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Towards a quantitative theory of automatic stabilizers: the role of demographics[☆]

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Abstract

Employment volatility is larger for young and old workers than for the prime aged. At the same time, in countries with high tax rates, the share of total hours supplied by young/old workers is lower. These two observations imply a negative correlation between government size and business cycle volatility. This paper assesses in a heterogeneous agent OLG model the quantitative importance of these two facts to account for the empirical relation between government size and macroeconomic stability.

Keywords: Automatic Stabilizers, Distortionary Taxes, Demographics.
JEL codes: E32, E62, H30, J10, J21.

1. Introduction

The motivation for this paper consists of two observations. The first is the substantial evidence that countries or regions with large governments display less volatile business cycles, as shown in Galí (1994) and Fatás and Mihov (2001). The second observation, documented by Clark and Summers (1981), Ríos-Rull (1996) and Gomme et al. (2005), is that fluctuations in hours of market work

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over the business cycle vary quite dramatically across different demographic groups of the population, with the young experiencing much greater volatility of employment and total hours worked than the prime-aged. Moreover, in a recent paper Jaimovich and Siu (2009) find that changes in the age composition of the work-force account for a significant fraction of the variation in cyclical volatility observed in G7 countries. Hence, this article poses the following question: can the relationship between government size and macroeconomic stability be explained by changes in the demographic composition of the workforce resulting from distortionary taxation?

The hypothesis we put forward is that large governments stabilize the economy because the share of total market hours supplied by young and old workers is smaller in countries with high tax rates, implying a lower *aggregate* labor supply elasticity. Thus, in the tax-distorted economy we analyze, a relationship emerges between government size (measured by the share of taxes in GDP) and aggregate volatility, consistent with the notion of automatic stabilizers.[1]

The suggestion that time devoted to market work is affected by changes in tax and transfer policies has received considerable attention. Recent work by Prescott (2004), Rogerson (2008) and Ohanian et al. (2008) argues that these changes account for a large share of the difference in the amount of hours spent working in Europe and in the US. Rogerson and Wallenius (2009) document that the differences in employment rates between Europe and the US are due almost exclusively to differences among young and old workers. This observation offers further motivation for our paper.

We examine the strength of automatic stabilizers using a heterogeneous agent OLG model along the lines of Ríos-Rull (1996), and based on the link between the tax system and the aggregate labor supply elasticity.[2] The model includes heterogeneous preferences and, in particular, labor supply elasticities that change over the life-cycle. These changes are calibrated to match differences in the relative cyclical volatility of employment over the life-cycle and differences in employment rates in high and low tax countries.

To be sure, several factors explain why different age groups experience different labor market fluctuations over the business cycle (Choi et al., 2014). These

[1] So-called ‘built-in stabilizers’ are features of the tax structure that make tax liabilities automatically respond to current economic conditions (for instance, distortionary labor and capital income taxes) and reduce aggregate volatility. The stabilizing effect of the income tax is traditionally thought to operate via an assumed sensitivity of consumption demand to changes in current tax liabilities. But this sensitivity is zero according to the Ricardian proposition. Thus, Christiano (1984) concludes that under the Ricardian proposition, the income tax cannot play a role as an automatic stabilizer. Nonetheless, distortionary taxes may affect macroeconomic stability by affecting the aggregate supply and, in particular, the aggregate labor supply elasticity.

[2] To be sure, our paper is not suitable to study the welfare implications of automatic stabilizers. Optimal taxation must balance distortions versus insurance. But, in our OLG framework, as in Ríos-Rull (1996), markets are sequentially complete. Thus, the insurance gains from automatic stabilizers are negligible. See McKay and Reis (2013) for a detailed study of the insurance role of automatic stabilizers in an incomplete markets DSGE model.

factors are related, for example, to family formation, human capital accumulation, saving behavior, retirement age and unemployment dynamics, among others. We do not model these elements explicitly and, in particular, abstract from involuntary unemployment. Clearly, differences in employment volatility across demographic groups are partially accounted for by differences in unemployment dynamics. But, we interpret the assumed heterogeneity in labor supply elasticities as a reduced form way to capture all these factors.

A related calibration strategy has recently been explored by Dyrda et al. (2012) who, for similar reasons, also generate age differences in the volatility of hours with differences in preferences. They provide a measurement of the aggregate labor supply elasticity that, although consistent with micro estimates, yields a much higher macro elasticity. In our paper we establish a similar result in the context of a large OLG economy. The labor supply elasticity of the prime-aged is small, as implied by the meta-analysis of quasi-experimental studies by Chetty et al. (2012) but, given the heterogeneity in preferences, the aggregate labor supply elasticity of the baseline calibration is equal to 0.84, a value recommended by Chetty et al. (2012) to calibrate stand-in agent RBC models.[3]

An important aspect that differentiates this paper from the literature examining the stabilizating role of the government sector is that we conduct a quantitative study, based on a carefully calibrated model.[4] The baseline calibration accounts for about 75% of the strength of automatic stabilizers. This is the result of changes in the workforce demographic composition that affect the aggregate labor supply elasticity.

The remainder of the paper is organized as follows. Section 2 documents the empirical motivation. Section 3 presents the model. Section 4 establishes three results on the aggregate labor supply elasticity. Section 5 examines the quantitative performance of the model. Finally, Section 6 concludes.

2. Motivating evidence

The hypothesis we put forward is that large governments are stabilizing because they lead the demographic groups with high labor supply volatility to work relatively less. Here we document empirical evidence to motivate this mechanism. We start by showing that in all OECD countries, employment volatility exhibits a u-shaped profile over the life-cycle. The employment share

[3]Mennuni (2013) in the context of an OLG model similar to ours, explores the possibility that changes in the composition of labor affect the evolution of aggregate volatility, but focuses on differences across gender and schooling.

[4]Earlier work focuses on the sign of the relationship. Greenwood and Huffman (1991) and Galí (1994) study if income taxes and government purchases behave as automatic stabilizers in the basic RBC model. Both papers obtain a counterfactual relationship between government size and macroeconomic stability. Andrés et al. (2008) extend the analysis in Galí (1994) and study how models of the business cycle featuring nominal rigidities and costs of capital adjustment can generate a negative correlation between government size and volatility.

of the young and old is lower in countries with large governments and these difference affect business cycle volatility.

2.1. The employment volatility profile over the life-cycle

We begin by documenting the relationship between age and employment volatility: the employment volatility of young and old workers is larger than that of prime-age workers. Jaimovich and Siu (2009) show that, in the G7, young and old workers experience much greater business cycle volatility of employment and hours worked than the prime-aged. We show that this empirical regularity is found in all OECD countries. To illustrate this fact, we follow the approach of Gomme et al. (2005) and Jaimovich and Siu (2009), who report cyclical employment volatilities for various age groups.

