as much, at 2.5 trillion. Focussing on the cyclical components, during the 2007-09 recession, which saw the largest increase in total spending as a ratio of GDP since the Korean war, 3/4 of that increase was in transfers spending (Oh and Reis, 2012), with the remaining 1/4 in government purchases.

nominal rigidities to study business-cycle questions. Oh and Reis (2012) and Guerrieri and Lorenzoni (2011) were the first to incorporate nominal rigidities into the standard model of incomplete markets. Both of them solved only for the impact of a one-time unexpected aggregate shock, whereas we are able to solve for recurring aggregate dynamics. Gornemann et al. (2012) solve a conceptually similar problem to ours, but they focus on the distributional consequences of monetary policy.

Empirically, Auerbach and Feenberg (2000), Auerbach (2009), and Dolls et al. (2012) use micro-simulations of tax systems to estimate the changes in taxes that follows a 1% increase in aggregate income. A much larger literature (e.g, Fatas and Mihov, 2012) has measured automatic stabilizers using macro data, estimating which components of revenue and spending are strongly correlated with the business cycle. Whereas this work focusses on measuring the presence of stabilizers, our goal is instead to judge their effectiveness.

## 2 A business-cycle model with automatic stabilizers

To quantitatively evaluate the role of automatic stabilizers, we would like to have a model that satisfies three requirements.

First, the model must include the four channels of stabilization that we discussed. We accomplish this by proposing a model that includes: (i) intertemporal substitution, so that marginal incentives matter, (ii) nominal rigidities, so that aggregate demand plays a role in fluctuations, (iii) liquidity constraints and unemployment, so that Ricardian equivalence does not hold and there is heterogeneity in marginal propensities to consume and willingness to work, and (iv) incomplete insurance markets and precautionary savings, so that social insurance affects the response to aggregate shocks.

Second, we would like to have a model that is close to existing frameworks that are known to capture the main features of the U.S. business cycle. With complete insurance markets, our model is similar to the neoclassical-synthesis DSGE models used for business cycles, as in Christiano et al. (2005), but augmented with a series of taxes and transfers. With incomplete insurance markets, our model is similar to the one in Krusell and Smith (1998), but including nominal rigidities and many taxes and transfers.

Third and finally, the model must include the main automatic stabilizers present in the data. Table 1 provides an overview of the main components of spending and revenue in the integrated U.S. government budget. Appendix A provides more details on how we define each category.

Table 1: The automatic stabilizers in the U.S. government budget

<b>Revenues</b>		<b>Outlays</b>	
<i>Progressive income taxes</i>		<i>Transfers</i>	
Personal Income Taxes	10.98%	Unemployment benefits	0.33%
		Safety net programs	1.02%
<i>Proportional taxes</i>		Supplemental nutrition assistance	0.24%
Corporate Income Taxes	2.57%	Family assistance programs	0.24%
Property Taxes	2.79%	Security income to the disabled	0.36%
Sales and excise taxes	3.85%	Others	0.19%
<i>Budget deficits</i>		<i>Budget deficits</i>	
Public deficit	1.87%	Government purchases	15.60%
		Net interest income	2.76%
<i>Out of the model</i>		<i>Out of the model</i>	
Payroll taxes	6.26%	Retirement-related transfers	7.13%
Customs taxes	0.24%	Health benefits (non-retirement)	1.56%
Licenses, fines, fees	1.69%	Others (esp. rest of the world)	1.85%
Sum	30.25%	Sum	30.25%

*Notes: Each cell shows the average of a component of the budget as a ratio of GDP, 1988-2007*

The first category on the revenue side is the classic automatic stabilizer, the *personal income tax* system. Because it is progressive in the United States, its revenue falls by more than income during a recession. Moreover, it lowers the volatility of after-tax income, it changes marginal returns from working over the cycle, it redistributes from high to low-income households, and it provides insurance. Therefore, it works through all of the four theoretical channels. We consider three more stabilizers on the revenue side: corporate income taxes, property taxes and sales and excise taxes. All of them lower the volatility of after tax income and so may potentially be stabilizing. Because they have, approximately, a fixed statutory rate, we will refer to them as a group as *proportional taxes*.<sup>4</sup>

On the spending side, we consider two stabilizers working through *transfers*. Unemployment benefits greatly increase in every recession as the number of unemployed rises. Safety-net programs include food stamps, cash assistance to the very poor, and transfers to the disabled. During recessions, more households have incomes that qualify them for these programs and the aggregate quantity of transfers increases.

A seventh stabilizer is the *budget deficit*, or the automatic constraint imposed by the government budget constraint. We will consider different rules for how deficits are reduced and how fast debt is paid down, especially with regards to how government purchases adjust.

<sup>4</sup>Average effective corporate income tax rates are in fact countercyclical in the data, mostly as result of recurrent changes in investment tax credits during recessions that are not automatic.

The convention in the literature measuring automatic stabilizers is to exclude government purchases because there is no automatic rule dictating their adjustment.<sup>5</sup> That literature distinguishes between the built-in stabilizers that respond automatically, by law, to current economic conditions, and the feedback rule that captures the behavior of fiscal authorities in response to current and past information. To give one example, receiving benefits when unemployed is an automatic feature of unemployment insurance, while the decision by policymakers to extend the duration of unemployment benefits in most recessions is not. Measuring automatic stabilizers requires reading and interpreting the written laws and regulations, whereas estimating fiscal policy rules faces difficult identification challenges. We will consider both the convention of excluding purchases, as well as an alternative where government purchases serve as a stabilizer by responding to budget deficits.

The last rows of table 1 include the fiscal programs that we will exclude from our study because they conflict with at least one of our desired model properties. Licenses and fines have no obvious stabilization role. We leave out international flows so that we stay within the standard closed-economy business-cycle model. More important in their size in the budget, we omit retirement, both in its expenses and in the payroll taxes that finance it, and we omit health benefits through Medicare and Medicaid. We exclude them for two complementary reasons. First, so that we follow the convention, since the vast literature on measuring automatic stabilizers to assess structural deficits almost never includes health and retirement spending.<sup>6</sup> Second, because conventional business-cycle models typically ignore the life-cycle considerations that dominate choices of retirement and health spending. Exploring possible effects of public spending on health and retirement on the business cycle is a priority for future work.

The model that follows is the simplest that we could write—and it is already quite complicated—that satisfies these three requirements and includes all of these stabilizers. To make the presentation easier, we will discuss several agents, so that we can introduce one automatic stabilizer per type of agent, but most of them could be centralized into a single household and a single firm without changing the equilibrium of the model.

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<sup>5</sup>See Perotti (2005) and Girouard and André (2005) for two of many examples.

<sup>6</sup>Even the increase in medical assistance to the poor during recessions is questionable: for instance, in 2007-09 the proportional increase in spending with Medicaid was as high as that with Medicare.



## 2.1 Capitalists and the personal income tax

There is a fixed unit measure of ex-ante identical consumers that have access to the stock market and which we refer to as capitalists or capital owners.<sup>7</sup> We assume they have access to financial markets where all idiosyncratic risks can be insured, but this is not a strong assumption. These agents enjoy significant wealth and would be close to self-insuring, even without state-contingent financial assets. We can then talk of a representative capitalist, whose preferences are:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[ \log c_t - \psi_1 \frac{n_t^{1+\psi_2}}{1+\psi_2} \right] \quad (1)$$

where  $c_t$  is consumption and  $n_t$  are hours worked, both non-negative. The parameters  $\beta$ ,  $\psi_1$  and  $\psi_2$  measure the discount factor, the relative willingness to work, and the Frisch elasticity of labor supply, respectively.

The budget constraint is:

$$\hat{p}_t c_t + b_{t+1} - b_t = p_t [x_t - \bar{\tau}^x(x_t) + T_t^e]. \quad (2)$$

The left-hand side has the uses of funds: consumption at the after-tax price  $\hat{p}_t$  plus saving in risk-less bonds  $b_t$  in nominal units. The right-hand side has after-tax income, where  $x_t$  is the real pre-tax income and  $\bar{\tau}^x(x_t)$  are personal income taxes. The  $T_t^e$  refers to lump-sum transfers, which we will calibrate to zero, but will be useful later to discuss counterfactuals.

The real income of the stock owner is:

$$x_t = (i_t/p_t)b_t + d_t + w_t \bar{s} n_t. \quad (3)$$

It equals the the sum of the returns on bonds at nominal rate  $i_t$ , dividends  $d_t$  from owning firms, and wage income. The wage rate is the product of the average wage in the economy,  $w_t$ , and the agent's productivity  $\bar{s}$ . This productivity could be an average of the individual-specific productivities of all capitalists, since these idiosyncratic draws are perfectly insured.

The first automatic stabilizer in the model is the *personal income tax* system. It satisfies:

$$\bar{\tau}^x(x) = \int_0^x \tau^x(x') dx', \quad (4)$$

where  $\tau^x : \mathfrak{R}^+ \rightarrow [0, 1]$  is the marginal tax rate that varies with the tax base, which equals

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<sup>7</sup>Because we will assume balanced-growth preferences, it would be straightforward to include population and economic growth.

real income. The system is progressive because  $\tau^x(\cdot)$  is weakly increasing.

## 2.2 Households and transfers

There is a measure  $\nu$  of impatient households indexed by  $i \in [0, \nu]$ , so that an individual variable, say consumption, will be denoted by  $c_t(i)$ . They have the same period felicity function as capitalists, but they are more impatient:  $\hat{\beta} \leq \beta$ . Following Krusell and Smith (1998), having heterogeneous discount factors allows us to match the very skewed wealth distribution that we observe in the data. We link this wealth inequality to participation in financial markets to match the well-known fact that most U.S. households do not directly own any equity (Mankiw and Zeldes, 1991). We assume that the impatient households do not own shares in the firms or own the capital stock.

Just like capitalists, individual households choose consumption, hours of work, and bond holdings  $\{c_t(i), n_t(i), b_{t+1}(i)\}$  to maximize:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \hat{\beta}^t \left[ \log c_t(i) - \psi_1 \frac{n_t(i)^{1+\psi_2}}{1+\psi_2} \right]. \quad (5)$$

Also like capitalists, households can borrow using government bonds, and pay personal income taxes, so their budget constraint is:

$$\hat{p}_t c_{t,i} + b_{t+1,i} - b_{t,i} = p_t [x_{t,i} - \bar{\tau}^x(x_{t,i}) + T_{t,i}^s], \quad (6)$$

together with a borrowing constraint,  $b_{t+1}(i) \geq 0$ . The lower bound equals the natural debt limit if households cannot borrow against future government transfers.

Unlike capital owners, households face two sources of uninsurable idiosyncratic risk: on their labor-force status,  $e_t(i)$ , and on their skill,  $s_t(i)$ . If the household is employed, then  $e_t(i) = 2$ , and she can choose how many hours to work. While working, her labor income is  $s_t(i)w_t n_t(i)$ . The shocks  $s_t(i)$  captures shocks to the worker's skill, her productivity at the job, or the wage offer she receives. They generate a cross-sectional distribution of labor income. With some probability, the worker loses her job, in which case  $e_t(i) = 1$  and labor income is zero. However, now the household collects unemployment benefits  $T_t^u(i)$ , which are taxable in the United States. Once unemployed, the household can either find a job with some probability, or exhaust her benefits and qualify for poverty benefits. This is the last state, and for lack of better terms, we refer to their members as the needy, the poor, or the long-term unemployed. If  $e_t(i) = 0$ , labor income is zero but the household collects

food stamps and other safety-net transfers,  $T_t^s(i)$ , which are non-taxable. Households in this labor market state are less likely than the unemployed to regain employment.

Collecting all of these cases, the taxable real income of a household is:

$$x_{t,i} = \begin{cases} \frac{i_t b_{t,i}}{p_t} + w_t s_{t,i} n_{t,i} & \text{if employed;} \\ \frac{i_t b_{t,i}}{p_t} + T_{t,i}^u & \text{if unemployed;} \\ \frac{i_t b_{t,i}}{p_t} & \text{if needy.} \end{cases} \quad (7)$$

For now, we model the transition across labor-force status as exogenous. Section 5.4 will consider the case where search effort affects these probabilities.

There are two new automatic stabilizers at play in the household problem. First, the household can collect unemployment benefits,  $T_t^u(i)$  which equal:

$$T_{t,i}^u = \bar{T}^u \min \{s_{t,i}, \bar{s}^u\}. \quad (8)$$

Making the benefits depend on the current skill-level captures the link between unemployment benefits and previous earnings, and relies on the persistence of  $s_{t,i}$  to achieve this. As is approximately the case in the U.S. law, we keep this relation linear with slope  $\bar{T}^u$  and a maximum cap  $\bar{s}^u$ .

The second stabilizer is the safety-net payment  $T_t^s(i)$ , which equals:

$$T_{t,i}^s = \bar{T}^s. \quad (9)$$

We assume that these transfers are lump-sum, providing a minimum living standard. In the data, transfers are means-tested, but in our model these families only receive interest income from holding bonds and this is a small amount for most households. When we impose a maximum income cap to be eligible for these benefits, we find that almost no household hits this cap. For simplicity, we keep the transfer lump-sum.

### 2.3 Final goods' producers and the sales tax

A competitive sector for final goods combines intermediate goods according to the production function:

$$y_t = \left( \int_0^1 y_t(j)^{1/\mu_t} dj \right)^{\mu_t}, \quad (10)$$

where  $y_t(j)$  is the input of the  $j^{\text{th}}$  intermediate input. There are shocks to the elasticity of substitution across intermediates that generate exogenous movements in desired markups,  $\mu_t > 1$ .

The representative firm in this sector takes as given the final-goods pre-tax price  $p_t$ , and pays  $p_t(j)$  for each of its inputs. Cost minimization together with zero profits imply that:

$$y_t(j) = \left( \frac{p_t(j)}{p_t} \right)^{\mu_t/(1-\mu_t)} y_t, \quad (11)$$

$$p_t = \left( \int_0^1 p_t(j)^{1/(1-\mu_t)} dj \right)^{1-\mu_t}. \quad (12)$$

Goods purchased for consumption are taxed at the rate  $\tau^c$ , so the after-tax price of consumption goods is:

$$\hat{p}_t = (1 + \tau^c)p_t. \quad (13)$$

This consumption tax is our next automatic stabilizer, as it makes actual consumption of goods a fraction  $1/(1 + \tau^c)$  of pre-tax spending on them.

## 2.4 Intermediate goods and corporate income taxes

There is a unit continuum of intermediate-goods monopolistic firms, each producing variety  $j$  using a production function:

$$y_t(j) = a_t k_t(j)^\alpha \ell_t(j)^{1-\alpha}, \quad (14)$$

where  $a_t$  is productivity,  $k_t(j)$  is capital used, and  $\ell_t(j)$  is effective labor.

The labor market clearing condition is

$$\int_0^1 \ell_t(j) dj = \int_0^\nu s_t(i) n_t(i) di + \bar{s} n_t. \quad (15)$$

The demand for labor on the left-hand side comes from the intermediate firms. The supply on the right-hand side comes from employed households and capitalists, adjusted for their productivity.

