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Progressive Taxation and Monetary Policy in a Currency Union

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Progressive Taxation and Monetary Policy in a Currency Union

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Abstract

We analyse the welfare properties of progressive income taxes in a stylized DSGE model of a currency union calibrated to the Eurozone. When the central bank follows a standard Taylor rule and volatility originates solely in productivity shocks, we find that considerable welfare gains can be achieved by introducing a progressive income tax schedule. The reason is that the slightly lower average levels of consumption and greater volatility of hours are more than offset in their effects on welfare by a significant reduction in consumption volatility. However, at the aggregate level this result is not robust to the introduction of rule-of-thumb households, but we find a positive welfare effect for the latter type of households while intertemporally optimizing households lose. Furthermore, under an optimal monetary policy, welfare falls even in the absence of rule-of-thumb households. When demand shocks are considered, progressive taxes cannot improve welfare. Increasing tax progression above the Eurozone average is a "beggar-thyself" policy for all specifications.

Keywords: Currency Union, Progressive Taxation, Monetary Policy, Automatic Stabilizers

JEL classification: F41, F44, E2, E3, E52, E62

1 Introduction

When policy makers accepted the Delors plan and thereby agreed to liberalize their countries' capital markets and ultimately join the Eurozone, they gave up the independent monetary policy as a stabilization device. This implies a stronger reliance on other stabilization policies when a country is hit by a country specific shock. One such policy instrument are automatic stabilizers. The large literature analyzing the effectiveness of automatic stabilizers has provided valuable insights into the extent to which they can be relied upon with regard to their stabilizing effects on output and income.¹

What has been less analyzed, however, is the normative question regarding their usefulness. In this paper, we first shed light on this question by employing a New Keynesian DSGE model of a monetary union consisting of two countries with price rigidity a la Calvo (1983). As it turns out that the main mechanisms at play are the same for both the closed and the currency union setting, we start our analysis with a closed economy and then proceed to the eurozone setting. To keep the analysis simple, we use a progressive wage income tax schedule as the sole automatic stabilizer and analyse its welfare implications in the presence of technology and government spending shocks.² As a welfare measure we employ a Lucas-type consumption equivalent (Lucas, 1987) for both intertemporally optimizing (“Ricardian”) households and households that do not optimize in this way but only consume their current disposable income (“rule-of-thumb households”).³

The literature has further shown that the size and effectiveness of automatic stabilizers differ widely across Eurozone members and that this matters for aggregate volatility.⁴ In this paper, we will also employ our two-country model to examine whether these macroeconomic differences

¹See e.g. Auerbach and Feenberg (2000) and Dolls et al. (2012).

²We thus abstract from other well-known automatic stabilizers like government transfers or unemployment benefits. This omission can be partly justified by the findings of e.g. Dolls et al. (2012) who show that the tax system, which is progressive in most countries, is the single most important automatic stabilizer with respect to cushioning proportional income shocks in the EU and the US.

³Colciago et al. (2008) also use a two-country DSGE model to analyse the role of automatic stabilizers in a currency union. However, they do not conduct an explicit welfare analysis.

⁴Dolls et al. (2012) show that “periphery” countries like Greece or Spain generally have relatively modest automatic stabilizers, which absorb only 29 or 28 percent of a proportional income shock, respectively, while “core” countries like Belgium or Germany have relatively strong ones absorbing 53 or 48 percent of the shock, respectively. Mattesini and Rossi (2012) estimate the degree of progressivity of the wage income tax schedule for different euro area countries. They observe substantial cross-country differences, with e.g. Ireland and Portugal at the bottom of the distribution in terms of tax progressivity and countries like Italy and the Netherlands at the top. The authors then show that these differences also matter for aggregate fluctuations: a higher degree of tax progression is e.g. associated with smaller fluctuations of employment and output.

are relevant for the optimal conduct of monetary policy. In particular, we are interested in the welfare effects of progressive taxes when monetary policy is conducted optimally and whether the optimal monetary policy strategy is affected by the presence of tax progressivity.