We use annual data on employment by age group from the OECD for an unbalanced panel of 25 countries from 1970 to 2009, and build seven categories: individuals aged between 15 and 19 years old, 20 – 24, 25 – 29, 30 – 39, 40 – 49, 50 – 59 and 60 – 64 years old. For each of these categories, we extract the business cycle component of employment by applying the Hodrick-Prescott (HP) filter to the logged series with smoothing parameter equal to 6.25 and we calculate the standard deviation. We report the relative volatility, given by the standard deviation of each age group relative to the standard deviation of the group aged between 40 and 49.

[Figure 1 about here]

Figure 1 displays the results for a large cross-section of OECD countries. It reveals an ubiquitous u-shaped relationship between age and employment volatility at business cycle frequencies. In all the countries, volatility is the highest either among workers aged 15 to 19, or those aged 60 to 64. The employment volatility of the youngest workers is, on average, nearly five times that of workers aged 40 to 49. The workers aged 60 to 64 also display large employment volatility, on average more than three times that of workers aged 40 to 49. Finally, in all the countries the prime-age workers (aged 40 to 49) have the most stable labor supply.[5]

2.2. Demographic composition of employment and government size

The second fact we document concerns the relationship between the workforce's demographic structure and government size. We are interested in the impact of government size on what Jaimovich and Siu (2009) call the *volatile-aged* employment share (the ratio of employment of individuals aged 15 to 29 and 60 to 64, to that of individuals aged 15 to 64).

The first column of Table 1 considers the regression of the *volatile-aged* employment share on government size. Each observation corresponds to an

[5]Although our focus is on employment, the cyclical volatility of unemployment also varies across age groups. For example, Elsby et al. (2010) and Choi et al. (2014) show that the young were the most affected during the Great Recession.

OECD country over one of the following periods: 1970 – 1979, 1980 – 1989, 1990 – 1999 and 2000 – 2009. The regression reveals a negative and precisely estimated coefficient.

[Table 1 about here]

Of course, countries with older populations may need large governments. For example, large governments help provide the old with social security and healthcare. At the same time, countries with an older population have a lower share of young workers in aggregate employment. Thus, the negative correlation between the government size and the volatile-aged employment share could be spurious and due to the varying share of old individuals.[6] To confront this issue, the second column in Table 1 controls for the share of individuals aged 60 or more in the population. The results confirm that countries with older populations have lower volatile-aged employment shares. This implies a weaker independent influence of government size, but still strongly significant. Columns (3) and (4) report the same regressions as in columns (1) and (2), excluding individuals aged 60 to 64 from the volatile-aged employment share. The estimates are very similar.

2.3. Government size and business cycle volatility: role of demographics

Next, we argue that as a result of the negative correlation between the volatile-aged share of employment and government size, business cycles are less volatile in countries with large governments. Column (1) of Table 2 reports the regression of the volatility of aggregate hours on the volatile-aged share of employment. The coefficient is positive and precisely estimated. In turn, countries with larger governments enjoy more stable aggregate hours, as shown in column (2) of Table 2. However, the latter relationship vanishes if we control for the volatile-aged share of employment, as illustrated in column (3) of Table 2. The coefficient falls by 52% and is no longer significant. This suggests that government size affects the volatility of aggregate hours by changing the volatile-aged share of employment.

[Table 2 about here]

Turning to the volatility of GDP, column (4) of Table 2 shows that higher volatility of aggregate hours implies higher output volatility. Finally, columns (5) to (6) consider the same regressions as in columns (2) to (3), but with the volatility of GDP as the dependent variable, with similar results.

2.4. The intensive margin of adjustment

The evidence discussed so far is about how taxes affect the demographic composition of employment and how this affects aggregate volatility. But, variation in hours worked in the intensive margin (hours worked by those in employment)

[6] We thank a referee for this comment.

was ignored. This component is quantitatively unimportant for the fluctuation of hours worked in the case of the US where most of the variation in total hours is on the extensive margin (Hansen, 1985), but it is more important in more regulated economies such as France (Ohanian and Raffo, 2012).[7] In Appendix H we show that there is a negative correlation between government size and the relative hours worked by employed young workers, but that the intensive margin contribution to explain the negative correlation between government size and macroeconomic volatility is small.[8]

2.5. Summary of the empirical evidence

This Section documented the four following facts: i) the employment of young/old individuals fluctuates much more over the business cycle than that of prime-age individuals; ii) across OECD countries, the volatile-aged share of employment declines as the size of the government increases, even after controlling for the population's demographic structure; iii) there exists a negative link between government size and the cyclical volatility of aggregate hours and output, however, controlling for the demographic composition of the workforce attenuates substantially this relationship; iv) this mechanism operates along the extensive margin. Next, we propose a heterogeneous agent OLG model motivated by these four facts.

3. The model

We present a model with life-cycle changes in the cyclical volatility of hours worked. The framework is that of an OLG economy as in Ríos-Rull (1996), and we model labor supply in the extensive margin by way of a non-linear production function of labor services, as in Prescott et al. (2009). Time is discrete and each date t corresponds to a year. Each year a continuum (measure μ_1) of individuals is born. We denote an individual's age by $i = 1, \dots, T$. Individuals live at most $T = 70$ periods, but face random lifespans. The conditional probability of surviving from age i to $i+1$ is ζ_i, with $\zeta_0 = 1$ and $\zeta_T = 0$. Thus, the mass of individuals alive at age i is $\mu_i = \mu_1 \prod_{j=1}^{i} \zeta_{j-1}$.[9] All individuals must retire when $i = M = 50$. The other features of the economy are those of the standard RBC model featuring capital adjustment costs and variable utilization.

[7] The data examined in Ohanian and Raffo (2012) is at quarterly frequencies. At the annual frequency, the importance of the extensive margin to explain cyclical variations in total hours is even more predominant. In the US the intensive margin accounts for only about 1/6 of the fluctuations in aggregate hours (Heckman, 1984), and in the majority of OECD countries the annual volatility of employment is at least twice that of hours.

[8] We thank the Associate Editor for suggesting to study this additional channel.

[9] The mass of newborns μ_1 is chosen so that the total population $\sum_{i=1}^{T} \mu_i$ has unit size.