The firm maximizes after-tax nominal profits

$$d_t(j) \equiv (1 - \tau^k) \left[ \frac{p_t(j)}{p_t} y_t(j) - w_t \ell_t(j) - (v r_t + \delta) k_t(j) - \xi \right] - (1 - v) r_t k_t(j), \quad (16)$$

taking into account the demand function in equation (11). The firm's costs are the wage bill to workers, the rental of capital at rate  $r_t$  plus depreciation of a share  $\delta$  of the capital used, and a fixed cost  $\xi$ . The parameter  $v$  measures the share of capital expenses that can be deducted from the corporate income tax. In the U.S., dividends and capital gains pay different taxes. While this distinction is important to understand the capital structure of firms and the choice of retaining earning, it is immaterial for the simple firms that we just described.<sup>8</sup>

Intermediate firms set prices subject to nominal rigidities a la Calvo (1983) with probability of price revision  $\theta$ . Since they are owned by the capitalists, they use their stochastic discount factor,  $\lambda_{t,t+s}$ , to choose price  $p_t(j)^*$  at a revision date with the aim of maximizing expected future profits:

$$\mathbb{E}_t \left[ \theta \sum_{s=0}^{\infty} (1-\theta)^s \lambda_{t,t+s} d_{t+s}(j) \right] \quad \text{subject to: } p_{t+s}(j) = p_t(j)^*. \quad (17)$$

The new automatic stabilizer is the corporate income tax, which is a flat rate  $\tau^k$  over corporate profits.

## 2.5 Capital-goods firms and property income taxes

A representative firm owns the capital stock and rents it to the intermediate-goods firms, taking  $r_t$  as given. If  $k_t$  denotes the capital held by this firm, then in the market for capital:

$$k_t = \int_0^1 k_t(j) dj. \quad (18)$$

This firm invests in new capital  $\Delta k_{t+1} = k_{t+1} - k_t$  subject to adjustment costs to maximize after-tax profits:

$$d_t^k = r_t k_t - \Delta k_{t+1} - \frac{\zeta}{2} \left( \frac{\Delta k_{t+1}}{k_t} \right)^2 k_t - \tau^p v_t. \quad (19)$$

The value of this firm, which owns the capital stock, is then given by the recursion:

$$v_t = \max \left[ d_t^k + \mathbb{E}_t (\lambda_{t,t+1} v_{t+1}) \right].$$

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<sup>8</sup>Another issue is the treatment of taxable losses (Devereux and Fuest, 2009). Because of carry-forward and backward rules in the U.S. tax system, these should not have a large effect on the effective tax rate faced by firms, although firms do not seem to claim most of these tax benefits. We were unable to find a satisfactory way to include these considerations into our model without greatly complicating the analysis.

The new automatic stabilizer, the property tax, is a fixed tax rate  $\tau^p$  that applies to the value of the only property in the model, the capital stock. A few steps of algebra show the conventional results from the q-theory of investment:

$$v_t = q_t k_t, \quad (20)$$

$$q_t = 1 + \zeta \left( \frac{\Delta k_{t+1}}{k_t} \right). \quad (21)$$

Because, from the second equation, the price of the capital stock is procyclical, so will property values, making the property tax a potential automatic stabilizer.

Finally, note that total dividends sent to capital owners,  $d_t$ , come from every intermediate firm and the capital-goods firm:

$$d_t = \int_0^1 d_t^i(j) dj + d_t^k. \quad (22)$$

We do not include investment tax credits. They are small in the data and, when used to attenuate the business cycle, they have been enacted as part of stimulus packages, not as automatic rules.

## 2.6 The government budget and deficits

The government budget constraint is:

$$\begin{aligned} & \tau^c \left( \int_0^\nu c_t(i) di + c_t \right) + \tau^p q_t k_t + \int_0^\nu \bar{\tau}^x(x_t(i)) di + \bar{\tau}^x(x_t) + \\ & \tau^k \left[ \int_0^1 \hat{d}^i(j) dj + (1 - v) r_t k_t \right] - \int_0^\nu [T_t^u(i) + T_t^s(i)] di \\ & = g_t + (i_t/p_t) B_t - (B_{t+1} - B_t) / p_t + T_t^e. \end{aligned} \quad (23)$$

On the left-hand side are all of the automatic stabilizers discussed so far: sales taxes, property taxes and personal income taxes in the first line, and corporate income taxes and transfers in the second line.<sup>9</sup> On the right-hand side are government purchases,  $g_t$  and government bonds  $B_t$ . The market for bonds will clear when:

$$B_t = \int_0^\nu b_t(i) di + b_t. \quad (24)$$

In steady state, the stabilizers on the left-hand side imply a positive surplus, which is

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<sup>9</sup> $\hat{d}^i(j)$  are taxable profits, the term in brackets on the right-hand side of equation (16).

offset by steady-state government purchases  $\bar{g}/\bar{y}$ . Since we set transfers to the entrepreneurs in the steady state to zero,  $\bar{T}^e = 0$ , the budget constraint then determines a steady state amount of debt  $\bar{B}$ , which is consistent with the government not being able to run a Ponzi scheme.

Outside of the steady state, as outlays rise and revenues fall during recessions, the left-hand side of equation (23) decreases. This is the last stabilizer that we consider: the automatic increase in the budget deficit during recessions. We study the stabilizing properties of deficits in terms how fast and with what tool the debt is paid.

We assume that the lump-sum tax on the stock-owners and government purchases adjust to close deficits because they are the fiscal tools that least interfere with the other stabilizers. They do not affect marginal returns like the distortionary tax rates, and they do not have an important effect on the wealth and income distribution like transfers to households. We assume simple linear rules similar to the ones estimated by Leeper et al. (2010):

$$\log(g_t/y_t) = \log(\bar{g}/\bar{y}) - \gamma^G \log\left(\frac{B_t/p_t}{\bar{B}}\right), \quad (25)$$

$$T_t^e = \bar{T}^e + \gamma^T \log\left(\frac{B_t/p_t}{\bar{B}}\right). \quad (26)$$

The parameters  $\gamma^G, \gamma^T > 0$  measure the speed at which the deficits from recessions are paid over time. If they are close to infinity, then the deficits caused by recessions are paid right away the following period; if they are close to zero, they take arbitrarily long to get paid. Their relative size determines the relative weight that purchases and taxes have on fiscal stabilizations.

## 2.7 Shocks and business cycles

In our baseline, monetary policy follows a simple Taylor rule:

$$i_t = \bar{i} + \phi \Delta \log(p_t) - \varepsilon_t, \quad (27)$$

with  $\phi > 1$ . We omitted the usual term in the output gap for two reasons. First, because with incomplete markets, it is no longer clear how to define a constrained-welfare natural level of output to which policy should respond. Second, because it is known that in this class of models with complete markets, a Taylor rule with an output term is quantitatively close to achieving the first best. We preferred to err on the side of having an inferior monetary

policy rule so as to raise the likelihood that fiscal policy may be effective. We will consider an alternative monetary policy rule that is plausibly closer to being optimal in section 5.2.

Three aggregate shocks hit the economy: technology,  $\log(a_t)$ , monetary policy,  $\varepsilon_t$ , and markups,  $\log(\mu_t)$ . Therefore, both aggregate-demand and aggregate-supply shocks may drive business cycles, and fluctuations may be efficient or inefficient. We assume that all shocks follow independent AR(1) processes for simplicity.

The idiosyncratic shocks to households,  $e_t(i)$  and  $s_t(i)$  are first-order Markov processes. Moreover, the transition matrix of labor-force status, the three-by-three matrix  $\Pi_t$ , depends on a linear combination of the aggregate shocks. In this way, we let unemployment vary with the business cycle to match Okun's law. This approach to modeling unemployment is clearly reduced-form and subject to the Lucas critique. Section 5.3 will endogenize the extensive margin of labor supply, which turns out to be numerically challenging. For now, note that workers choose how many hours to work, so the model already has an endogenous intensive margin of labor supply, and that section 5.2 will study how important it is.

## 2.8 Equilibrium

An equilibrium in this economy is a collection of aggregate quantities  $(y_t, k_t, d_t, v_t, c_t, n_t, b_{t+1}, x_t, d_t^k)$ ; aggregate prices  $(p_t, \hat{p}_t, w_t, q_t)$ ; individual consumer decision rules  $(c_t(b, s, e), n_t(b, s, e))$ ; a distribution of households over assets, skill levels, and employment statuses; individual firm variables  $(y_t(j), p_t(j), k_t(j), l_t(j), d_t(j))$ ; and government choices  $(B_t, i_t, g_t)$  such that:

- (i) owners maximize expression (1) subject to the budget constraint in equations (2)-(3),
- (ii) the household decision rules maximize expression (5) subject to their budget constraint in equations (6)-(7),
- (iii) the distribution of households over assets and skill and employment levels evolves in a manner consistent with the decision rules and the exogenous idiosyncratic shocks,
- (iv) final-goods firms behave optimally according to equations (11)-(13),
- (v) intermediate-goods firms maximize expression (17) subject to equations (11), (14), (16),
- (vi) capital-goods firms maximize expression (19) so their value is in equations (20)-(21),
- (vii) fiscal policy respects equation (23) and follows the rules in equations (25)-(26) while monetary policy follows the rule in (27),
- (viii) markets clear for labor in equation (15), for capital in equation (18), for dividends in equation (22) and for bonds in equation (24).

Appendix C derives the optimality conditions that we use to solve the model. We evaluate the mean and variance of aggregate endogenous variables in the ergodic distribution at the



equilibrium in this economy.

### 3 The positive properties of the model

The model just laid out combines the uninsurable idiosyncratic risk familiar from the literature on incomplete markets with the nominal rigidities commonly used in the literature on business cycles. Our first contribution is to show how to solve this general class of models, and to briefly discuss some of their properties.

#### 3.1 Solution algorithm

Our full model is challenging to analyze because the solution method must keep track not only of aggregate state variables, but also of the distribution of wealth across agents. One candidate algorithm is the Krusell and Smith (1998) algorithm, which summarizes the distribution of wealth with a few moments of the distribution. We opt instead for the solution algorithm developed by Reiter (2009, 2010), because this method can be easily applied to models with a rich structure at the aggregate level, including a large number of aggregate state variables. Here we give an overview of the solution algorithm, while Appendix E provides more details.

The Reiter algorithm first approximates the distribution of wealth with a histogram that has a large number of bins. The mass of households in each bin becomes a state variable of the model. The algorithm then approximates the household decision rules with a discrete approximation, a spline. In this way, the model is converted from one that has infinite-dimensional objects to one that has a large, but finite, number of variables. In our case, there are 10,236 variables.

Using standard techniques, one can find the stationary competitive equilibrium of this economy in which there is idiosyncratic uncertainty, but no aggregate shocks. Reiter (2009)'s method then calls for linearizing the model with respect to aggregate shocks, and solving for the dynamics of the economy as a perturbation around the stationary equilibrium without aggregate shocks using existing linear rational-expectations algorithms. The resulting solution is non-linear with respect to the idiosyncratic variables, but linear with respect to the aggregate states and to the bins of the wealth distribution.

This approach works well for small versions of the model, but linear rational-expectation solution methods cannot handle 10,236 equations. To proceed, we follow Reiter (2010) and compress the system using model-reduction techniques. This compression comes with

virtually no loss of accuracy relative to the larger linearized system because many dimensions of the state space are not needed. Intuitively, this is for two reasons: because the system never varies along that dimension and/or because variation along it is not relevant for the variables of interest.<sup>10</sup> We verified this claim using simpler versions of our model for which it was possible to both solve the reduced linear system as well as the full system, and found negligible losses in accuracy. It should be noted that while the model reduction step greatly speeds up the actual solution of the model, it has its own cost, which is that the full system must be analyzed to determine how it can be reduced. As a result, the solution algorithm still takes several hours of computing time.

To verify the accuracy of the solution, we compute Euler-equation errors. They arise both because the projection method to solve the Euler equation involves some approximation error between grid points, and because of the linearization with respect to aggregate states. We construct Euler equation errors on a fine grid of idiosyncratic state variables. At the steady state around which we linearize, the unit-free Euler equation errors are on the order of 0.0002. Simulating the economy and randomly picking 50 aggregate state vectors, the absolute value of the Euler equations errors were around 0.004. Therefore, an agent that spends \$100, is making a mistake of only \$0.40 by using our approximate decision rules.

### 3.2 Calibrating the model

We calibrate as many parameters as possible to the properties of the automatic stabilizers in the data. For the government spending and revenues our target data is in table 1, which recall averaged over the period 1988-2007. For macroeconomic aggregates, we use quarterly data over a longer period, 1960-2011, so that we can include more recessions in the sample and periods outside the Great Moderation and do not underestimate the amplitude of the business cycle.

For the three proportional taxes, we use parameters related to preferences or technology to match the tax base in the NIPA accounts, and choose the tax rate to match the average revenue reported in table 1, following the strategy of Mendoza et al. (1994). The top panel of table 2 shows the parameter values and the respective targets.

For the personal income tax, we followed Auerbach and Feenberg (2000) and simulated TAXSIM, including federal and state taxes, for a typical household. We averaged the tax rates across states weighted by population, and across years between 1988 and 2007. We

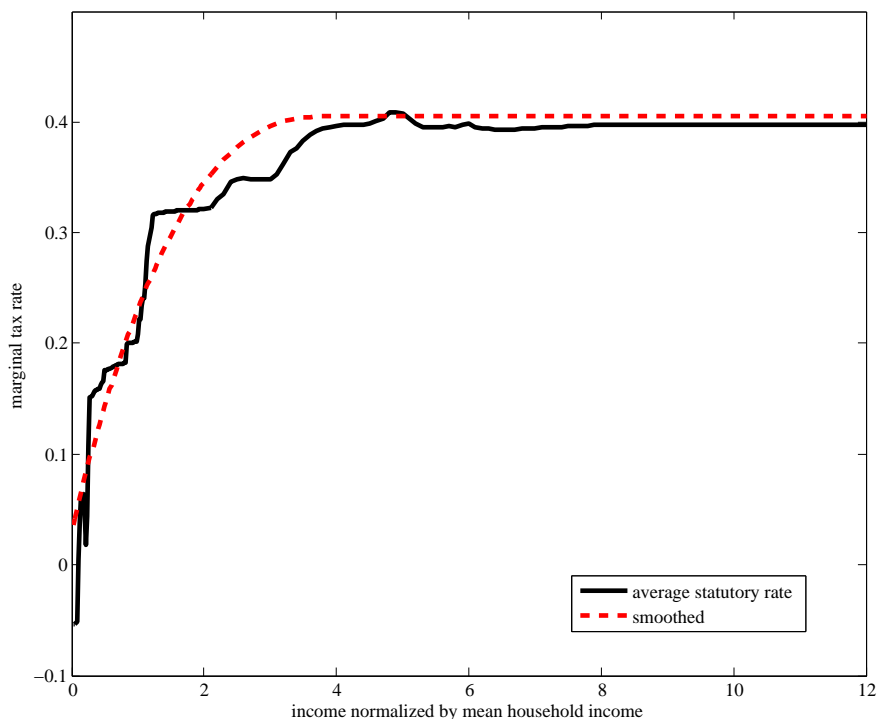
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<sup>10</sup>See Antoulas (2005) for a discussion of model reduction in a general context and see Reiter (2010) for their application to forward-looking economic systems.