We find five main results from our exercises: First, when the central bank follows a standard Taylor rule and when only Ricardian households are considered, there are welfare gains from a progressive tax system when productivity shocks hit the economy, but not when government spending shocks drive the business cycle. The reason for this is a strong reduction of consumption volatility in the former and an increase in consumption volatility in the latter case which dominate all other effects on welfare. These other effects are changes in the volatility of hours worked and a reduction of the average level of consumption which is present in all specifications analysed. This latter effect is due to the increased convexity of the marginal cost function which causes higher average inflation and real interest rates and which pushes down average consumption. We further find that these results hold both for members of a currency union and for a closed economy. In a currency union, the beneficial welfare effects for productivity shocks are reduced and the welfare losses under demand shocks are increased, however, as the central bank's welfare enhancing countercyclical stabilization is smaller in the presence of idiosyncratic shocks. The macroeconomic welfare effects of progressive taxes thus crucially depend on the interaction of monetary policy and the tax system.

Second, when rule-of-thumb households are included and the central bank follows a Taylor rule, the first result with respect to the productivity shocks evaporates, at least at the aggregate level and for the Ricardian households. This follows from the interaction of the progressive tax schedule and the rule-of-thumb households' volatile goods demand: the tax schedule implies a smaller volatility in rule-of-thumb households' disposable income and goods demand which significantly boosts these households' welfare. As a consequence, however, aggregate demand rises (falls) less in the face of expansionary (contractionary) productivity shocks resulting in bigger price reductions (increases) and hence greater volatility of the real interest rate and Ricardian households' consumption volatility. Ricardian households' welfare thus falls significantly.

Third, when the central bank adheres to a Ramsey-type optimal policy, the first finding with respect to productivity shocks evaporates too and progressive taxes reduce welfare for both shocks. The optimal monetary policy virtually implies zero average inflation across the

member states of the currency union and an optimal inflation volatility at the country level given the restrictions imposed by the monetary union. There is thus no room for progressive taxes to further reduce inefficient price dispersion in the case of the productivity shock and the microeconomic inefficiencies that result from a progressive tax system dominate. Again, this result holds for both the closed economy and the currency union setting.

Fourth, our simulations show that differences in the progressivity of the tax system across the union members do not affect the design of the optimal monetary policy. The common central bank aims at stabilizing union inflation at zero at all times. National inflation rates fluctuate inversely after shocks hit the economies and share the burden of adjustment equally, irrespective of differences in the national tax systems. We thus confirm the desirability of an easily implementable zero inflation policy also in this special case.

Fifth, when taking account of the observed differences in tax progression across the eurozone, we show that countries with higher tax progression harm themselves and benefit the remaining countries. Increasing the degree of tax progression above your partners' level is thus a beggar-thyself policy.

The paper is structured as follows. In Section 2, we introduce the model framework, followed by a description of the calibration and the welfare measure we employ in Section 3. In Sections 4 and 5, we present the results from the simulation exercises for the standard Taylor rule and the optimal monetary policy, respectively. Section 6 concludes.

2 The Model

The model economy consists of two countries, home (H) and foreign (F), with relative sizes $(1 - n)$ and n , respectively, that form a currency union. As in Galí et al. (2007), each country is populated by Ricardian as well as rule-of-thumb households. Ricardian households have access to financial markets and own the domestic firm sector while rule-of-thumb households are excluded from financial markets and hence use their entire period income for consumption purposes. Households consume a bundle of domestic and foreign goods and supply (homogenous) labor to the firm sector taking the wage rate as given. The firm sector of each country consists of a continuum of monopolistically competitive firms which use labor as the sole production input and set prices in a staggered manner as in Calvo (1983). Monetary policy is set uniformly

for both countries by the union central bank. Fiscal policy, however, is set at the national level. An exogenous stream of government consumption is financed by taxing wages, in a progressive fashion as in Guo and Lansing (1998), and firm profits. Due to symmetry between countries we only refer to the foreign economy when necessary in the following. The foreign variables are then denoted with an asterisk. Furthermore, letters without time index always denote the (non-stochastic) steady state value of the respective variable.