3.1. Preferences and labor supply

Preferences of an agent aged i are specified over consumption and total hours worked and take the form

$$u(c, n; i) = \frac{1}{1-\sigma}\left(c - \frac{\lambda_i n^{1+1/\eta_i}}{1+1/\eta_i}\right)^{1-\sigma}, \tag{1}$$

with $\sigma > 0$ and where c denotes consumption and n the total hours worked in the year.[10] The preference parameters λ_i and η_i are age dependent and, in particular, η_i is the wage-elasticity of labor supply. As in Bils and Cho (1994) and Cho and Cooley (1994), for example, we distinguish between the number of hours worked per unit of time (say a week), denoted $h \in [0, \underline{\mathrm{h}}]$, and the number of weeks the individual works in the year, denoted $e \in [0, \underline{\mathrm{e}}]$. Hence, total hours worked in a year are $n = eh$.

Without loss of generality, we normalize the total "number of weeks" in the year, $\underline{\mathrm{e}}$, to unity and interpret e as the employment rate as in Cho and Cooley (1994). Preferences are specified over total hours worked in the year, but the mapping from hours worked per week and labor services per week is non-linear and workers face a choice between work-week length and the number of work weeks per year. For an individual aged i, the mapping from weekly hours worked to labor services per week obeys

$$\ell_i = g(h; i), \tag{2}$$

where the function $g(h; i)$ has the following properties: for each age group i, $g(h; i)$ is increasing in h; it is equal to zero at the origin; over the domain $[0, 1]$, $g(h, i)$ is first convex and then becomes concave. This captures two key features: first, that over some domain of hours, a part-time worker is often less productive than a full-time worker; second, that after some point working longer hours leads to fatigue and lower returns to work. The length of the optimally chosen workweek must satisfy the condition

$$\frac{g(\bar{h}_i; i)}{\bar{h}_i} = g'(\bar{h}_i; i), \tag{3}$$

with the interpretation that the average productivity in the week is equal to the marginal productivity of an additional hour of work that week. Despite being endogenous, the optimal workweek length does not depend on wealth or the wage rate.

[10]If $\sigma = 1$, the utility function specializes to $u(c, n; i) = \ln\left(c - \frac{\lambda_i n^{1+1/\eta_i}}{1+1/\eta_i}\right)$.

Individuals maximize their life-time expected utility, given by

$$E_t\left[\sum_{i=1}^{T}\beta^{i-1}\left(\prod_{j=1}^{i}\zeta_{j-1}\right)u\left(c_{i,t+i-1},n_{i,t+i-1};i\right)\right], \tag{4}$$

where $c_{i,t}\geq 0$ and $n_{i,t}\in(0,\underline{\mathrm{h}}\times\underline{\mathrm{e}})$.[11]

3.2. Financial markets

As in Ríos-Rull (1996), markets are sequentially complete. In addition, two outside assets are traded: government bonds and shares in the stand-in firm.[12] There are also actuarially fair contracts for annuities. These contracts are arrangements whereby all members of the same cohort sign a contract in which survivors share the assets (or debts) of the agents that die. Next period's assets are the current savings divided by the probability of surviving. The resulting budget constraint faced by an individual aged i is

$$\begin{aligned}(1+\tau_c)\,c_{i,t}+p_t s_{i+1,t+1}+d_t b_{i+1,t+1}+\sum_{z\in\mathcal{Z}}q_t^z x_{i+1,t+1}^z&\\ =(1-\tau_h)\,w_t g\left(\bar{h}_i;i\right)e_{i,t}+a_{i,t}+L_t&,\end{aligned} \tag{5}$$

where τ_c and τ_h are the consumption and labor income tax rates, $x_{i+1,t+1}^z$ constitutes the amount of state-contingent Arrow securities for each event $z\in\mathcal{Z}$, bought by individuals aged i, at price q_t^z; $b_{i+1,t+1}$ are the government bonds, bought at discount price d_t; $s_{i+1,t+1}$ are the shares in the firm owned by an individual aged i, bought at the ex-dividend price p_t. The taxable labor income of an individual aged i is $w_t g\left(\bar{h}_i;i\right)e_{i,t}$. Finally, the individual's resources include lump-sum transfers received from the government L_t and her start of period wealth, given by

$$a_{i,t}=\frac{(\pi_t+p_t)\,s_{i,t}+b_{i,t}+x_{i,t}}{\zeta_{i-1}}, \tag{6}$$

where $x_{i,t}$ and $b_{i,t}$ are the payments from the Arrow securities and from the government bonds, and π_t is the after-tax profits distributed to shareholders.

3.3. Firms

The production function of the representative firm is

$$Y_t=\exp\left(\epsilon_t^1\right)\left(\left(u_t/\bar{u}\right)K_t\right)^{\alpha}H_t^{1-\alpha}, \tag{7}$$

[11] See the Appendix B.1 for a detailed derivation of the optimality conditions.
[12] The volume of outstanding equity shares is normalized to unity.

where the capital services are the product of the stock of capital K_t and the rate of capital utilization, $(u_t/\bar{u})$, and where

$$H_t \equiv \sum_{i=1}^{M} \mu_i g\left(\bar{h}_i; i\right) e_{it}, \tag{8}$$

are the efficiency units of labor services. Shocks to productivity, ϵ_t^1, follow an exogenous Markov process. Raising the capital utilization rate is costly because it implies a faster capital depreciation; the depreciation function is

$$\delta\left(u_t\right) = \delta_0 + \delta_1 \left(u_t/\bar{u}\right)^{1+\varsigma}, \tag{9}$$

with $\varsigma > 0$ and $\bar{\delta} \equiv \delta_0 + \delta_1 \in (0,1)$ the steady state depreciation rate. The firm faces adjustment costs in investment, so that

$$K_{t+1} - K_t = \Phi\left(I_t/K_t\right) K_t - \delta\left(u_t\right) K_t. \tag{10}$$

with $\Phi\left(\bullet\right)$ increasing and concave. The representative firm maximizes[13]

$$J\left(K_t; \epsilon_t^1\right) = \max_{I_t, H_t} \left\{\pi_t + E_t\Big[\Lambda_{t+1} J\left(K_{t+1}; \epsilon_{t+1}^1\right)\Big]\right\}, \tag{11}$$

subject to (10), and where Λ_{t+1} is the stochastic discount factor of the firm's shareholders, and after-tax profits, π_t, are given by

$$\pi_t = \left(1 - \tau_k\right)\Big[\exp\left(\epsilon_t^1\right) K_t^{\alpha} H_t^{1-\alpha} - w_t H_t - I_t\Big]. \tag{12}$$

3.4. Government

The government taxes capital income, labor income and consumption, at the rates τ_k, τ_h and τ_c, respectively. It spends G_t as government consumption and provides lump-sum transfers, L_t. The government budget constraint is

$$d_t B_{t+1} = G_t + L_t + B_t - \tau_k\left(Y_t - w_t H_t - I_t\right) - \tau_h w_t H_t - \tau_c C_t. \tag{13}$$