Table 2: Calibration of the parameters

Symbol	Parameter	Value	Target (Source)
<i>Panel A. Tax bases and rates</i>			
$\tau^c$	Tax rate on consumption	0.0535	Avg. revenue from sales taxes (Table 1)
$\beta$	Discount factor of stock owners	0.989	Consumption-income ratio = 0.689 (NIPA)
$\tau^p$	Tax rate on property	0.00258	Avg. revenue from property taxes (Table 1)
$\alpha$	Labor coefficient in production	0.296	Capital income share = 0.36 (NIPA)
$\tau^k$	Tax rate on corporate income	0.35	Statutory rate
$v$	Deduction of capital costs	0.68	Avg. revenue from corporate income tax (Table 1)
$\xi$	Fixed costs of production	0.575	Corporate profits / GDP = 9.13% (NIPA)
<i>Panel B. Government outlays and debt</i>			
$\bar{T}^u$	Unemployment benefits	0.144	Avg. outlays on unemp. benefits (Table 1)
$\bar{s}^u / \bar{T}^u$	Max. UI benefit / avg. income	0.66	Typical state law (BLS, 2008)
$\bar{T}^s$	Safety-net transfers	0.151	Avg. outlays on safety-net benefits (Table 1)
$G/Y$	Steady-state purchases / output	0.145	Avg. outlays on purchases (Table 1)
$\gamma^T$	Fiscal adjustment speed (tax)	-1.6	St. dev. of deficit/GDP = 0.0093 (NIPA)
$\gamma^G$	Fiscal adjustment speed (spending)	-1.28	Rel. response to debt (Leeper et al., 2010)
$B/Y$	Steady-state debt / output	1.7	Avg. interest expenses (Table 1)
<i>Panel C. Income and wealth distribution</i>			
$\nu$	Non-participants / stock owners	4	
$\beta^h$	Discount factor of households	0.979	Wealth of top 20% by wealth
$\bar{s}$	Skill level of stock owners	3.72	Income of top 20% by wealth (SCF)
<i>Panel D. Business-cycle parameters</i>			
$\theta$	Calvo price stickiness	0.286	Avg. price spell duration = 3.5
$\mu$	Steady-state desired markup	1.1	Avg. U.S. markup
$\psi_1$	Disutility of work	21.6	Avg. hours worked = 0.31
$\psi_2$	Labor supply elasticity	2	Frisch elasticity = 1/2 (Chetty, 2012)
$\delta$	Depreciation rate	0.0114	Annual depreciation / GDP = 0.046 (NIPA)
$\zeta$	Adjustment costs for investment	6	Corr. of $Y$ and $C$ = 0.88 (NIPA)
$\rho_a$	Autocorrelation productivity shock	0.75	Autocorrel. of log GDP = 0.864 (NIPA)
$\sigma_a$	St. dev. of productivity shock	0.0034	St. dev. of log GDP = 1.539 (NIPA)
$\rho_\varepsilon$	Autocorrelation monetary shock	0.62	Largest AR for inflation = 0.85
$\sigma_\varepsilon$	St. dev. of monetary shock	0.00322	Share of output variance due to shock = 0.25
$\rho_\mu$	Autocorrelation markup shock	0.85	
$\sigma_\mu$	St. dev. of markup shock	0.04	Share of output variance due to shock = 0.25
$\phi$	Interest-rate rule on inflation	1.55	St. dev. of inflation = 0.638 (NIPA)

Figure 1: The personal income tax rate from TAXSIM



then fit a cubic function of income to the resulting schedule, and splined it with a flat line above a certain level of income so that the fitted function would be non-decreasing. The result is in figure 1. The cubic-linear schedule approximates the actual taxes well, and its smoothness is useful for the numerical analysis. We then added an intercept to this schedule to fit the effective average tax rate. This way, we made sure we fitted both the progressivity of the tax system (via TAXSIM) and the average tax rates (via the intercept).

Panel B calibrates the parameters related to government spending. Both parameters governing transfer payments are set to equate the average outlays from these programs, while the cap on unemployment benefits uses an approximation of existing law. The parameters of the fiscal rule to pay deficits fit the standard deviation of budget deficits and the estimate by Leeper et al. (2010) of the relative weight of spending versus revenues in fiscal adjustments.

Panel C contains parameters that relate to the distribution of income and wealth across households. According to the Survey of Consumer Finances, 83.4% of the wealth is held by the top 20% in the United States (Díaz-Giménez et al., 2011). We then picked the discount factor of the households to match this target.

Omitted from the table for brevity, but available in Appendix B, are the Markov transition matrices for skill level and employment. We used a 3-point grid for household skill

levels, which we constructed from data on wages in the Panel Study for Income Dynamics. The transition matrix across employment status varies linearly with a weighted average of the three aggregate shocks to match the correlation between employment and output. We set its parameters to match the flows in and out of the two main government transfer programs, food stamps and unemployment benefits, both on average and over the business cycle.

Finally, Panel D has all the remaining parameters. Most are standard, but two deserve some explanation. First, the Frisch elasticity of labor supply plays an important role in most intertemporal business-cycle models. Consistent with our focus on taxes and spending, we use the value suggested in the recent survey by Chetty (2012) on the response of hours worked to several tax and benefit changes. We will examine the robustness to this number in section 5.3. Second, we choose the variance of monetary shocks and markup shocks so that a variance decomposition of output attributes them each 25% of aggregate fluctuations. There is great uncertainty on the empirical estimates of the sources of business cycles, but this number is not out of line with some of the estimates in the literature. Our results turn out to not be sensitive to this number.

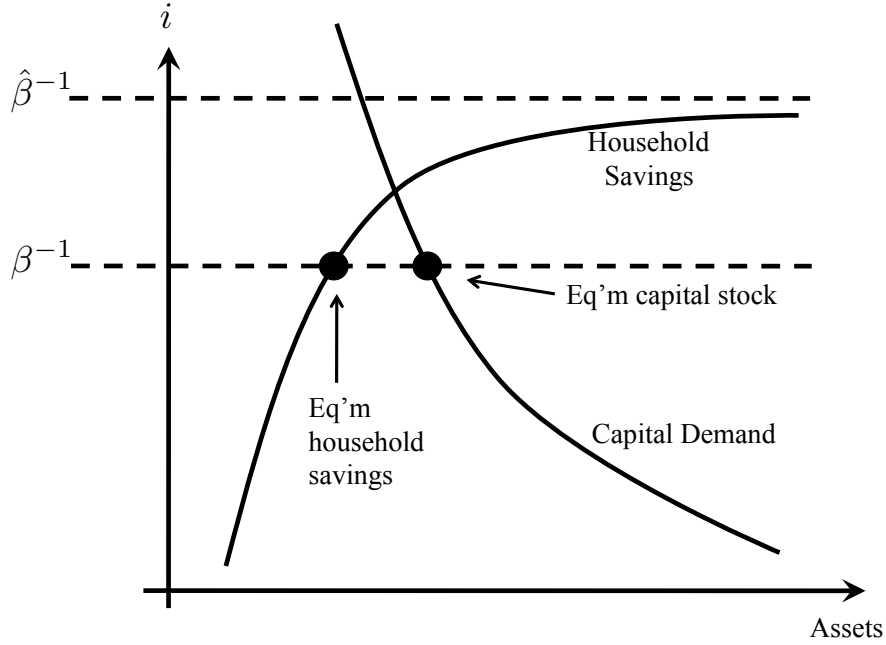
### 3.3 Optimal behavior and equilibrium inequality

Figure 2 uses a simple diagram to describe the stationary equilibrium of the model without aggregate shocks. For the sake of clarity, the figure depicts an environment in which there are no taxes that distort saving decisions.

The downward-sloping curve is the demand for capital, with slope determined by diminishing marginal returns. The demand for assets by capital owners is perfectly elastic at the inverse of their time-preference rate just as in the neoclassical growth model. Because they are the sole holders of capital, the equilibrium capital stock in the model is determined by the intersection of these two curves. Introducing taxes on capital income, like the personal or corporate income taxes, shifts the demand curve leftwards and lower the equilibrium capital stock.

If households were also fully insured, their demand for assets would be the horizontal line at  $\hat{\beta}^{-1}$ . But, because of the idiosyncratic risk they face, they have a precautionary demand for assets. Therefore, they are willing to hold bonds even at lower interest rates. Their asset demand is given by the upward-sloping curve. Because in the steady state without aggregate shocks, bonds and capital must yield the same return, equilibrium bond holdings by households are given by the point to the left of the equilibrium capital stock. The difference between the total amount of government bonds outstanding and those held

Figure 2: Steady-state capital and household bond holdings



by households gives the bond holdings of capital owners.

Figure 3 shows the optimal savings decisions of households at each of their  $e_t$  states. When households are employed, they save, so the policy function is above the  $45^\circ$  line. When they do not have a job, they run down their assets. As wealth reaches zero, those out of a job consume all of their safety-net earnings, leading to the horizontal segment along the horizontal axis in their savings policies.

Figure 4 shows the ergodic wealth distribution for households. Three features of these distributions will play a role in our results. First, the needy households have essentially no assets, so they live hand to mouth. Second, employed households are wealthier than the unemployed so when a recession hits, households draw down their wealth to smooth out higher unemployment. Third, the figure shows a counterfactual wealth distribution if the two transfer programs are significantly cut. Because not being employed now comes with higher income risk, households save more, which raises their wealth in all states.

### 3.4 Business cycles and fiscal shocks in the model

Before we use this model to perform counterfactuals on the effect of the automatic stabilizers on the business cycle, we inspect whether it makes plausible predictions on more familiar experiments.

Figure 3: Optimal savings policies

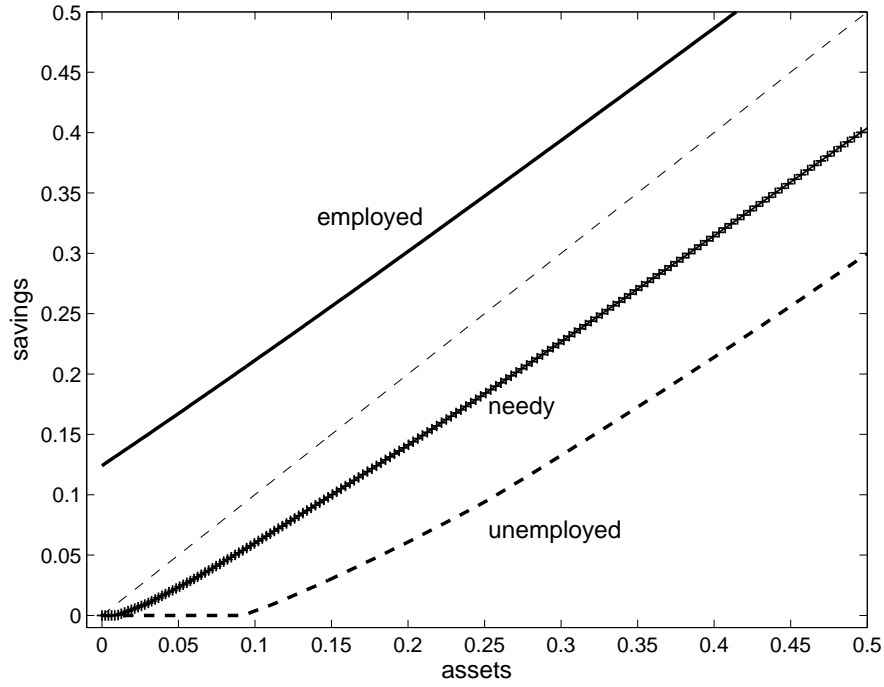


Figure 4: The ergodic wealth distribution

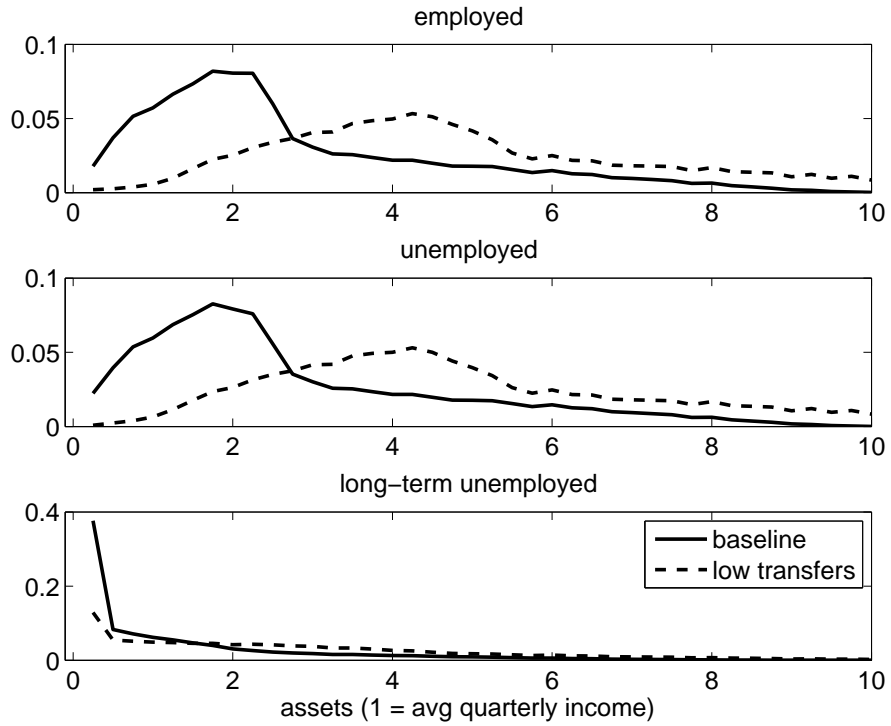


Figure 5: Impulse responses to the aggregate shocks

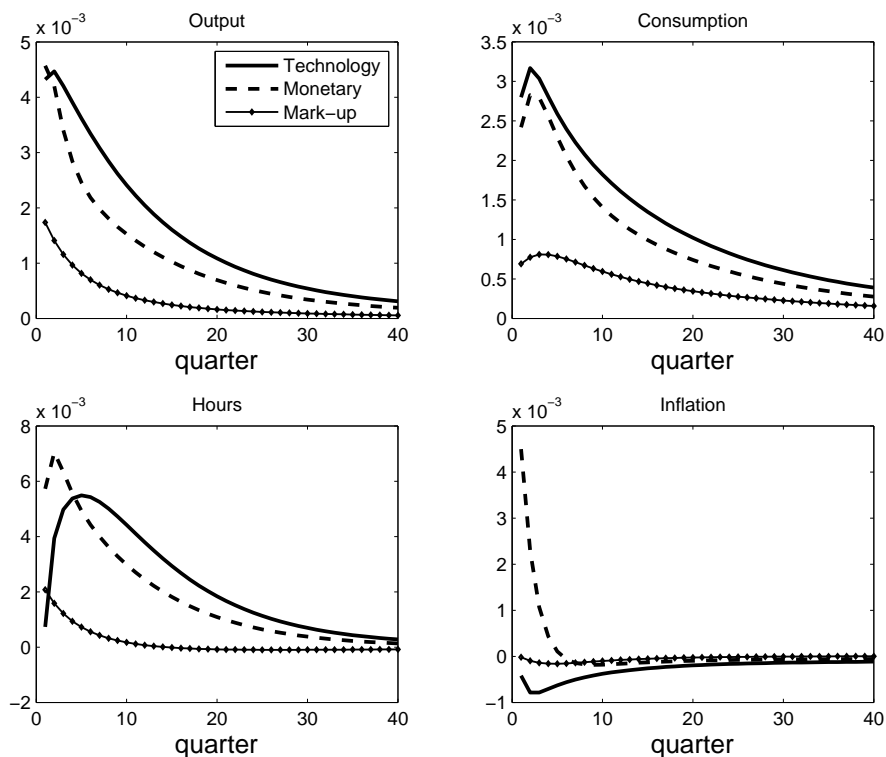
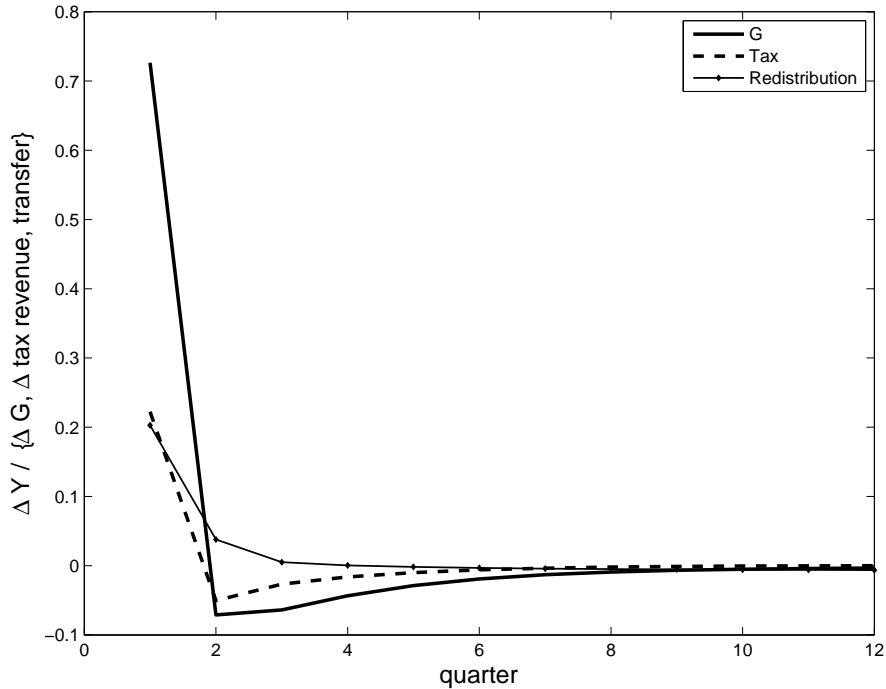


Figure 5 shows the impulse responses to the three aggregate shocks, with impulses equal to one standard deviation. The model captures the positive co-movement of output, hours and consumption, as well as the hump-shaped responses of hours to a TFP shock. Inflation rises with expansionary monetary shocks, but falls with productivity and markup shocks, and as usual in the standard Calvo model, the responses are fairly short-lived. In spite of all the heterogeneity, the aggregate responses to shocks are similar to those of the standard new neoclassical-synthesis model in Woodford (2003) and Christiano et al. (2005) that has been widely used to study business cycles in the past decade.

Turning to the unconditional moments of the business cycle, we chose the moments of our model so that it mimics the standard deviations of output, unemployment and inflation. Therefore, the model already matches the unconditional second moments in these variables. One variable that we did not target in the calibration, but which has received much attention in the study of business cycle, is the labor wedge. We estimate it using simulated data from our model following precisely the same steps as Shimer (2009). He finds in the U.S. data that the standard deviation of the log wedge is 0.055; our model predicts it is 0.052. This number is large, suggesting that our model leaves much room for policy to stabilize inefficient



Figure 6: Impulse responses to three fiscal experiments



fluctuations.

Figure 6 shows the impulse responses of output to shocks to three fiscal variables: an increase in government purchases, a cut in the personal income tax paid by households, and a redistribution of wealth from capitalists to the needy. In the first two cases we change one parameter of the model unexpectedly and only at date 1, and trace out the aggregate dynamics as the economy converges back to its old ergodic distribution. In the third case, we redistribute wealth at date 1 and simulate the model starting from that new distribution towards the ergodic case. In each case, we normalize the response of output by the size of the policy change measured in terms of its impact on the government budget. The response to redistribution is non-linear in the size of the transfer, which we set so that each needy household receives one percent of average household income.

Because these shocks have no persistence, their aggregate effect will always be limited. Yet, we find that they induce relatively large changes in output. Calculating multipliers as the ratio of the change in output to the change in the deficit over the first year of the experiment, we find reasonably-sized numbers: 0.93 for purchases, 0.20 for taxes, and 0.25 for redistribution. These are larger than the typical response in the neoclassical-synthesis model. Our model is therefore able to generate significant effects of fiscal policy.

The marginal propensity to consume (MPC) has received a great deal of attention in the

Table 3: Marginal propensity to consume

Skill group ( $s$ )	Employment ( $e$ )	Wealth percentile		
		10th	25th	50th
Low	Employed	0.10	0.08	0.07
Medium	Employed	0.04	0.03	0.03
High	Employed	0.03	0.03	0.02
Low	Unemployed	0.47	0.33	0.21
Medium	Unemployed	0.10	0.06	0.05
High	Unemployed	0.06	0.04	0.03
Low	Needy	0.48	0.48	0.48
Medium	Needy	0.49	0.49	0.10
High	Needy	0.49	0.13	0.07

study of fiscal policy and it also plays an important role in our model. All else equal, a larger MPC would raise the strength of the disposable-income channel as any fluctuation in disposable income would translate into a larger movement in aggregate demand. Moreover, with more heterogeneous MPCs, the redistribution channel will be stronger as moving resources from agents with higher to lower MPCs will have a larger impact on aggregate demand.

Table 3 shows the distribution of MPCs in our economy according to employment status and wealth percentile. Parker et al. (2011) use tax rebates to estimate an average MPC between 0.12 and 0.3. Our model is able to generate MPCs that go from 0.02 to 0.49, so that both in the spread and on average, it has the potential to give these two channels a strong role. Among the poor and those without a job, the MPCs are quite large and this large group of the population hits their borrowing constraint often, especially during recessions, so many households are far from self-insuring themselves.

### 3.5 Two special cases

In the analysis that follows, we consider two special cases of our model as benchmarks that help isolate different stabilization channels. First, with complete markets, households can diversify idiosyncratic risks to their income. The following assumption eliminates these risks:

**Assumption 1.** *Households and capitalists trade a full set of Arrow securities, so they are fully insured, and they are equally patient,  $\hat{\beta} = \beta$ .*

It will not come as a surprise that if this assumptions holds, there is a representative agent in this economy. More interesting, the problem she solves is familiar:

**Proposition 1.** *Under assumption 1, there is a representative agent with preferences:*

$$\max \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \log(c_t) - (1 + E_t) \psi_1 \frac{n_t^{1+\psi_2}}{1 + \psi_2} \right\},$$

*and with the following constraints:*

$$\begin{aligned} \hat{p}_t c_t + b_{t+1} - b_t &= p_t [x_t - \bar{\tau}(x_t) + T_t^n], \\ x_t &= \frac{i_t}{p_t} b_t + w_t s_t (1 + E_t) n_t + d_t + T_t^u, \\ s_t &= \left[ \frac{1}{1 + E_t} \bar{s}_t^{1+1/\psi_2} + \frac{E_t}{1 + E_t} \int_0^\nu s_{i,t}^{1+1/\psi_2} di \right]^{\frac{1}{1+1/\psi_2}}, \end{aligned}$$

where  $1 + E_t$  is total employment, including capital-owners and households and  $T_t^n$  is net non-taxable transfers to the household.

The proof is in Appendix D. With the exception of the exogenous shocks to employment, the problem of this representative agent is fairly standard. Moreover, on the firm side, optimal behavior by the goods-producing firms leads to a new Keynesian Phillips curve, while optimal behavior by the capital-goods firm produces a familiar IS equation. Therefore, with complete markets, our model is of the standard neoclassical synthesis variety (Woodford, 2003) that has been intensively used to study business cycles over the past decade.

The complete-markets case is useful, not just because it is familiar, but also because it allows us to study the effectiveness of automatic stabilizers when distributional issues are set aside. In this version of the model, the marginal incentives and the disposable income channels are the only two mechanisms at work.

A second special case that we will consider replaces the impatient household's optimal savings function with the assumption that people live hand-to-mouth. That is, they consume all of their after-tax income at every date and hold zero bonds. This can be seen as a limit when  $\hat{\beta}$  approaches zero. It is inspired in the savers-spenders model of Mankiw (2000). In this case, a measure of 80% of all consumers behave as if they were at the borrowing constraint, with an MPC of 1.

This benchmark is useful for three reasons. First, because it is close to the ultra-Keynesian model in Gali et al. (2007) that combines hand-to-mouth behavior with nominal rigidities to be able to generate a positive multiplier of government purchases on private consumption. For the study of fiscal policy, this is one of the closest optimizing models to the IS-LM benchmark that is at the center of policy debates on fiscal policy. Second, the

assumption of hand-to-mouth behavior raises the marginal propensity to consume by brute force.<sup>11</sup> A large MPC, here literally equal to one for the households, maximizes the strength of the disposable income channel. Third, in the hand-to-mouth model, there are no precautionary savings so the social insurance channel is shut off. Compared to our full model, the hand-to-mouth alternative is therefore useful to isolate the channels at work.

## 4 Inspecting the channels of stabilization

We measure the effectiveness of the automatic stabilizers by the fraction by which the variance of aggregate activity would increase if we removed some, or all, of the automatic stabilizers. If  $V$  is the ergodic variance at the calibrated parameters, and  $V'$  is the variance at the counterfactual with some of the stabilizers shut off, then our measure of effectiveness, following Smyth (1966), is the stabilization coefficient:

$$\mathbf{S} = \frac{V'}{V} - 1.$$

This differs from the measure of “built-in flexibility” introduced by Pechman (1973), which equals the ratio of changes in taxes to changes in before-tax income, and is widely used in the public finance literature.<sup>12</sup> Whereas built-in flexibility measures whether there are automatic stabilizers, our goal is instead to estimate whether they are effective.

To best understand the difference, consider the following result, proven in Appendix D:

**Proposition 2.** *If assumption 1 holds, so there is a representative agent, and:*

1. *the personal income tax is proportional, so  $\tau^x(\cdot)$  is constant;*
2. *the probability of being employed is constant over time;*
3. *the Calvo probability of price adjustment  $\theta = 1$ , so prices are flexible;*
4. *there are infinite adjustments costs,  $\gamma \rightarrow +\infty$ , and no depreciation,  $\delta = 0$ , so capital is fixed;*

---

<sup>11</sup>Heathcote (2005) and Kaplan and Violante (2012) raise the MPC in a more elegant way by, respectively, lowering the discount factor and introducing illiquid assets, but these are hard to accomplish in our model while simultaneously keeping it tractable and able to fit the business-cycle facts and the wealth and income distributions.

<sup>12</sup>See Dolls et al. (2012) for a recent example, and an attempt to go from built-in flexibility to effectiveness, by making the strong assumption that aggregate demand equals output and that poor households have MPCs of 1 while rich households have MPCs of zero.

5. *there are no fixed costs of production,  $\xi = 0$ ;*

*then the variance of the log of output is equal to the variance of the log of productivity. Therefore,  $\mathbf{S} = 0$  and the automatic stabilizers are ineffective.*

While this result and the assumptions supporting it are extreme, it serves a useful purpose. Note that the estimates of the size of the stabilizer following the Pechman (1973) approach would be large in this economy. Yet, the stabilizers in this economy are completely ineffective using our version of the Smyth (1966) measure. An economy may have high measured built-in flexibility while not being effectively flexible at all.

To measure the effectiveness of individual stabilizers, we cut each of them at a time: first proportional taxes, then transfers, next progressive taxes, and finally the deficit. We then calculate  $\mathbf{S}$  for output, hours, aggregate consumption, and the variance of household consumption, as well as the proportional change in the ergodic mean.

We also present two different approaches to assess the impact of the stabilizers on social welfare. First, we compute the change in the variance of three aggregate statistics that have been used to measure the performance of policy in the business-cycle literature: the labor wedge, inflation, and an output gap. There are many different ways to define an output gap in an economy that has sticky prices, incomplete markets, and many taxes and transfers moving it away from the first best. We define the natural level of output as the equilibrium output in an economy with flexible prices and a constant price level, so that there are no monetary non-neutralities due to either nominal rigidities or the taxation of nominal capital income.

Second, we calculate consumption-equivalent measures of welfare for each agent, and then average them using their weights in the cross-sectional ergodic distribution. We include either all agents, leading to a utilitarian measure of welfare in units of consumption, or only those employed or those without a job, to understand which groups benefit and lose with the stabilizers.

Throughout this section, we set  $\gamma^G = 0$  in the fiscal rule so that we show the effect of changing the stabilizers as cleanly as possible without changing the dynamics of government purchases due to the new dynamics for government debt. Because the lump-sum taxes, which are the other means for fiscal adjustment, are approximately neutral, they do not risk confusing the effectiveness of the stabilizers with their financing. Section 4.4 focuses on deficits and government purchases.

Table 4: The effect of proportional taxes on the business cycle

	Full model		Representative agent		Hand-to-mouth	
	variance	average	variance	average	variance	average
output	-0.0092	0.0117	-0.0016	0.0115	0.0103	0.0116
hours	-0.0017	0.0004	0.0031	0.0015	0.0057	0.0006
consumption	-0.0091	0.0093	-0.0199	0.0090	0.0482	0.0092
hhld. cons.	0.0008					

Welfare effects in full model:						
Variances			Consumption-equivalents			
Inflation	Output gap	Labor wedge	Utilitarian	Employed	Not-employed	
-0.0068	-0.0156	-0.0013	0.0107	0.0105	0.0122	

Notes: for variances and means, the table shows the proportional change caused by cutting the stabilizer. Positive numbers for the variance imply that the stabilizer was effective, while positive numbers for the average imply it lowered average real activity. For the consumption-equivalents, a number of  $-0.01$  says that the stabilizer raises welfare by on average 1% of consumption.

## 4.1 The effectiveness of proportional taxes

Proposition 2 imposed no restrictions on proportional taxes, yet their effect on volatility or welfare was nil. Table 4 considers the following experiment: we cut the tax rates  $\tau^c$ ,  $\tau^p$  and  $\tau^k$  each by 10%, and replaced the lost revenue of 0.6% of GDP by a lump-sum tax on the entrepreneurs.

Lowering proportional taxes lowers the variance of the business cycle by a negligible amount, always below 1% in the full model. That is, removing the stabilizer, actually leads to a more stable economy. In the hand-to-mouth economy, as expected, consumption is less stable as the variance of after-tax income is higher without the proportional taxes. But even then, the effect on the variance of output is only 1%. At the same time, when these taxes are removed, output and consumption are significantly higher on average in all economies. Looking at welfare, cutting proportional tax rates lowers the volatility of all three macroeconomic variables, and raises welfare for the different groups.

Intuitively, a higher tax rate on consumption lowers the returns from working and so lowers labor supply and output on average. However, because the tax rate is the same in good and bad times, it does not induce any intertemporal substitution of hours worked, nor does it change the share of disposable income available in booms versus recessions. Likewise, the taxes on corporate and property income may discourage saving and affect the average

Table 5: The effect of the level of tax rates on the business cycle.