The dynamics of L_t and G_t are described by the following two equations

$$\widehat{L}_t = -\varphi_L \widehat{B}_t, \tag{14}$$

$$\widetilde{G}_t = \rho_G \widetilde{G}_{t-1} - \varphi_G \widehat{B}_t + \sigma_g \epsilon_t^2, \tag{15}$$

where ϵ_t^2 is an exogenous shock; $\widehat{L}_t \equiv \left(L_t - \bar{L}\right)/\bar{Y}$ and $\widehat{B}_t \equiv \left(B_t - \bar{B}\right)/\bar{Y}$ are lump-sum transfers and debt in deviation from steady state as percentage of the steady state output; $\widetilde{G}_t$ is government spending in log-deviation from steady state; the parameters φ_L, ρ_G and φ_G are positive, consistent with the

[13] The optimality condition solving the firm's problem are in Appendix B.2.

transversality condition of the government sector

$$E_t\left[\lim_{z\to\infty}\left(\Pi_{i=t}^{z}d_i\right)B_{z+1}\right]=0. \tag{16}$$

3.5. Equilibrium and solution method

We consider the model's competitive equilibrium, carefully defined in the Appendix B.3. As in Ríos-Rull (1996), the computation of equilibrium is based on linear decision rules. Following standard steps, the firm's and the individual optimality conditions, and the market clearing conditions are log-linearized around steady state. A detailed derivation of the equilibrium conditions is collected in the Appendix B.4, while Appendix B.5 includes a detailed description of the algorithm to find the steady state equilibrium. The log-linear model is described in Appendix B.6.

4. Government size and aggregate labor supply elasticity

This Section, first characterizes the differences in employment volatility across demographic groups. Second, we ask how the employment share of each group varies as the size of the government is changed. Third, we show the relation between the aggregate labor supply elasticity and taxation.

4.1. Cyclical properties of hours over the life-cycle

The optimality condition for the choice of total hours and workweek length for an individual aged $i=1,\ldots,M$, is

$$n_{i,t}=\left[\left(\frac{1-\tau_h}{1+\tau_c}\right)\frac{g\left(h_{i,t};i\right)h_{i,t}^{-1}w_t}{\lambda_i}\right]^{\eta_i}, \tag{17}$$

and

$$\frac{g\left(h_{i,t};i\right)}{h_{i,t}}=g'\left(h_{i,t};i\right). \tag{18}$$

From (18), $h_{i,t}=\bar{h}_i$, so that the workweek length is acyclical and all the cyclical fluctuations in total hours occur in the extensive margin. The result that follows compares total hours volatility across demographic groups.

Lemma 1. *Denote by σ_i the standard deviation of the logarithm of total hours worked by individuals aged i and σ_w the standard deviation of the logarithm of the wage rate. It follows that*

$$\sigma_i=\eta_i\sigma_w, \tag{19}$$

where η_i is the Frisch labor supply elasticity of individuals aged i.

Lemma 1 follows immediately from equation (17). The upshot is that the demographic groups with large labor supply elasticities display more volatile employment rates (and, hence, total hours worked) over the business cycle.

4.2. Steady state: taxation and labor force composition

Let the employment rates of individuals aged i in two countries with different fiscal profiles be denoted $\bar{e}_i$ and $\bar{e}'_i$, and the employment rates for a different demographic group j in the same two countries be $\bar{e}_j$ and $\bar{e}'_j$. Then

$$\frac{\ln\left(\bar{e}_i/\bar{e}'_i\right)}{\ln\left(\bar{e}_j/\bar{e}'_j\right)} = \frac{\eta_i}{\eta_j} \tag{20}$$

This result is summarized in the following lemma (proven in Appendix C).

Lemma 2. *Consider the steady state of two economies with different fiscal policy profiles. The relative percentage difference in employment rates in the two countries for individuals aged i and individuals aged j, is given by (η_i/η_j).*

The upshot is that an increase in tax rates changes the composition of the aggregate labor supply towards the less volatile individuals.

4.3. The aggregate labor supply elasticity

The third result we obtain is about the relationship between the aggregate labor supply elasticity and taxes. We establish the Proposition that follows.

Proposition 1. *Around steady state the aggregate labor supply elasticity is*

$$\frac{d\ln H_t}{d\ln w_t} \equiv \mathcal{E}_n = \sum_{i=1}^{M} \bar{s}_{hi}\eta_i, \tag{21}$$

where $\bar{s}_{hi} \equiv \mu_i g\left(\bar{h}_i; i\right)\bar{e}_i/\bar{H}$ is the share of efficient units of labor supplied by individuals aged i in steady state. Moreover,

$$\frac{d\mathcal{E}_n}{d\tau_j} = \frac{\daleth_j}{\tau_j}\sigma_\eta, \forall j = \{h, k, c\}, \tag{22}$$

where $\sigma_\eta \equiv \sum_{i=1}^{M} \bar{s}_{hi}\eta_i^2 - (\sum_{i=1}^{M} \bar{s}_{hi}\eta_i)^2$ is the cross-sectional variance of the labor supply elasticities, and

$$\daleth_j = \begin{cases} \frac{d\ln\bar{w}}{d\ln\tau_h} - \frac{\tau_h}{1-\tau_h} & \textit{if } j = h, \\ \frac{d\ln\bar{w}}{d\ln\tau_c} - \frac{\tau_c}{1+\tau_c} & \textit{if } j = c \textit{ and} \\ \frac{d\ln\bar{w}}{d\ln\tau_k} & \textit{if } j = k. \end{cases} \tag{23}$$

Thus, the sensitivity of the aggregate labor supply elasticity to changes in tax rates is increasing in the dispersion of the elasticities η_i across age groups.

The proof of Proposition 1 is in Appendix D.

5. Quantitative evaluation

In what follows, we study the quantitative importance of our mechanism to generate a negative correlation between government size and aggregate volatility. Our strategy is the following. We first calibrate our model to the US, in Section 5.1. In Section 5.2, we evaluate the model's fit by looking at how it matches some moments of the US economy that are not used as calibration targets. Finally, in Section 5.3, we let the fiscal profile of the calibrated economy vary in the same way that it varies across the OECD countries, and evaluate the implications of these changes for business cycle volatility. Based on this exercise, we study if our mechanism is quantitatively important by comparing the strength of the relationship between government size and aggregate volatility implied by the model and in the data.

5.1. Calibration

We calibrate the baseline economy to the US. The calibration makes use of three types of data: i) the NIPA tables, ii) the US fiscal policy parameters, and iii) life-cycle earnings, employment and hours data. We first describe the targets determining the technology and the preference parameters that are stable over the life-cycle, $\left(\alpha, \beta, \bar{\delta}, \varsigma, \phi, \sigma, \rho, \sigma_{\epsilon^1}\right)$. Next, we explain how the parameters of the government sector are set, $(\tau_k, \tau_c, \tau_h, \varphi_L, \rho_G, \varphi_G, \sigma_g, \bar{g}_y)$. Finally, we describe the targets determining the preference parameters that change over the life-cycle.