	Full model		Representative agent		Hand-to-mouth	
	variance	average	variance	average	variance	average
output	-0.0057	0.0078	-0.0129	0.0076	-0.0329	0.0075
hours	-0.0101	0.0036	-0.0107	0.0076	-0.0085	0.0034
consumption	-0.0171	0.0089	-0.0145	0.0087	0.0602	0.0086
hhld. cons.	0.0117					

Welfare effects in full model:						
Variances			Consumption-equivalents			
Inflation	Output gap	Labor wedge	Utilitarian	Employed	Not-employed	
-0.1063	-0.0137	-0.0135	0.0110	0.0104	0.0153	

Notes: same as those in Table 4.

capital stock. But they do not do so differentially across different stages of the business cycle and so they have a negligible effect on volatility.

Table 5 instead cuts the intercept in the personal income tax by two percentage points. The conclusions for the full model are similar. Again, no intertemporal trade-offs change and, with the exception of aggregate consumption in the hand-to-mouth model, lower taxes actually come with slightly less volatile business cycles. Section 4.3 discusses the mechanism behind this fall in volatility.

## 4.2 The effectiveness of transfers

To evaluate the effectiveness of our two transfer programs, unemployment and poverty benefits, we reduced spending on both by 0.6% of GDP, the same amount in the experiment on proportional taxes. This is a uniform 80% reduction in the transfers amounts. Recall that these transfers redistributed resources from capitalists and employed households to the unemployed and the needy. Again, we replaced the fall in outlays with a lump-sum transfer to capital owners. The results are in table 6.

Transfers have a close-to-zero effect on the average level of output and hours, yet they have a large effect on their volatility. Reducing transfer payments would raise output volatility by 4% and the variance of hours worked by as much as 8%. Unemployment and poverty benefits also significantly lower the volatility of the output gap and the labor wedge, and when they are not present there is a large fall in welfare, especially of course for those without a job.

At the same time, without transfers, the volatility of aggregate consumption falls by

Table 6: The effect of transfers on the business cycle.

	Full model		Representative agent		Hand-to-mouth	
	variance	average	variance	average	variance	average
output	0.0417	-0.0004	-0.0061	0.0002	-0.0110	-0.0042
hours	0.0787	-0.0098	-0.0030	0.0002	0.0037	-0.0017
consumption	-0.0241	-0.0004	-0.0112	0.0002	0.1328	-0.0048
hhld. cons.	0.3456					
Welfare effects in full model:						
	Variances			Consumption-equivalents		
	Inflation	Output gap	Labor wedge	Utilitarian	Employed	Not-employed
	-0.2170	0.0374	0.0633	-0.0677	-0.0516	-0.2028

Notes: same as those in Table 4.

2%. To understand why, note that the transfers provide social insurance against the major idiosyncratic shock that households face. As a result, when we cut transfers, the variance of household consumption in logs rises substantially, by 35%. As households face more risk without transfers, they accumulate more assets. This was visible in figure 4, with the large shift of the wealth distribution to the right when transfers are reduced. Therefore, when aggregate shocks hit, they are better able to smooth them out and aggregate consumption becomes more stable.

The accumulation of saving when the safety net is cut has a second effect that partly explains why the economy becomes more unstable. A household with higher savings does not increase consumption by as much when wages rise. The income effect on labor supply is smaller, and so the uncompensated labor supply elasticity is higher. Therefore, in response to shocks of a given size, hours worked vary more and so does output.

Aside from the social-insurance channel, there is also a redistribution channel behind the effectiveness of transfers. In a recession, there are more households without a job so more transfers in the aggregate. Transfers have no direct effect on the labor supply of recipients as they do not have a job in the first place. However, they are funded by higher taxes on the capital owners, who raise their hours worked in response to the reduction in their wealth. This stabilizes hours worked and output.

The two special cases also confirm that redistribution and precautionary savings are what is behind the effectiveness of transfers. In the representative-agent economy, both of these channels are shut off, and the transfer experiment has a negligible effect on all variables. In



the hand-to-mouth economy, eliminating the public insurance provided by transfers raises the volatility of both household and aggregate consumption now. This is as expected, since there are no precautionary savings in this economy. Moreover, the volatility of output now slightly falls without transfers. The savers-spenders economy maximizes the disposable-income channel since every dollar given to households is spent, raising output because of sticky prices. Yet, we see that, quantitatively, this effect accounts for little of the stabilizing effects of transfers in our economy.

To further confirm that it is precautionary savings and redistribution behind our results, we performed a final experiment. We lowered the households' discount factor at the same time that we reduced transfers, so that the aggregate assets of the households did not change. This is not a valid policy experiment, since we are changing not just policy but also preferences, but it serves to highlight the role of precautionary savings. Now, when we lower transfers and the discount factor, the volatility of aggregate consumption rises substantially (17%), while the volatility of hours increases by less (2%) than in table 6, leading to a small  $\mathbf{S}$  for output. This confirms our intuition, since once the precautionary savings channel is attenuated by lowering the discount factor, then transfers are not as effective at boosting hours worked during recessions and now do stabilize aggregate consumption by stabilizing disposable income.

### 4.3 The effectiveness of progressive income taxes

The next experiment replaces the progressive personal income tax with a proportional, or flat, tax that raises the same revenue in steady state. Table 7 has the results.

Progressive income taxes have a modest effect on the volatility of output or hours, but moving to a flat tax would raise the average level of economic activity significantly, output by 4% and consumption by 5%. This stands in contrast with our results for transfers, even though both are redistributive policies. To understand this difference, we need to look at it through the four channels.

First, because marginal tax rates rise with income this discourages labor supply and lowers average hours and investment leading to reduce average income. This well-understood mechanism works in the cross-section, discouraging individual households from trying to raise their individual income. However, the level of progressivity in the current U.S. tax system is modest in the sense that the marginal tax rate function is relative flat above median income—recall figure 1. Therefore, the marginal tax rate that capitalists and many employed households face changes little between booms and recessions. This induces little

Table 7: The effect of progressive taxes on the business cycle.

	Full model		Representative agent		Hand-to-mouth	
	variance	average	variance	average	variance	average
output	-0.0091	0.0446	-0.0620	0.0382	-0.0963	0.0466
hours	-0.0109	0.0388	-0.0322	0.0383	-0.0394	0.0316
consumption	-0.0545	0.0507	0.0232	0.0436	0.2342	0.0531
hhld. cons.	0.1953					

Welfare effects in full model:						
Variances			Consumption-equivalents			
Inflation	Output gap	Labor wedge	Utilitarian	Employed	Not-employed	
-0.3207	-0.0376	-0.0273	-0.0371	-0.0330	-0.0715	

Notes: same as those in Table 4.

substitution over time, and therefore has a negligible effect on the variance.

On average activity, though, the effect is large. With a flat tax, because more tax revenue is collected from households with less income, then the wealthier households and especially the capitalists face a significantly lower marginal tax rate. Therefore, they save more, the average capital stock is higher, and so the impact of flattening the tax system on average income is large.

Second, the redistribution channel is significantly weaker than with transfers, because it is less targeted. When the needy receive transfers they cannot reduce their labor supply any further. In contrast, the personal income tax mostly redistributes from rich employed households to less rich employed households. The recipients lower their labor supply in response to their higher income, and little stabilization results.

At the same time, in the cross section, the progressivity of the personal income tax provides some social insurance. Therefore, as with transfers, removing this progressivity increases after-tax income risk, which on the one hand raises the variance of log household consumption by 20%, and on the other hand induces households to save more thus lowering aggregate consumption volatility. All combined, welfare falls for all groups with a flat tax.

The important roles of redistribution and precautionary savings is again highlighted by the two special cases, where these two channels are shut off. The table shows that in either the representative-agent or the hand-to-mouth economies, a flat tax leads instead to significantly less volatile business cycles. Further calculations, that we do not report for brevity, show that this fall in volatility is in large part driven by the joint presence of monetary policy

shocks and sticky prices.

To understand what is going on, recall the basic mechanism for why a positive monetary policy shock causes a boom with sticky prices: lower nominal interest rates lead to lower real interest rates, which raises consumption, demand for output, and if prices do not change, then raises hours worked and investment. Now, with a progressive tax, first the after-tax return on saving faced by the capital-owners,  $(1 - \tau^x(x_t))i_t$ , is both lower as well as less sensitive to variations in the nominal interest rate, which are driven by inflation. As a result, the progressive tax makes the after-tax real interest rate respond less strongly to inflation and so fall more with higher real income. Second, with a progressive tax, the increase in real income in a boom raises the marginal tax rate, which lowers the after-tax real interest rate by even more. Therefore, progressive taxes lead to lower real rates after positive monetary policy shocks, and thus more volatile responses of output and hours. Part of this effect was evident in table 5 where lower marginal tax rates led to a more stable economy.

#### 4.4 The effectiveness of budget deficits

To assess the role of the budget deficit, we conducted two final experiments. First, we contrasted our baseline economy with  $\gamma^G > 0$  with an alternative economy where only the lump-sum taxes adjust to close the deficits so  $\gamma^G = 0$ . In this economy, government purchases are always constant as a ratio of output. The second column of table 8 shows the results.<sup>13</sup>

This counterfactual economy is more stable in output but more volatile in consumption. The intuition is simple. After a positive aggregate shock, the economy enters a boom, and the automatic stabilizers produce a surplus that lowers public debt. Under the benchmark fiscal rule, this induces government purchases to rise. This lowers the income available for private consumption, and through this income effect, labor supply increases, amplifying the shock. When we remove the response of purchases, this effect disappears and so output is more stable.

The last column of table 8 shows the effect of not only setting  $\gamma^G$  to zero, but also of raising  $\gamma^T$  to infinity so that the government balances its budget every period. The results are almost identical to the first column. While Ricardian equivalence does not hold in our economy, changing the time profile of the taxes on capital owners has a small quantitative effect.

To conclude, changing the timing of deficits per se has little effect on the economy. But

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<sup>13</sup>We left out the results for the two special cases from this table since they were very similar to those for the full model. Similarly, the effect on the ergodic mean is numerically close to zero.

Table 8: The effect of budget deficits on the business cycle.

	Fixed purchases, only taxes respond	Fixed purchases and balanced budget
	Change in variance	
output	-0.0281	-0.0291
hours	-0.0133	-0.0136
consumption	0.1876	0.1845
	Welfare in consumption-equivalents	
utilitarian	-0.0005	-0.0005
employed	-0.0004	-0.0004
not employed	-0.0012	-0.0012

Notes: for variances, the table shows the proportional change caused by cutting the stabilizer, so a positive number implies that the stabilizer was effective. For the consumption-equivalents, a number of  $-0.01$  says that the stabilizer raises welfare by on average 1% of consumption.

the way in which these deficits are financed can have a significant effect on volatility. In particular, not cutting government purchases in response to public deficits is an effective stabilizer.

## 5 Have the U.S. stabilizers been effective overall?

In this section, we combine all of the experiments before. In the counterfactual, a flat tax replaces the progressive personal income tax, proportional taxes are cut by 10%, and unemployment and poverty benefits are cut by the same amount in the government budget. Finally, we decrease the two fiscal adjustment coefficients proportionately so that the variance of budget deficits falls by 10%. Altogether, we see this as a feasible across-the-board reduction in the scope of the automatic stabilizers.

### 5.1 Baseline estimates

Table 9 shows the results of the overall experiment in our full model. The main result is in the first two numbers in the table: the stabilizers have had a marginal effect on the volatility of the U.S. business cycle in output or hours. Removing the stabilizers would significantly raise the variance of both household consumption, because of the reduction in social insurance, and aggregate consumption, because government purchases would not be as cyclical. But an

Table 9: The joint effect of all stabilizers on the business cycle.

	Full model		Representative agent		Hand-to-mouth	
	variance	average	variance	average	variance	average
output	-0.0182	0.0567	-0.0911	0.0533	-0.0847	0.0557
hours	0.0002	0.0344	-0.0616	0.0429	-0.0262	0.0311
consumption	0.1409	0.0603	0.2014	0.0565	0.5568	0.0593
hhld. cons.	0.7829					

Welfare effects in full model:						
Variances			Consumption-equivalents			
Inflation	Output gap	Labor wedge	Utilitarian	Employed	Not-employed	
-0.2182	-0.0343	0.0204	-0.0928	-0.0732	-0.2573	

Notes: same as those in Table 4.

economy with smaller stabilizers would actually have more stable inflation as well as output gaps. Moreover, by lowering marginal tax rates, it would be a significantly richer economy on average. Even though we found in the previous section that the stabilizers, and especially the safety-net transfers, could be quite powerful at stabilizing the business cycle, the current mix of stabilizers falls short of achieving this goal.

In spite of the negligible impact of the stabilizers on the volatility of output, eliminating the stabilizers would significantly reduce welfare across the main groups in the population. To understand what is behind this discrepancy, we repeated the experiment in an economy where there were no aggregate shocks. The consumption-equivalents for the whole population, only for those employed, and only for those non-employed were  $(-0.0918, -0.0724, -0.2552)$ , quite close to the numbers in the table. Most of the measured welfare benefits that the stabilizers bring come from the provision of social insurance and redistribution, and little because of the business cycle.

This distinction suggests that two versions of the stabilizers that are equivalent in a representative-agent model have different effects with heterogeneity. Having tax rates indexed to aggregate income, instead of individual income, would induce little redistribution and social insurance, but could have a stronger effect on intertemporal substitution.

## 5.2 The role of monetary policy and price stickiness

A common finding in the representative-agent version of our business-cycle model without taxes and transfers is that a finely-tuned monetary policy can come close to reaching the

Table 10: The effect of the stabilizers with alternative roles for monetary policy.

	Baseline	Optimal monetary policy	Natural levels
	Change in variance		
output	-0.0182	-0.0277	-0.0683
hours	0.0002	-0.0211	-0.0470
consumption	0.1409	0.1620	0.1465
inflation	-0.2182	-0.3675	–
output gap	-0.0343	-0.0251	-0.2981
labor wedge	0.0204	0.0066	-0.0098
	Welfare in consumption-equivalents		
utilitarian	-0.0928	-0.0918	-0.0617
employed	-0.0732	-0.0724	-0.0454
not employed	-0.2573	-0.2551	-0.1984

Notes: same as in Table 8. The optimal monetary policy column uses the rule:  $\log(i_t/i_{t-1}) = 0.77 \log(i_t/i_{t-1}) + 0.75 \log(\pi_{t-1}) + 0.02 \log(y_{t-1}/y_{t-2})$ .

first best (Woodford, 2003). If that is the case, then there may be little room for fiscal policy to provide any further improvements, biasing our results against the role of the stabilizers. In our baseline model, we guarded against this possibility both by including markup shocks, which pose trade-offs for monetary policy, and by including a simple rule for nominal interest rates that did not respond to aggregate activity.

Table 10 compares our baseline results with those in the full model replacing the simple monetary-policy rule with a rule that Schmitt-Grohé and Uribe (2007) showed is close to optimal in a version of the Christiano et al. (2005) model. This rule has the virtue of depending only on observables, so it avoids the difficulty of defining the right concept of the output gap. As expected, the stabilizers are even less effective with this alternative, as monetary policy goes further in stabilizing the business cycle leaving less room for fiscal policy.