The preference parameters that change over the life-cycle include those of the function $g\left(h; i\right)$ and the parameters λ_i, for $i = 1, \ldots, 50$, that determine the life-cycle profile of earnings and hours worked by those in employment, and the labor supply elasticities, η_i, for $i = 1, \ldots, 50$. The main target we use to calibrate these elasticities is the relative volatility of employment of the young. This target allows us to pin down η_1 for a given list of relative elsticities (η_i/η_1), for $i = 2, \ldots, 15$ and (η_i/η_{40}), for $i = 41, \ldots, 50$. In turn, as explained in Section 5.1.4, we pin down these relative elasticities by making use of Lemma 2 and data on employment over the life-cycle in a second country with a different fiscal profile from the US. This allows us to match the effect that changing the tax profile exerts on the relative demographic composition of the workforce.

5.1.1. Technology and stable preference parameters

The calibration of the technology and preference parameters that are stable over the life-cycle follows standard practices. The capital income share α is set to 0.283 based on the NIPA. The discount factor β is set to 0.992, to match an investment-output ratio of 14% (NIPA). The steady state annual depreciation rate $\bar{\delta}$ is set to 0.05, as in Cooley and Prescott (1995). The elasticity of marginal depreciation with respect to utilization is set to $\varsigma = 0.560$, as in Burnside and Eichenbaum (1996). Based on Basu and Kimball (1997) ϕ, the elasticity of the investment-capital ratio to Tobin's $\mathcal{Q}$, is set to 2.5. The inverse elasticity of intertemporal substitution σ is set equal to 2, as in Greenwood et al. (1988).

Finally, based on an estimated AR(1) model for the Solow residuals (see Appendix G for details), we set $\rho = 0.847$, while restricting $\sigma_{\epsilon^1} = 0.016$ to match the volatility of US output.

5.1.2. Government sector

We choose values for the tax rates on capital income, labor income and consumption based on evidence in Carey and Rabesona (2002), who have produced series for average effective tax rates in the OECD based on the methodology of Mendoza et al. (1994). The tax rates for the US are: $\tau_k = 0.3712$, $\tau_c = 0.0526$ and $\tau_h = 0.2567$. We set values for the parameters φ_L, ρ_G, φ_G and σ_g, based on an estimated VAR model of government spending and public debt (see Appendix F for details). This gives: $\rho_G = 0.913$, $\varphi_G = 0.110$, $\varphi_L = 0.180$ and $\sigma_{\epsilon^2} = 0.015$. Finally, using data from the BEA, the steady state ratio of government consumption to GDP, $\bar{g}_y$, is calculated to be 22%, which corresponds to the average share of government spending in output over the period 1970 – 2009.

5.1.3. Parameterization of $g(\bullet)$ and λ_i

We calibrate the $g(\bullet)$ function to match the life-cycle profile of earnings and hours by those in employment. We assume the following form for $g(\bullet)$

$$g(h;i) \equiv \frac{1}{1 + \kappa_i h^{-\varrho_i}}, \tag{24}$$

where $\kappa_i > 0$ and $\varrho_i > 1$ are age-specific parameters. From condition (3), the optimal number of hours by those in employment is

$$\bar{h}_i = \left[\kappa_i (\varrho_i - 1)\right]^{1/\varrho_i}. \tag{25}$$

Using (25) to substitute in (24), we obtain $g\left(\bar{h}_i; i\right) = 1 - 1/\varrho_i$. Thus, the labor services produced per week are dependent only on ϱ_i, and we set their values to match earnings over the life-cycle obtained from the PSID. We set κ_i to match the life-cycle profile of hours worked by those in employment, obtained from Blundell et al. (2013).[14] We set λ_i to match the employment rates over the life-cycle in the US (Blundell et al., 2013) and, hence, match both hours and employment over the life-cycle, as shown in Figure 2.

[Figure 2 about here]

5.1.4. Calibration of the labor supply elasticities

We now describe the aspects of the calibration that have to do with the labor supply elasticity parameters, η_i. Prime aged workers (aged 30 to 54) all have the same labor supply elasticity $\eta_i = \eta_{\text{ prime age}} = 0.20$ for all $i = 16 \ldots 40$, based on the meta-analysis of quasi-experimental studies by Chetty et al. (2012). This

[14] We thank Antoine Bozio for kindly providing us with their data.

leaves the parameters $\eta_1 \dots \eta_{15}$, and $\eta_{41} \dots \eta_{50}$, still to be determined. They are set to match two targets: the relative employment volatility of the young (aged 15 to 29), and the relative life-cycle profile of employment in the US and a second country with a different fiscal profile. The first target determines η_1 given the ratios (η_i/η_1), for $i = 2 \dots 15$, and (η_i/η_{40}), for $i = 41 \dots 50$. In turn, these ratios are pinned down using the second target, based on Lemma 2. The second country is chosen to be France because the data from Blundell et al. (2013) is only for the US, UK and France and the latter has a tax profile that contrasts more with the US than that of the UK.

The details are as follows. Let σ^n_{15-29} denote the standard deviation of total hours (in logs) worked by the young, and σ^n_{30-64} that of those aged 30 to 64. Given $\eta_{\text{ prime age}} = 0.20$, we show in Appendix E that

$$\eta_1 \sum_{i=1}^{15} \frac{\mu_i \bar{n}_i \left(\eta_i/\eta_1\right)}{\bar{N}_{15-29}} = 0.20 \left[\frac{\bar{N}_{30-54}}{\bar{N}_{30-64}} + \sum_{i=41}^{50} \frac{\mu_i \bar{n}_i \left(\eta_i/\eta_{40}\right)}{\bar{N}_{30-64}}\right] \frac{\sigma^n_{15-29}}{\sigma^n_{30-64}}, \tag{26}$$

where $\bar{N}_{15-29} = \sum_{i=1}^{15} \mu_i \bar{n}_i$ and $\bar{N}_{30-64} = \sum_{i=16}^{50} \mu_i \bar{n}_i$. In the above equation, the parameters μ_i (the population of individuals aged i) are obtained from the OECD population statistics.