Second, we eliminate the role of monetary policy entirely by assuming that prices are flexible and the price level is constant as in the natural equilibrium that defined the output gap. The differences with the baseline are large. Nominal rigidities and aggregate demand are important for the dynamics of aggregate variables and for the effect that the stabilizers have on the business cycle through their multiple channels. This was already clear when we discussed the impact of price rigidity in explaining the effect of flattening personal income taxes. The more general lesson is that even if the Keynesian disposable-income channel of

Table 11: The role of the Frisch elasticity of labor supply.

	elasticity = 1/2		elasticity = 1/5		elasticity = 1	
	variance	average	variance	average	variance	average
output	-0.0182	0.0567	-0.0134	0.0327	-0.0170	0.0818
hours	0.0002	0.0344	0.0022	0.0166	0.0067	0.0531
consumption	0.1409	0.0603	0.1305	0.0333	0.1385	0.0885
	variance					
inflation	-0.2182		-0.2726		-0.2033	
output gap	-0.0343		-0.0301		-0.0173	
labor wedge	0.0204		0.0194		0.0262	
	consumption equivalents					
utilitarian	-0.0928		-0.1010		-0.0834	
employed	-0.0732		-0.0813		-0.0640	
not employed	-0.2573		-0.2664		-0.2452	

Notes: same as in Table 9

fiscal policy seems to be weak, the Keynesian role of sticky prices and aggregate demand on the business cycle is important in this economy.

### 5.3 The role of hours and the intensive margin of work

In our calibration, we assumed that the Frisch elasticity of labor supply was 0.5. We found that two of the channels through which the automatic stabilizers are more effective are by redistributing funds away from the rich, inducing them to work more, and by lowering the need to save for self insurance reducing the uncompensated elasticities of labor supply. Moreover, inattention and other frictions may lead to long-run Frisch elasticities between 0.5 and 1, while the short-run Frisch elasticities more relevant for the business cycle are between 0.2 and 0.5 (Chetty, 2012). Table 11 investigate the effect on our conclusions of changing  $\psi_2$  in two opposite directions: lowering the Frisch elasticity to 0.2 and raising it to 1.

The major effect of changing the Frisch elasticity is not on the response of second moments to the stabilizers, but on that of the first moments. The higher is the elasticity, the larger the distortion from taxes, and so removing the stabilizers leads to a larger increase in average output, hours worked and consumption. The effects on the second moments are all small quantitatively. Therefore, looking at welfare, a lower estimate of the elasticity of labor supply makes the automatic stabilizers more desirable, without reverting our earlier conclusions.

Table 12: Endogenous job-finding probabilities

	Baseline		Endogenous search effort	
	variance	average	variance	average
output	-0.0182	0.0567	-0.2042	0.0701
hours	0.0002	0.0344	-0.2500	0.0609
consumption	0.1409	0.0603	-0.1248	0.0752
Welfare in consumption-equivalents				
utilitarian	-0.0928		-0.0727	
employed	-0.0732		-0.0548	
not employed	-0.2573		-0.2202	

Notes: same as in Table 9.

## 5.4 The extensive margin of hours and endogenous unemployment

In our baseline model, transitions across employment states  $e_t(i)$  are exogenous. We now consider an extension of the model in which job-finding probabilities depend positively on a household's search effort, measured by the hours  $n_t(i)$  that households without a job spend looking. This extension captures the possible incentive effects of providing transfers to those who are not working. This model poses some additional computational challenges we lead us to reduce the extent of heterogeneity in the population by abstracting from skill heterogeneity.

Now, the household moves into employment with probability  $1 - \exp\{-q_t(e_t(i))n_t(i)\}$ , the functional form used by Hopenhayn and Nicolini (1997). The search efficiency,  $q_t(\cdot)$ , depends on the current employment status of the household, with the needy being less likely to find a job. Higher effort in terms of hours  $n_t(i)$  spent searching for a job raises the probability of finding employment. Whereas before the efficiency of this search process was zero, so the probability of finding a job was exogenous, now it is  $q_t(\cdot) > 0$ . Search efficiency also varies exogenously over the business cycle to match the volatility of unemployment.

We calibrate the steady state level and dynamics of  $q_t(e)$  to match the same moments as in our baseline calibration. Table 12 shows the results.

The effect on the economy is large and the stabilizers destabilize the economy quite substantially. Transferring resources to those without a job discourages their search effort, prolongs unemployment spells, and therefore amplifies the business cycle. Similarly, the welfare analysis shows that the insurance provided by the stabilizers becomes less important for welfare as unemployed households can adjust their search effort as they run down their



assets.

## 6 Conclusion

Milton Friedman (1948) famously railed against the use of discretionary policy to stabilize the business cycle. He defended the power instead of fiscal automatic stabilizers as a preferred tool for countercyclical policy. More recently, Solow (2005) strongly argued that policy and research should focus more on automatic stabilizers as a route through which fiscal policy could and should affect the business cycle.

We constructed a business-cycle model with many of the stabilizers and calibrated it to replicate the U.S. data. The model has some interesting features in its own right. First, it nests both the standard incomplete markets model, as well as the standard new-Keynesian business cycle model. Second, it matches the first and second moments of U.S. business cycles, as well as the broad features of the U.S. wealth and income distributions. Third, solving it requires using new methods that may be useful for other models that combine nominal rigidities and incomplete markets.

We found that lowering taxes on sales, property, and corporate and personal income, or reducing the progressivity of the personal income tax, did not have a significant impact on the volatility of the business cycle. Moreover, lowering these taxes raised average output and improved several measures of welfare. At the same time, higher transfers to the unemployed and poor were quite effective at lowering volatility with negligible effects on averages. This suggests that expanding the safety net might lead to a more stable economy.

In terms of the channels of stabilization, we found that the traditional disposable-income channel used to support automatic stabilizers is quantitatively weak. Considerably more important was the role of precautionary savings and social insurance. Policies that redistribute from the richer, who have lower MPCs and respond more strongly to cuts in wages, lower the amplitude of the business cycle and especially the cross-sectional dispersion of household consumption. Much of their welfare benefits come from the insurance they provide, and not from their impact on the business cycle.

Overall, we found that reducing the scope of all the stabilizers had a modest impact on the business cycle. While there is potential to use some of the stabilizers and exploit some of the stabilization channels to affect the business cycle, we concluded that most of this potential is currently unfulfilled. Aside from expanding the safety net, making tax rates explicitly vary with aggregate, rather than individual, income are two possible policy reforms.

Our results leave open a few questions for future research. First, we do not study the optimal design of stabilizers. Before doing so, we had to understand the positive predictions of the model regarding the stabilizers, a task that took this whole paper. Future work can take up the challenge of optimal policy design. Second, it is possible that the efficacy of the stabilizers changes at the zero lower bound on nominal interest rates. Progress on these avenues for future research will have to overcome some challenging computational hurdles, which prevented us from undertaking them in this paper.

Finally, each of the automatic stabilizers that we considered is more complex than our description and distorts behavior in more ways than the ones we modeled. We wanted our model to be sufficiently simple so that we could understand the channels through which the stabilizers might work, and we were limited by what we could solve. To obtain sharper quantitative estimate of the role of the stabilizers, it would be desirable to include the findings from the rich micro literatures that study each of these government programs in isolation. Perhaps the main point of this paper is that to assess automatic stabilizers requires having a fully articulated business-cycle model, so that we can move beyond the disposable-income channel, and consider other channels as well as quantify their relevance. Our hope is that as computational constraints diminish, we can keep this macroeconomic approach of solving for general equilibrium, while being able to consider the richness of the micro data.

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# Appendix

## A From the NIPA tables to table 1

For each entry in table 1, we construct a sum of one or more entries in the NIPA tables, divide by nominal GDP, and average over 1988 to 2007. Here we describe the components of each entry in table 1.

### A.1 Revenues

- **Personal income taxes** are the sum of federal and state income taxes (table 3.4) plus contributions for government social insurance less contributions to retirement programs (NIPA table 3.6, line 1 minus lines 4, 12, 13, 22, and 29).
- **Corporate income taxes** are from line 5 of table 3.1.
- **Property taxes** are the sum of business property taxes (table 3.5) and individual property taxes (table 3.4).
- **Sales and excise taxes** are state sales taxes (table 3.5) plus federal excise taxes (table 3.5).
- **Public deficit** is the residual between the two columns of the table.
- **Customs taxes** are from table 3.5, line 11.
- **Licenses, fines, fees** are the residual between current tax receipts from table 3.1 and the other revenue listed in our table.
- **Payroll taxes** are contributions to retirement programs (table 3.6, lines 4, 12, 13, 22, and 29).

### A.2 Outlays

- **Unemployment benefits** are from table 3.12, line 7.
- **Safety net programs** are the sum of the listed sub-components from table 3.12, where “security income to the disabled” is the sum of lines 23, 29 and 36 and “Others” is the sum of lines 37 - 39.

- **Government purchases** are current consumption expenditure from table 3.1.
- **Net interest income** is the difference between interest expense and interest and asset income both from table 3.1.
- **Health benefits (non-retirement)** are spending on Medicaid (table 3.12, line 33). multiplied by the share of Medicaid spending that was spent on children, disabled, and non-elderly adults in 2007 plus other medical care (table 3.12, line 34).<sup>14</sup>
- **Retirement-related transfers** are the share of Medicaid spent on the elderly plus Social Security, Medicare, pension benefit guarantees, and railroad retirement programs (all from table 3.12).
- **Other outlays** are the difference between total outlays in table 3.1 and those listed here.

## B Calibration of the idiosyncratic shock processes

Each household at every date has a draw of  $s_t(i)$  determining the wage they receive if they are employed, and a draw of  $e_t(i)$  on their employment status. This section describes how we calibrate the distribution and dynamics of these two random variables.

### B.1 Skill shocks

We use PSID data on wages to calibrate the skill process. To do this, we start with sample C from Heathcote et al. (2010a) and work with the log wages of household heads in years 1968 to 2002. Computational considerations limit us to three skill levels and we construct a grid by splitting the sample into three groups at the 33<sup>rd</sup> and 67<sup>th</sup> percentiles and then using the median wage in each group as the three grid points. Skills are proportional to the level (not log) of these wages. Computational considerations also lead us to choose a skill transition matrix with as few non-zero elements as possible. We impose the structure

$$\begin{pmatrix} 1-p & p & 0 \\ p & 1-2p & p \\ 0 & p & 1-p \end{pmatrix},$$

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<sup>14</sup>See table 2 in the 2008 actuarial report of the Centers for Medicare and Medicaid Services. <https://www.cms.gov/ActuarialStudies/downloads/MedicaidReport2008.pdf>

where  $p$  is a parameter that we calibrate as follows. From the PSID data, we compute the first, second and fourth auto-covariances of log wages. Let  $\Gamma_i$  be the  $i^{th}$  auto-covariance. We use the moments  $\Gamma_2/\Gamma_1$  and  $\sqrt{\Gamma_4/\Gamma_2}$ , each of which can be viewed as an estimate of the autoregressive parameter if the log wages follow an AR(1) process.<sup>15</sup> The empirical moments are 0.9356 and 0.9496, respectively. To map these moments into a value of  $p$ , we minimize the equally-weighted sum of squared deviations between these empirical moments and those implied by the three-state Markov chain. As our time period is one quarter, while the PSID data are annual, we use  $\Gamma_8/\Gamma_1$  and  $\sqrt{\Gamma_{16}/\Gamma_8}$  from the model. This procedure results in a value of  $p$  of 0.015.

## B.2 Employment shocks

**Steady state** In addition to differences in skill levels, households differ in their employment status. A household can be (1) employed (E), (2) unemployed (U) or (3) needy (N). To construct a steady state transition matrix between these three states we need six moments. First, it is reasonable to assume that a household does not transit directly from employed to long-term unemployed or from long-term unemployed back to unemployed. Those two elements of the transition matrix are therefore set to zero.

The distribution of households across states gives us two more moments. As the focus of our work is on the level and fluctuation in the number of individuals receiving different types of transfers, we define unemployed as individuals who are receiving unemployment benefits and needy as those receiving food stamps.

In the U.S., the Supplemental Nutritional Assistance Program is the largest non-health, non-retirement social safety net program. SNAP assists low-income households in being able to purchase a minimally adequate low-cost diet. Recipients of these benefits are generally not working.<sup>16</sup> One virtue of using SNAP participation as a proxy for long-term unemployment is that it avoids the subtle distinction between unemployment and non-participation in the Current Population Survey while still focussing on those individuals who likely have poor labor market prospects. If we instead used time since last employment to identify those in long-term unemployment, we would include a number of individuals with decent opportunities to work if they chose to do so such as individuals who have retired or who

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<sup>15</sup>The ratio  $\Gamma_1/\Gamma_0$  is not used as this ratio is heavily influenced by measurement error, which leads to an underestimate of the persistence of wages. The moments that we use are also used by Heathcote et al. (2010b) to estimate the persistence of the wage process.

<sup>16</sup>In 2009, 71% of SNAP recipient households had no earned income and only 17% had elderly individuals (Leftin et al., 2010).

choose to work in the home. Between 1971, when the data begin, and 2011, the average insured unemployment rate was 2.9%.<sup>17</sup> Between 1974, when the SNAP program was fully implemented nationwide, and 2011, the average ratio of SNAP participation to the insured labor force was 8.7%. We refer to this as the SNAP ratio.<sup>18</sup>

Our final two moments speak to the flows across labor market states. We calibrate the flow into unemployment using the ratio of initial claims for unemployment insurance to the stock of employed persons covered by unemployment insurance. Between 1971 and 2011, the average value of this ratio was 5.16%. Many spells of unemployment insurance receipt are short and such spells are an important component of the data on flows.<sup>19</sup> In our model, the minimum unemployment spell length is one quarter so we take care to account for the short spells in the data as part of our calibration strategy. We imagine that when a worker separates from their job, they immediately join the pool of job seekers and can immediately regain employment without an intervening (quarter-long) period of unemployment. To identify the probability of immediate reemployment, we assume it is the same as the job finding probability of other unemployed workers. In addition, we calibrate the probability of transitioning from long-term unemployment to employment based on the finding of Mabl et al. (2011) that 3% of SNAP participants leave the program each month.

Our procedure is as follows: we use the moments above to create a target transition matrix across employment states that our model should generate. This transition matrix has the form:

$$\begin{matrix} E \\ U \\ N \end{matrix} \begin{pmatrix} 1 - s_1(1 - f_2) & s_1(1 - f_2) & 0 \\ f_2 & (1 - f_2)(1 - s_2) & (1 - f_2)s_2 \\ f_3 & 0 & 1 - f_3 \end{pmatrix}$$

where element  $(i, j)$  is the probability of moving from state  $i$  to state  $j$ . There are four parameters here  $s_1, s_2, f_2, f_3$ , which we set as follows:  $f_3 = 0.0873$ , equivalent to 3% per month;  $s_1 = 0.0516$  is the ratio of initial claims to covered employment;  $f_2 = 0.540$  and  $s_2 = 0.577$  are chosen so the invariant distribution of the Markov chain matches the average shares of the population in each state.

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<sup>17</sup>The insured unemployment rate is the ratio of the number of individuals receiving unemployment insurance benefits to the number of employed workers covered by unemployment insurance.

<sup>18</sup>This ratio is calculated as the number of SNAP participants divided by the sum of the number of workers covered by unemployment insurance and the number of individuals receiving UI benefits.