Thus, we solve for the η_1 matching the relative volatility of employment of the young, $\left(\sigma^n_{15-29}/\sigma^n_{30-64}\right)$. But, to do this we need values for the ratios (η_i/η_1), for $i = 2 \dots 15$, and (η_i/η_{40}), for $i = 41 \dots 50$, obtained based on Lemma 2, as follows

$$\frac{\eta_i}{\eta_1} = \frac{\ln\left(\bar{e}_i^{\mathrm{US}}/\bar{e}_i^{\mathrm{FR}}\right)}{\ln\left(\bar{e}_1^{\mathrm{US}}/\bar{e}_1^{\mathrm{FR}}\right)}, \qquad \text{and} \qquad \frac{\eta_i}{\eta_{40}} = \frac{\ln\left(\bar{e}_i^{\mathrm{US}}/\bar{e}_i^{\mathrm{FR}}\right)}{\ln\left(\bar{e}_{40}^{\mathrm{US}}/\bar{e}_{40}^{\mathrm{FR}}\right)}. \tag{27}$$

Notice that, while we use data from a second country in (27) we do not target employment levels in France. Only if the model is exactly correct and taxes are the only explanation for differences in employment rates across countries, would we match employment in France exactly.[15]

[Figure 3 about here]

Figure 3 contrasts employment in the US and France from the model and the data. The fact that we match quite well France's employment is an encouraging measure of the model's fit. This result is also consistent with the findings in Chetty et al. (2012), who show that estimates of steady state elasticities of the response of employment to taxes are similar whether one relies on macro or micro data, although they differ when one estimates intertemporal substitution elasticities based on short-run fluctuations.

[15]For example, the calibration strategy implies that although we match exactly the ratio

$$\ln\left(\bar{e}_{39}^{\mathrm{US}}/\bar{e}_{39}^{\mathrm{FR}}\right) / \ln\left(\bar{e}_1^{\mathrm{US}}/\bar{e}_1^{\mathrm{FR}}\right),$$

we may underestimate both e_{39}^{FR} and e_1^{FR}.

The life-cycle profile of labor supply elasticities is shown in Figure 4. For all prime aged individuals, aged 30 to 54, the labor supply elasticity is set at 0.2. Instead, for young and old individuals, the elasticities are allowed to vary, reaching a maximum of around 8.22.[16] The implied aggregate labor supply elasticity, $\mathcal{E}_n$, is 0.84. This is remarkably close to 0.86, the macro elasticity recommended by Chetty et al. (2012). Thus, heterogeneity in labor supply elasticities helps reconcile micro-econometric evidence and macro models.

[Figure 4 about here]

Table 3 summarizes the baseline calibration and corresponding targets.

[Table 3 about here]

5.2. Properties of the baseline economy

We now study the behavior of the model under the baseline calibration. In particular, we look at the implications of our calibration for aggregate business cycle statistics and for relative employment volatilities of different demographic groups, not used as targets in the calibration.

5.2.1. Aggregate business cycle statistics

Panel A of Table 4, compares aggregate business cycle moments under the baseline calibration to the US business cycle statistics. The table shows the properties of output, consumption, investment, government spending and total hours worked in both the data and the model.

[Table 4 about here]

The baseline model matches the volatility of aggregate variables at least as well as the standard RBC model. Consumption and investment volatility are similar to their empirical counterparts. The model suffers from the same drawback as the standard RBC model: the volatility of total hours is about half that of output, while the empirical counterpart is 90%. But, this is achieved with a low labor supply elasticity for the prime aged population. So the fact that it performs at least as well as the standard RBC model (typically calibrated with an elasticity around 1) is significant. Also, since fluctuations in total hours occur only through employment it is better to look at the volatility of employment in the data. The model accounts for 75% of employment volatility. The high correlations between output and the private components of aggregate expenditure are the result of the model's RBC structure.

[16]The large elasticities for the young and the old are consistent with the evidence that is reviewed in Keane and Rogerson (2012) for some demographic groups.

5.2.2. Employment fluctuations by age group

One of our calibration targets was the volatility of the young relative to that of those aged 30 to 64. This relative volatility is equal to 2.20 and is exactly matched by the model. But, to judge the fit of the model, it is useful to look at moments not used as targets for the calibration. Panel B of Table 4 looks at the model's ability to match the volatility of employment for specific age groups, the young (15 to 29), the prime aged (30 to 44) and the old (54 to 64), in levels and relative to the total hours volatility. None of these moments is used as a target in the calibration.

The model matches very well the relative volatility of the young (1.57 in the data and 1.64 in the model), and also that of individuals aged 30 to 64 (0.70 versus 0.74). However, it produces a relative volatility for the prime aged that is too low compared to the data (0.75 versus 0.20) and, as a consequence, a relative volatility for those aged 55 to 64 that is too high. This follows from the low labor supply elasticity attributed to this group.[17]

5.3. Government size and automatic stabilizers

Next, we solve the model under alternative fiscal policy parameters, with each combination mimicking the fiscal profile of an OECD country, based on the estimates by Carey and Rabesona (2002), and the observed government spending to GDP ratios. In turn, for each OECD country, we calculate the model implied government size and the corresponding business cycle volatility measures.

Figure 5 shows that the link between government size, the demographic composition of the workforce and volatility is qualitatively consistent with the facts documented in Section 2. Higher taxes imply a low volatile-worker employment share. The smaller the employment share of volatile workers, the lower the volatility of aggregate hours worked and output.

[Figure 5 about here]

Table 5 reports the estimates from a OLS regression between aggregate volatility and government size using the empirical OECD data, and compared to the same regression coefficients implied by the model. This exercise allows us to interpret our results from a quantitative perspective.

[Table 5 about here]

Our baseline calibration implies a slope coefficient in the regression of output volatility on government size that is 75% of its empirical counterpart. The slope associated with the regression of hours volatility on government size corresponds to 114% of its empirical counterpart. Thus, the model is able to reproduce almost exactly the automatic stabilizers' strength.[18]

[17] In Appendix I, we consider an alternative calibration of the labor supply elasticities that overcomes this problem by attributing a larger elasticity to prime aged workers.

[18] In Appendix I we show that once we introduce exogenous demographic changes in the

6. Conclusion

Two empirical facts serve as motivation for this paper. The first is the strong negative correlation between government size and the volatility of business cycles across OECD countries. The second fact, is the substantial heterogeneity across demographic groups in terms of the cyclical volatility of employment. We develop a heterogeneous agent OLG model quantitatively consistent with these empirical facts. Our results suggest that differences over the life-cycle in labor supply behavior help explain salient business cycle features and, in particular, automatic stabilizers.