<sup>19</sup>In a typical quarter, the number of people who file an initial claim for UI is greater than the stock of recipients at a point in time.

**Business-cycle dynamics of employment risk** An important component of our model is the evolution of labor market conditions over the business cycle. One effect of the fluctuations in labor market conditions is to alter the number of households receiving different types of benefits over the cycle. A second effect is to alter the amount of risk that households face, which has consequences for the consumption and work decisions.

As we analyze the aggregate dynamics of the model with a linear approximation around the stationary equilibrium, it is sufficient to specify how the labor market risk evolves in the neighborhood of the stationary equilibrium. Let  $\Pi_t$  be the matrix of transition probabilities between employment states at date  $t$  and  $t + 1$ . We impose the following structure on the evolution of  $\Pi_t$

$$\Pi_t = \Pi^0 + \Pi^1 [\chi \log z_t - (1 - \chi)\varepsilon_t],$$

where  $\Pi^0$  and  $\Pi^1$  are constant  $3 \times 3$  matrices.  $\Pi^0$  is the matrix of transition probabilities between employment states in steady state. The term in brackets is a composite of the technology and labor market shocks and the parameter  $\chi$  controls how much the labor market is driven by technology shocks as opposed to monetary shocks. We set  $\chi$  so that the technology shocks account for 50% of the variance of the unemployment rate in keeping with the view that they drive 50% of the variance of output.

What remains is to specify the matrix  $\Pi^1$ .<sup>20</sup> We use a  $\Pi^1$  that has two non-zero, off-diagonal elements that allow the probability of losing employment to be counter-cyclical and allow the probability of moving from long-term unemployment to employment to be procyclical. We limit ourselves to these two parameters so as to economize on the number of parameters that must be calibrated. We choose these two elements of  $\Pi^1$  to match the standard deviations of the insured unemployment rate and the SNAP ratio defined above.

The standard deviation of the insured unemployment rate is 0.00937 and the standard deviation of the SNAP ratio is 0.0205. These procedures leave us with the following:

$$\Pi^0 = \begin{pmatrix} 0.9694 & 0.0306 & 0 \\ 0.5398 & 0.1948 & 0.2654 \\ 0.0873 & 0 & 0.9127 \end{pmatrix}, \quad \Pi^1 = \begin{pmatrix} 3.21 & -3.21 & 0 \\ 0 & 0 & 0 \\ 5.06 & 0 & -5.06 \end{pmatrix}, \quad \chi = 0.45,$$

where the the  $(i, j)$  element of the  $\Pi$  matrices refers to the transition probability from state  $i$  to state  $j$  and the states are ordered as employed, unemployed, long-term unemployed.

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<sup>20</sup>The rows of  $\Pi^1$  must sum to zero so that the rows of  $\Pi_t$  always sum to one.

## C Decision problems and model equations

In this section of the appendix, we derive the optimality conditions that we use to compute the equilibrium of the model.

### C.1 Capital owner's problem

The capital owner chooses  $\{c_t, n_t\}$  to maximize expression (1) subject to equations (2) and (3). Define  $\tilde{b}_t = b_t/p_t$  and  $\pi_t = p_t/p_{t-1}$  and note that  $\hat{p}_t/p_t = 1 + \tau^c$ . Then we can rewrite the constraints as:

$$(1 + \tau^c)c_t + \tilde{b}_{t+1}\pi_{t+1} - \tilde{b}_t = x_t - \bar{\tau}^x(x_t) + T_t^e \quad (28)$$

$$x_t = i_t\tilde{b}_t + w_t\bar{s}n_t + d_t. \quad (29)$$

Setting up the Lagrangian, with  $m_t^1$  and  $m_t^2$  as the Lagrange multipliers on constraints (28) and (29), respectively, the optimality conditions are:

$$\begin{aligned} \beta^t c_t^{-1} &= m_t^1(1 + \tau^c) \\ m_t^1 \pi_{t+1} &= E_t [m_{t+1}^1 + i_{t+1} m_{t+1}^2] \\ m_t^2 &= m_t^1 (1 - \tau^x(x_t)) \\ \beta^t \psi_1 n_t^{\psi_2} &= m_t^2 w_t \bar{s}, \end{aligned}$$

These can be rearranged to give:

$$\psi_1 n_t^{\psi_2} = \left(\frac{1}{c_t}\right) \left(\frac{1 - \tau^x(x_t)}{1 + \tau^c}\right) w_t \bar{s}, \quad (30)$$

$$\frac{1}{c_t} = \beta E_t \left\{ \frac{1 + i_{t+1}(1 - \tau^x(x_{t+1}))}{c_{t+1} \pi_{t+1}} \right\}, \quad (31)$$

which are the capital-owner's labor-supply and Euler conditions. Finally, notice that the capital owner's stochastic discount factor is:

$$\lambda_{t,s} = \frac{m_{t+s}^2}{m_t^2} = \frac{\beta^s c_{t+s}^{-1} (1 - \tau^x(x_{t+s}))}{c_t^{-1} (1 - \tau^x(x_t))}. \quad (32)$$

## C.2 Other households' problem

The idiosyncratic state of a household is its real bond holdings  $\tilde{b}$ , its employment status  $e$  and its skill level  $s$ . Let  $\mathcal{J}$  be the set of all  $(e, s)$  pairs and let  $S$  be the collection of aggregate state variables. Then the problem of a household with real assets  $\tilde{b}$  and labor market states  $j \in \mathcal{J}$  can be written as

$$V(\tilde{b}, j, S) = \max_{c, n} \left\{ \log(c) - \psi_1 \frac{n^{1+\psi_2}}{1+\psi_2} + \hat{\beta} \mathbb{E}_t \sum_{j' \in \mathcal{J}} \omega_{jj'}(n, S) V(\tilde{b}', j', S') \right\}$$

subject to

$$\begin{aligned} (1 + \tau^c)c + \tilde{b}'\pi' - \tilde{b} &= x - \bar{\tau}^x(x) + T^s(j) \\ x &= i(S)\tilde{b} + I_{\{e(j)=2\}}s(j)w(S)n + T^u(j). \end{aligned}$$

Here the expectation operator is over aggregate states and  $\omega_{jj'}(n, S)$  is the probability of moving from state  $j$  to  $j'$ . This probability can potentially be influenced by search effort if  $e(j) \neq 2$  and  $e(j') = 2$ .

From this problem, one can derive an Euler equation and a labor supply condition that are analogous to those for the capital owner's problem. One difference, however, is that in these analogous expressions the expectation operator reflects an expectation over idiosyncratic uncertainty as well as over aggregate uncertainty.

For the extension in Section 5.4, there is an additional optimality condition for households that are not employed, which determines the household's search effort

$$\psi_1 n^{\psi_2} = \hat{\beta} \mathbb{E}_t \sum_{j' \in \mathcal{J}} \frac{\partial \omega_{jj'}(n, S)}{\partial n} V(\tilde{b}', j', S'). \quad (33)$$

## C.3 Intermediate Goods' Firm

A firm that sets its price at date  $t$  chooses  $p_t^*, \{y_s(j), k_s(j), l_s(j)\}_{s=t}^{\infty}$  to solve

$$\max E_t \sum_{s=t}^{\infty} \lambda_{t,s} (1 - \theta)^{s-t} \left\{ (1 - \tau^k) \left[ \frac{p_t^*}{p_s} y_s(j) - w_s l_s(j) - (vr_s + \delta) k_s(j) - \xi \right] - (1 - v) r_s k_s(j) \right\},$$

subject to

$$y_s(j) = \left(\frac{p_t^*}{p_s}\right)^{\mu/(1-\mu)} y_s$$

$$y_s(j) = a_s k_s(j)^\alpha l(j)^{1-\alpha}.$$

where the first constraint is the demand for the firm's good and the second its production function. By defining  $\hat{r}_t \equiv (1 - v\tau^k)/(1 - \tau^k)r_t$ , we can rewrite the objective function as if all capital costs were deductible, but the cost of capital were higher ( $\hat{r}_t > r_t$  if  $v < 1$ ). Dropping the constant  $1 - \tau^K$  and substituting in the demand curve gives the modified problem:

$$\max_{p_t^*, \{k_s(j), l_s(j)\}_{s=t}^\infty} E_t \sum_{s=t}^{\infty} \left[ \left(\frac{p_t^*}{p_s}\right)^{1/(1-\mu)} y_s - w_s l_s(j) - (\hat{r}_s + \delta) k_s(j) - \xi \right] \lambda_{t,s} (1 - \theta)^{s-t}$$

subject to

$$\left(\frac{p_t^*}{p_s}\right)^{\mu/(1-\mu)} y_s = a_s k_s(j)^\alpha l(j)^{1-\alpha}.$$

The first order conditions with respect to  $k_s(j)$  and  $l_s(j)$  are:

$$(\hat{r}_s + \delta) = M_s \alpha a_s k_s(j)^{\alpha-1} l_s(j)^{1-\alpha}. \quad (34)$$

$$w_s = M_s (1 - \alpha) a_s k_s(j)^\alpha l_s(j)^{-\alpha}, \quad (35)$$

where  $M_s$  is the Lagrange multiplier on the production function constraint at date  $s$ , which is real marginal cost at date  $s$ .

We can derive several useful features of the solution from these two optimality conditions. First, taking their ratio:

$$\frac{w_s}{\hat{r}_s + \delta} = \frac{1 - \alpha}{\alpha} \frac{k_s(j)}{l_s(j)},$$

so that all firms have the same capital-labor ratio and, by market clearing,  $k_s(j)/l_s(j) = k_s/l_s$  for all firms.

Second, these optimality conditions allow us already to derive the expression for dividends



as a function of factor prices. Total factor payments are

$$(\hat{r}_s + \delta) k_s = M_s \alpha a_s k_s^\alpha l_s^{1-\alpha}, \quad (36)$$

$$w_s l_s = M_s (1 - \alpha) a_s k_s^\alpha l_s^{1-\alpha}. \quad (37)$$

The aggregate after-tax dividend of the intermediate goods firms is then

$$\int_0^1 d_t^i(j) dj = (1 - \tau^k) \int_0^1 \left[ \frac{p_t(j)}{p_t} y_t(j) - w_t(j) l_t(j) - (\hat{r}_t + \delta) k_t(j) - \xi \right] dj$$

and by market clearing this becomes

$$\int_0^1 d_t^i(j) dj = (1 - \tau^k) [y_t - M_t a_t k_t^\alpha l_t^{1-\alpha} - \xi]. \quad (38)$$

Similarly, total profits are

$$\begin{aligned} & \int_0^1 \left[ \frac{p_t(j)}{p_t} y_t(j) - w_t l_t(j) - (r_t + \delta) k_t(j) - \xi \right] dj \\ &= \int_0^1 \left[ \frac{p_t(j)}{p_t} y_t(j) - w_t l_t(j) - (\hat{r}_t + \delta + r_t - \hat{r}_t) k_t(j) - \xi \right] dj \\ &= y_t - M_t a_t k_t^\alpha l_t^{1-\alpha} - \xi + \tau^k \frac{1 - \nu}{1 - \nu \tau^k} \hat{r}_t k_t. \end{aligned} \quad (39)$$

And revenue from the corporate income tax is the difference between (39) and (38).

Finally, we turn to the optimality condition with respect to  $p_t^*$ :

$$\mathbb{E}_t \sum_{s=t}^{\infty} \lambda_{t,s} (1 - \theta)^{s-t} \left[ \frac{1}{1 - \mu} \left( \frac{p_t^*}{p_s} \right)^{1/(1-\mu)-1} \frac{y_s}{p_s} - M_s \frac{\mu}{1 - \mu} \left( \frac{p_t^*}{p_s} \right)^{\mu/(1-\mu)-1} \frac{y_s}{p_s} \right] = 0,$$

which we can rewrite as

$$\begin{aligned} \mathbb{E}_t \sum_{s=t}^{\infty} \frac{1}{1 - \mu} \left( \frac{p_t^*}{p_s} \right)^{1/(1-\mu)-1} \frac{y_s}{p_s} \lambda_{t,s} (1 - \theta)^{s-t} &= \mathbb{E}_t \sum_{s=t}^{\infty} \lambda_{t,s} (1 - \theta)^{s-t} M_s \frac{\mu}{1 - \mu} \left( \frac{p_t^*}{p_s} \right)^{\mu/(1-\mu)-1} \frac{y_s}{p_s} \\ \frac{p_t^*}{p_t} &= \frac{p_t \mathbb{E}_t \sum_{s=t}^{\infty} \lambda_{t,s} (1 - \theta)^{s-t} M_s \mu_t \left( \frac{p_t}{p_s} \right)^{\mu/(1-\mu)-1} \frac{y_s}{p_s}}{p_t \mathbb{E}_t \sum_{s=t}^{\infty} \left( \frac{p_t}{p_s} \right)^{\mu/(1-\mu)} \frac{y_s}{p_s} \lambda_{t,s} (1 - \theta)^{s-t}} \equiv \frac{\bar{p}_t^A}{\bar{p}_t^B}. \end{aligned} \quad (40)$$

This equation gives the solution for  $p_t^*$ . It is useful to write  $\bar{p}_t^A$  and  $\bar{p}_t^B$  recursively. To that end,

$$\begin{aligned}
\bar{p}_t^A &= p_t \mathbb{E}_t \sum_{s=t}^{\infty} \lambda_{t,s} (1-\theta)^{s-t} M_s \mu_t \left( \frac{p_t}{p_s} \right)^{\mu/(1-\mu)-1} \frac{y_s}{p_s} \\
&= M_t \mu_t y_t + \\
&\quad \mathbb{E}_t p_{t+1} \pi_{t+1}^{-1} \mathbb{E}_{t+1} \lambda_{t,t+1} (1-\theta) \left( \frac{p_t}{p_{t+1}} \right)^{\mu/(1-\mu)-1} \\
&\quad \times \sum_{s=t+1}^{\infty} \lambda_{t+1,s} (1-\theta)^{s-t-1} M_s \mu \left( \frac{p_{t+1}}{p_s} \right)^{\mu/(1-\mu)-1} \frac{y_s}{p_s} \\
&= M_t \mu_t y_t + \mathbb{E}_t \left[ \lambda_{t,t+1} (1-\theta) \pi_{t+1}^{-\mu/(1-\mu)} \bar{p}_{t+1}^A \right], \tag{41}
\end{aligned}$$

where  $\pi_{t+1} \equiv p_{t+1}/p_t$ . Similar logic for  $\bar{p}_t^B$  yields

$$\bar{p}_t^B = y_t + \mathbb{E}_t \left[ \lambda_{t,t+1} (1-\theta) \pi_{t+1}^{-\mu/(1-\mu)-1} \bar{p}_{t+1}^B \right]. \tag{42}$$

Next, comes the relationship between  $p_t^*$  and inflation. The price index is

$$p_t = \left( \int_0^1 p_t(j)^{1/(1-\mu)} dj \right)^{1-\mu}$$

and with Calvo pricing we have

$$\begin{aligned}
p_t &= \left( (1-\theta) \int_0^1 (p_{t-1}(j))^{1/(1-\mu)} dj + \theta (p_t^*)^{1/(1-\mu)} \right)^{1-\mu} \\
&= \left( (1-\theta) p_{t-1}^{1/(1-\mu)} + \theta (p_t^*)^{1/(1-\mu)} \right)^{1-\mu}.
\end{aligned}$$

Therefore

$$\pi_t = \left( \frac{1-\theta}{1-\theta \left( \frac{p_t^*}{p_t} \right)^{1/(1-\mu)}} \right)^{1-\mu}. \tag{43}$$

Finally, note that because the capital-labor ratio is constant across firms, the production of variety  $j$  follows:

$$y_t(j) = a_t \left( \frac{k_t}{l_t} \right)^\alpha l_t(j).$$

The demand for variety  $j$  can be written in terms of the relative price to arrive at

$$\left(\frac{p_t(j)}{p_t}\right)^{\mu/(1-\mu)} y_t = a_t \left(\frac{k_t}{\ell_t}\right)^\alpha \ell_t(j).$$

Integrating both sides yields

$$\int_0^1 \left(\frac{p_t(j)}{p_t}\right)^{\mu/(1-\mu)} dj y_t = a_t \left(\frac{k_t}{\ell_t}\right)^\alpha \int_0^1 \ell_t(j) dj.$$

By market clearing we have then that:

$$S_t y_t = a_t k_t^\alpha \ell_t^{1-\alpha}, \quad (44)$$

where

$$S_t = \int_0^1 \left(\frac{p_t(j)}{p_t}\right)^{\mu/(1-\mu)} dj.$$

$S_t$  reflects the efficiency loss due to price dispersion and it evolves according to

$$S_t = (1 - \theta) S_{t-1} \pi_t^{-\mu/(1-\mu)} + \theta \left(\frac{p_t^*}{p_t}\right)^{\mu/(1-\mu)}. \quad (45)$$

Throughout this subsection, we have dropped most of the  $t$  subscripts on  $\mu_t$ . When the equations in this subsection are linearized around the zero-inflation steady state, the markup shock only enters equation (41).