Appendix. Supplementary material

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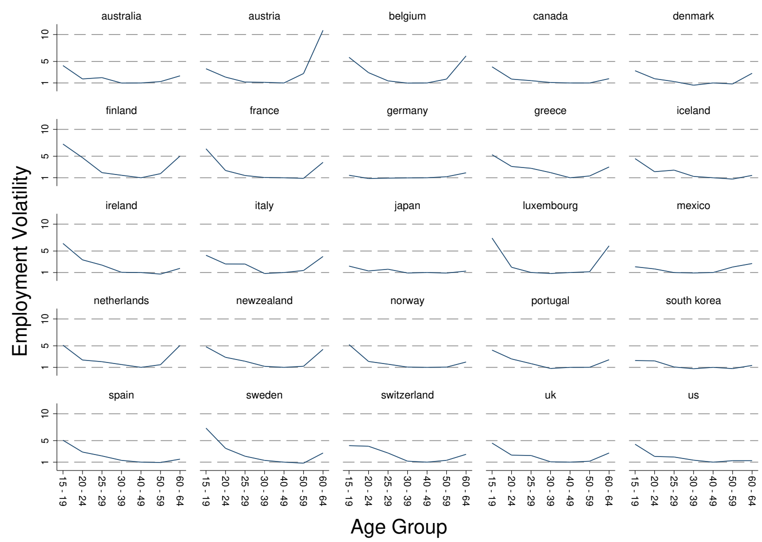
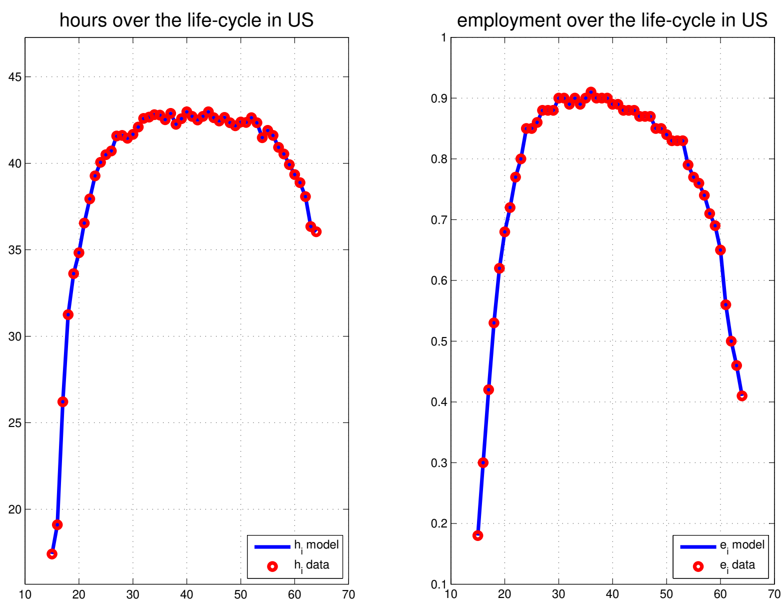
Figure 1: volatility of employment by demographic group (OECD)



Note: The data is annual and the source is the OECD Labour Force Statistics. All variables are reported in logs as deviations from an HP trend with smoothing parameter 6.25. The volatility is expressed relative to the $40-49$ age group.

Figure 2: Calibration targets: employment and hours over the life-cycle

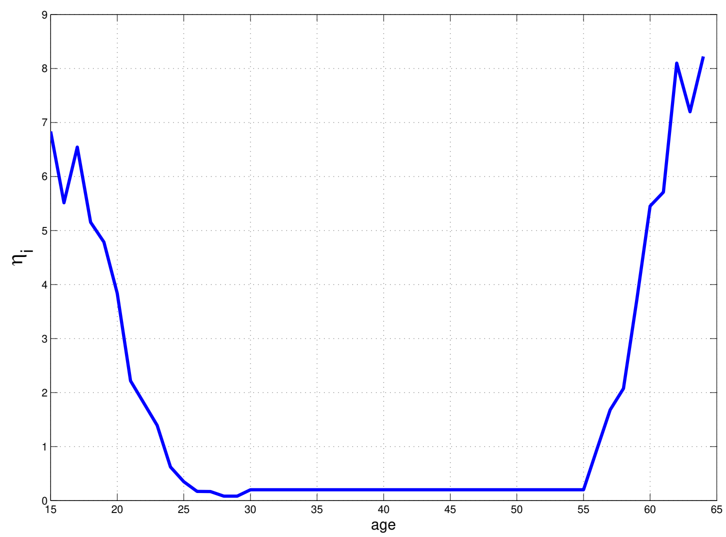


Note: the data source is Blundell, Bozio, and Laroque (2013).

Figure 3: Model evaluation: employment rates in two countries (model/data)

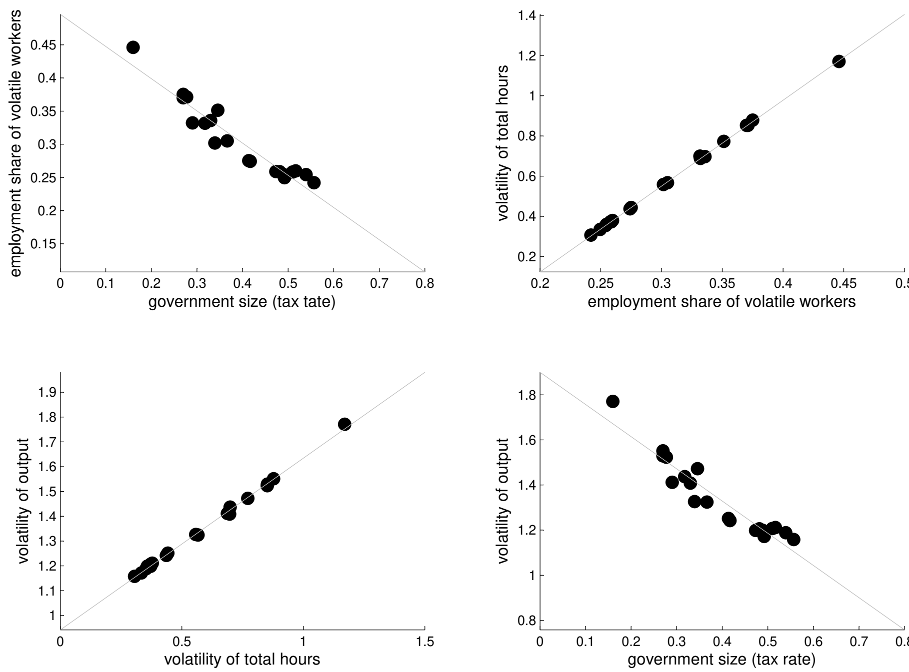
Note: the data source is Blundell, Bozio, and Laroque (2013). US employment is a calibration target while France's employment is not.

Figure 4: Calibrated parameters: labor supply elasticity over the life-cycle



Note: values for η_i for $i = 1, \ldots, 50$, corresponding to workers aged between 15 and 64.

Figure 5: Quantitative results: government size and volatility (model)



Note: Volatility of output and hours from the model are the standard deviation of the HP filtered output and hours implied by the model. Each observation corresponds to an economy whose fiscal policy parameters are chosen to mimic the fiscal profile of a specific OECD economy.

Table 1: government size and demographic structure

	(1) vol. share	(2) vol. share	(3) young share	(4) young share
Gov. Size	-20.180^{***}	-16.250^{***}	-20.145^{***}	-16.217^{***}
	(5.226)	(5.256)	(5.232)	(5.263)
Share of 60+ in pop.		-20.584^{**}		-20.576^{**}
		(8.009)		(8.019)
Obs.	75	75	75	75
R^2	0.472	0.518	0.471	0.517

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: Each observation corresponds to a country and one of the following time periods: 1970 – 1979, 1980 – 1989, 1990 – 1999, and 2000 – 2009. Time dummies are included but not listed. The volatile share corresponds to the share of employment of the population aged 15 to 29 and 60 to 64 in the total employment of the population aged 15 to 64. The young share corresponds to the share of employment of the population aged 15 to 29 in the total employment of the population aged 15 to 64. Gov size is the ratio between total tax revenue and GDP. Share of 60+ in pop. is the share of individuals aged 60 or more in the population. See Appendix A for details about the data.

Table 2: government size, demographic structure and aggregate volatility

	vol. hours			vol. GDP		
	(1)	(2)	(3)	(4)	(5)	(6)
Gov. Size		-1.819^{**}	-0.868		-1.909^{**}	-1.275
		(0.794)	(0.848)		(0.768)	(0.841)
Vol. Share	0.056^{***}		0.049^{***}			0.035^{**}
	(0.016)		(0.018)			(0.017)
Vol. Hours				0.713^{***}		
				(0.078)		
% Change Fiscal Coef.			−52%			−33%
Obs.	75	77	75	77	77	75
R^2	0.169	0.099	0.182	0.565	0.134	0.180

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: Each observation corresponds to a country and one of the following time periods: 1970 – 1979, 1980 – 1989, 1990 – 1999, and 2000 – 2009. Time dummies are included but not listed. Volatility of output and volatility of hours are the standard deviation of the respective cyclical component (calculated using the HP filter with smoothing parameter 6.25). The Vol. Share corresponds to the share of employment of the population aged 15 to 29 and 60 to 64 in the total employment of the population aged 15 to 64. Gov. Size is the ratio between total tax revenue and GDP. See Appendix A for details about the data.

Table 3: baseline calibration (summary)

parameter		target/source
stable parameters		
α	0.283	Targets capital income share
β	0.992	Targets investment/GDP ratio of 14%
ρ	0.847	Targets Solow residuals autocorrelation
σ_{ϵ^1}	0.016	Targets US output volatility
ρ_G	0.919	Target: VAR estimation
σ_{ϵ^2}	0.015	Target: VAR estimation, standard deviation of residuals
φ_G	0.110	Target: VAR estimation
φ_L	0.180	Target: VAR estimation
$\bar{g}_y$	0.220	Targets government spending as fraction of GDP of 22%
$\bar{\delta}$	0.050	Source: Cooley and Prescott (1995)
ϕ	2.500	Source: Basu and Kimball (1997)
ς	0.560	Source: Burnside and Eichenbaum (1996)
σ	2.000	Source: Greenwood et al. (1988)
τ_h	0.256	Source: Carey and Rabesona (2002)
τ_k	0.371	Source: Carey and Rabesona (2002)
τ_c	0.053	Source: Carey and Rabesona (2002)
life-cycle parameters		
ϱ_i	i=1,...,50	Target weakly earnings (PSID)
κ_i	i=1,...,50	Target hours worked by employed (Blundell et al., 2013)
λ_i	i=1,...,50	Target life-cycle employment rates, US (Blundell et al., 2013)
μ_i	i=1,...,70	Target OECD population statistics, US
η_1	6.834	Target relative volatility of workers aged 15 – 29, US
$\left\{ \begin{array}{l} \eta_i/\eta_1, \\ \eta_i/\eta_{40}, \end{array} \right.$	$\begin{array}{l} i = 2\ldots15 \\ i = 41\ldots50 \end{array}$	Target rel. emp. rates, US & FR (Blundell et al., 2013)
$\eta_{\text{prime age}}$	0.200	Source: Chetty et al. (2012)

Note: target/source indicates either the target used to obtain the parameter or the source informing the choice of parameter value. See Appendix A for details about the data. See Figure 4, which displays the calibrated values of each Frisch elasticity.

Table 4: Model evaluation: US business cycle statistics (model and data)

	PANEL A (aggregate vol.)			
	std. dev.		correlation	
variable	data	model	data	model
output	1.45	1.45	1.00	1.00
consumption	1.20	1.42	0.90	0.99
investment	5.13	4.00	0.94	0.98
government spending	0.93	0.96	-0.13	0.02
total hours	1.28	0.78	0.92	1.00
employment rate $15-64$	1.04	0.78	0.89	1.00

	PANEL B (emp. vol. by group)			
age group	std.dev		std. dev. relative to $15-64$	
	data	model	data	model
$15-29$	1.63	1.27	1.57	1.64
$30-54$	0.78	0.16	0.75	0.20
$55-64$	0.70	2.73	0.66	3.52
$30-64$	0.74	0.58	0.70	0.74

Note: data on GDP, consumption, investment and government spending is from the NIPA tables. Inventories are excluded from the measure of investment. Data on hours worked is from the Conference Board Total Economy Database. Employment rate $15-64$ is from the OECD and corresponds to the employment/population ratio among the individuals aged 15 to 64. Cyclical component is the log in deviations from an HP trend with smoothing parameter 6.25. The model's reported statistics are calculated under the US fiscal profile. See Appendix A for details about the data.

Table 5: Quantitative results: volatility and government size (model/data)

$\sigma = \beta_0 + \beta_1$ (tax rate)		data	model	$\left(\beta_1^{\text{model}}/\beta_1^{\text{data}}\right)$
$\text{std}\,(Y)$	β_1	-1.909	-1.428	75%
$\text{std}\,(H)$	β_1	-1.819	-2.074	114%

Note: OLS regressions where the dependent variables are, respectively, output volatility, $\text{std}\,(Y)$, and aggregate hours volatility, $\text{std}\,(Y)$, and the explanatory variable is the tax revenue to output ratio. The volatility of output and hours is the standard deviation of the series in log deviations from an HP trend with smoothing parameter 6.25. The tax rates used to calibrate the fiscal profile of each economy in the simulations are from Carey and Rabesona (2002). For the empirical regressions, each observation corresponds to a country and one of the following time periods: 1970 – 1979, 1980 – 1989, 1990 – 1999, and 2000 – 2009. Time dummies are included but not listed.