## C.4 Capital goods firm

The capital goods firm chooses a sequence  $\{k_{t+1}, k_{t+2}, \dots\}$  to maximize

$$\mathbb{E}_t \sum_{s=t}^{\infty} \lambda_{t,s} (1 + \tau^P)^{-(s-t+1)} \left[ r_s k_s - k_{s+1} + k_s - \frac{\zeta}{2} \left(\frac{k_{s+1} - k_s}{k_s}\right)^2 k_s \right].$$

The discounting by  $1/(1 + \tau^P)$  comes from the property tax since:

$$v_t = \frac{1}{1 - \tau^P} d_t^k + \frac{1}{1 - \tau^P} \mathbb{E}_t [\lambda_{t,t+1} v_{t+1}]. \quad (46)$$

This problem leads to the first-order condition

$$1 + \zeta \left( \frac{k_{t+1} - k_t}{\hat{k}_t} \right) = \mathbb{E}_t \left\{ \frac{\lambda_{t,t+1}}{1 + \tau^p} \left[ r_{t+1} + 1 - \frac{\zeta}{2} \left( \frac{k_{t+2} - k_{t+1}}{k_{t+1}} \right)^2 + \zeta \left( \frac{k_{t+2} - k_{t+1}}{k_{t+1}} \right) \frac{k_{t+2}}{\hat{k}_{t+1}} \right] \right\}. \quad (47)$$

This expression can be transformed into one that only includes variables dated  $t$  and  $t + 1$  by writing it in terms of  $\hat{k}_t = k_{t+1}$  and introducing  $\hat{k}_t^{\text{lag}} = \hat{k}_{t-1}$ . Dividends paid by the capital goods firm are the term in brackets in the objective function less  $\tau^p$  times the value of the firm, which follows equation (46).

## D Proofs for propositions

*Proof of proposition 1.* Before turning to the full proof, we highlight the intuition for the result. With flexible prices, there is an aggregate Cobb-Douglas production function, so if the capital stock and employment are fixed, then the proposition will be true as long as the labor supply is fixed. Equating the marginal rate of substitution between consumption and leisure for households to their after-tax wage gives the standard labor supply condition:

$$n_t(i) = \left( \frac{(1 - \tau^x) s_t(i) w_t}{\psi_1 c_t(i) (1 + \tau^c)} \right)^{1/\psi_2}$$

Perfect insurance implies that consumption is equated across households. But then, our balanced-growth preferences and technologies imply that  $c_t/w_t$  is fixed over time, so the condition above, once aggregated over all households, gives a constant labor supply.

The full proof goes as follows. Under complete markets, the households will fully insure idiosyncratic risks. Therefore, we treat them as a large family that pools risks among its members. In determining the family's tax bracket, we assume the tax collector applies the tax rate corresponding to the average income of its members.

The large family maximizes

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[ \ln(c_t) - \psi_1 \frac{n_t^{1+\psi_2}}{1 + \psi_2} + \int_0^\nu \ln c_t(i) - \psi_1 \frac{n_t(i)^{1+\psi_2}}{1 + \psi_2} di \right]$$

subject to

$$\hat{p}_t \left[ \int_0^\nu c_t(i) di + c_t \right] + b_{t+1} - b_t = p_t [x_t - \bar{\tau}^x(x_t)] + T_t,$$

where  $T_t$  is net non-taxable transfers to the household and

$$x_t = (i_t/p_t)b_t + w_t \bar{s} n_t + d_t + \int_0^\nu s_t(i) n_t(i) + T_t^u(i) di.$$

The household also faces the constraint  $n_t(i) = 0$  if  $e_t(i) \neq 2$ . Let  $m_t^1$  be the Lagrange multiplier on the former constraint and  $m_t^2$  be the Lagrange multiplier on the latter. Then the first order conditions of this problem are

$$\begin{aligned} \frac{\beta^t}{c_t} &= \hat{p}_t m_t^1 && c_t \\ \frac{\beta^t}{c_t(i)} &= \hat{p}_t m_t^1 && n_t(i) \\ m_t^1 &= \mathbb{E}_t \{ m_{t+1}^1 + m_{t+1}^2 (i_t/p_t) \} && b_{t+1} \\ m_t^1 p_t [1 - \tau^x(x_t)] &= m_t^2 && x_t \\ \beta^t \psi_1 n_t^{\psi_2} &= m_t^2 w_t \bar{s} && n_t \\ \beta^t \psi_1 n_t(i)^{\psi_2} &= m_t^2 w_t s_t(i) && n_t(i) \end{aligned}$$

These first order conditions can be rearranged to obtain

$$\begin{aligned} c_t(i) &= c_t, \\ \frac{1}{c_t} &= \beta \mathbb{E}_t \left\{ \frac{1 + i_{t+1} [1 - \tau^x(x_{t+1})]}{c_{t+1} \pi_{t+1}} \right\}, \end{aligned}$$

and aggregate labor input satisfies

$$\bar{s} n_t + \int_0^\nu s_t(i) n_t(i) di = \left\{ \frac{1}{\psi_1} \frac{1}{c_t} \frac{1 - \tau^x(x_t)}{1 + \tau^c} w_t \right\}^{1/\psi_2} \left[ \bar{s}^{1+1/\psi_2} + E_t \int_0^\nu (s_t(i))^{1+1/\psi_2} di \right],$$

where  $E_t$  is defined as the mass of non-capital-owner households who are employed. In this final step we should only integrate over those households that are not at a corner solution, but this is trivial as the marginal disutility of labor goes to zero as  $n_t(i)$  goes to zero so all households with positive wages are employed and it is only those who exogenously lack

employment opportunities who will set  $n_t(i) = 0$ .

Proceeding similarly for the representative agent decision problem stated in the proposition and defining aggregate labor input in that case to be  $(1 + E_t)s_t n_t$ , one reaches the conclusion that the two models will deliver the same Euler equation and condition for aggregate labor supply. Therefore, the two models will generate the same aggregate dynamics.  $\square$

*Proof of proposition 2.* Under assumption 1, we can use the representative agent formulation from proposition 1. The labor supply condition for this problem is

$$n_t = \left[ \frac{(1 - \tau^x)w_t s_t}{c_t(1 + \tau^c)\psi_1} \right]^{1/\psi_2},$$

where  $\tau^x$  is the (constant) marginal tax rate. Under the conditions of assumption 2, the aggregate resource constraint is:  $c_t + g_t = y_t$ . But, since there is a constant ratio of  $g_t$  to  $y_t$ , the resource constraint implies that  $c_t/y_t$  is constant and equal to  $1 - \bar{g}/\bar{y}$ . Moreover, with flexible prices, we can write  $w_t = \frac{(1-\alpha)y_t}{\mu L_t}$ , where  $L_t$  is aggregate labor input. Using these two results to substitute out  $c_t$  and  $w_t$  we obtain

$$n_t = \left[ \frac{(1 - \tau^x)(1 - \alpha)y_t}{(1 - \bar{g}/\bar{y})y_t(1 + \tau^c)\psi_1\mu n_t(1 + E)} \right]^{1/\psi_2},$$

where we have used the fact that the aggregate labor input is  $n_t s_t(1 + E)$ , where employment is constant by assumption. Using this expression, we can solve for  $n_t$  as

$$n_t^{1+1/\psi_2} = \left[ \frac{(1 - \tau^x)(1 - \alpha)}{(1 - \bar{g}/\bar{y})(1 + \tau^c)\psi_1\mu(1 + E)} \right]^{1/\psi_2}.$$

Because the right-hand-side does not depend on time, it follows that  $n_t$  is constant over time.

Next, recall that capital is fixed and prices are flexible, so aggregate output is

$$y_t = a_t K^\alpha [(1 + E)sn]^{1-\alpha},$$

where  $K$  and  $n$  are the constant inputs of capital and hours,  $1 + E$  is total employment and  $s$  is the skill level of the representative agent, which is also constant over time by the fact that the labor market risk is unchanging over time so the composition of the pool of workers is stable. It follows from this equation that the variance of log output is equal to the variance of log productivity,  $a_t$ .

That  $\mathbf{S} = 0$  follows from the fact that the productivity process is exogenous and therefore

not affected by the presence or absence of automatic stabilizers. Notice that  $\mathbf{S} = 0$  holds regardless of whether one uses output or consumption as the measure of activity as  $c_t/y_t$  is constant. For hours, the ratio is not defined since there is no variation in hours worked.

□

## E Numerical solution algorithm

As the main text described, the key steps involved in solving the model are: (i) to discretize the cross-sectional distributions and decision rules, (ii) to solve for the stationary equilibrium, (iii) to collect all of the many equations defining the approximate equilibrium, and (iv) reducing these to a smaller system with little loss in accuracy. We elaborate on each of these steps next.

### E.1 Discretizing the model

For each discrete type of household characterized by a skill level and an employment status, we approximate the distribution of wealth by a histogram with 1000 bins. We approximate the policy rules for savings and labor supply by two piece-wise linear splines with 100 knot points each. We deal with the borrowing constraint in the approximation of the policy functions by, following Reiter (2010), parameterizing the point at which the borrowing constraint is just binding, and then constructing a grid for higher levels of assets. As a result of these approximations, there are now 1200 variables for employed workers, and 1100 variables for unemployed workers (who do not choose labor supply).

### E.2 Solving for the stationary equilibrium

Solving for the steady state of the model requires two steps: first, solving for the household policy rules and distribution of wealth and second, solving for the aggregate variables including the assets and consumption of the representative capital owner. These two steps are interrelated as the equilibrium interest rate depends on the capital-owner's marginal tax rate, which depends on the capital-owner's income and therefore wealth, which in turn depends on the level of wealth held by households.

We use an iterative procedure to find the equilibrium income of the capital owners. Given a guess of the capital-owner's income and therefore marginal tax rate, we find the equilibrium interest rate from the capital-owner's Euler equation and then the solution of

the intermediate goods firm’s problem to find the equilibrium wage. With these objects, we solve the households problem to find their consumption and asset positions. With these in hand, we use standard techniques from the analysis of representative agent models to find the rest of the aggregate variables. Finally, we check our guess of the capital-owner’s income and iterate from here.

### E.3 System of equations

**Keeping track of the wealth distribution** We track real assets at the beginning of the period using Reiter’s procedure to allocate households to the discrete grid in a way that preserves total assets. As we have nominal bonds in the model, we account for the effect of inflation in the evolution of the household’s asset position. For each discrete type of household this provides 1000 equations.

**Solving for household decision rules** We use the household’s Euler equation and the household’s labor supply condition to solve for their decision rules by imposing that these equations hold with equality at the spline knot points. This provides 100 equations for unemployed households and 200 for employed households.

**Aggregate equations** In addition to those equations that relate to the solution of the household’s problem and the distribution of wealth across households, we have equations that correspond to the capital-owner’s savings and labor supply decisions, as well as those that correspond to the firms’ problems. These equations are discussed in more detail in Appendix B. We use equations (28), (30), (31), (40), (41), (42), (43), (36), (37), (44), (45), (46), (47), and an auxiliary variable that carries an extra lag of capital. In addition, from the main text we have equations (22), (23), (24), (26), (25), (27), and exogenous AR(1) processes for  $\epsilon_t$ ,  $a_t$ , and  $\mu_t$ . We use these equations to solve for  $c_t$ ,  $n_t$ ,  $b_t$ ,  $M_t$ ,  $p_t^*/p_t$ ,  $\bar{p}_t^A$ ,  $\bar{p}_t^B$ ,  $S_t$ ,  $\pi_t$ ,  $y_t$ ,  $w_t$ ,  $r_t$ ,  $v_t$ ,  $k_t$ , lag of capital  $k_t^{\text{lag}}$ ,  $d_t$ ,  $B_t$ ,  $T_t^e$ ,  $g_t$ , and  $i_t$ .

### E.4 Linearization and model reduction

At this stage, we have a large system of non-linear equations that the discretized model must satisfy. We follow Reiter (2010, 2009) in linearizing this system around the stationary equilibrium using automatic differentiation and then solving the linearized system as a linear rational expectations model. The full linear system is too large to solve directly so we use



the model reduction step introduced by Reiter (2010). The only change that we make to Reiter’s procedure is the way we select the observation matrix ( $C$  in Reiter’s notation). The importance of this matrix is that it specifies those variables that the model should reproduce accurately. Reiter includes those aggregate variables that enter the household’s decision problem. In his case, that is the capital stock, which determines prices. In addition to these variables, we add those that we are interested in for our results (output, hours and aggregate consumption). Finally, we found it necessary to include the level of government debt in order to achieve an accurate solution.<sup>21</sup> We believe that the importance of government debt stems from its strong influence on the equilibrium interest rate.

## E.5 Endogenous search effort

In Section 5.4, we consider an extension of the model with endogenous search effort. Solving the model in that case has some extra steps. First, we must parameterize the search decision rule of unemployed households much as we parameterize the labor supply decision rule for employed households. To do that, we use equation (33) evaluated at 100 points for each discrete type of household. In order to evaluate that equation, we must calculate the household’s value function. Therefore, we parameterize the value functions with splines with 50 grid points for each discrete type of household and use the Bellman equation at those points to find the value function.<sup>22</sup>

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<sup>21</sup>We found this in initial exploration of models for which was possible to find the exact solution of the linear model (i.e. versions of the model with less heterogeneity so the model reduction step was not necessary).

<sup>22</sup>To improve the accuracy of the spline approximation, we interpolate over a transformation of household assets given by  $\log(b + 1)$ . After this transformation, the value function is closer to linear, which improves the accuracy of the spline approximation.