2.1 The Household Sector

Each country is populated by a continuum of households. In each country a fraction of households λ consists of rule-of-thumb households while the rest $(1 - \lambda)$ consists of Ricardian households. Variables related to Ricardian households are denoted with a superscript A (asset-holders) while those related to rule-of-thumb households are denoted with a superscript N (non-asset holders).

2.1.1 Ricardian households

The representative Ricardian household seeks to maximize the lifetime utility given by

$$E_t \sum_{k=0}^{\infty} \beta^k \left\{ \frac{(C_{t+k}^A)^{1-\sigma}}{1-\sigma} - \frac{(N_{t+k}^A)^{1+\varphi}}{1+\varphi} \right\}$$

subject to a sequence of flow budget constraints

$$P_t C_t^A + B_t = R_{t-1} B_{t-1} + (1 - \tau_t^A) W_t N_t^A + (\Pi_t - \Pi) - T_t$$

where C_t^A denotes a consumption index (defined below), P_t the corresponding price index (also defined below), N_t^A hours worked, and W_t the (nominal) wage. Prices and wages are taken as given by the household. B_t is the beginning of period amount of an international bond, R_t is the corresponding (nominal) interest rate. The international bond constitutes a creditor-debtor relationship between home and foreign Ricardian households. Π_t are firm profits (per Ricardian household).⁵ σ determines the degree of relative risk aversion and φ the degree of

⁵Note that in our calibration the steady state value of firm profits is taxed away (see below). Thereby we ensure that consumption levels between Ricardian and rule-of-thumb households are equalized in the steady state. We discuss this assumption in section 4.5.

labor disutility (inverse of the Frisch labor supply elasticity), β is the subjective discount factor. Finally, the household faces a tax rate τ_t on wage income as well as lump-sum taxes T_t .

Following Guo and Lansing (1998), and, more recently, Mattesini and Rossi (2012), we assume that the tax schedule τ_t is given by

$$\tau_t = 1 - \eta \left(\frac{Y_n}{Y_{n,t}} \right)^{\phi_n} \quad (1)$$

where $Y_{n,t} = \frac{W_t N_t}{P_t}$ and where $Y_n = \frac{WN}{P}$ is the steady state level of real wage income. Note that $\eta \in (0, 1]$ determines the level of the tax schedule while $\phi_n \in [0, 1)$ determines the slope. It is easy to show (see Mattesini and Rossi 2012) that the following relationship between the marginal tax rate $\tau_t^m = \frac{\partial(\tau_t Y_{n,t})}{\partial Y_{n,t}}$ and the average tax rate τ_t holds:

$$\tau_t^m = \tau_t + \eta \phi_n \left(\frac{Y_n}{Y_{n,t}} \right)^{\phi_n}.$$

Accordingly, the marginal tax rate is higher than the average tax rate whenever $\phi_n > 0$. In this case the tax schedule will be referred to as “progressive”. When $\phi_n = 0$ the marginal tax rate coincides with the average tax rate and the tax schedule will be referred to as “flat”.

The Ricardian household’s first-order conditions are given by

$$(N_t^A)^{\varphi + \phi_n} = (C_t^A)^{-\sigma} \left(\frac{W_t}{P_t} \right)^{1 - \phi_n} \eta (1 - \phi_n) \left(\frac{WN}{P} \right)^{\phi_n} \quad (2)$$

$$1 = \beta E_t \left\{ \left(\frac{C_{t+1}^A}{C_t^A} \right)^{-\sigma} \frac{P_t}{P_{t+1}} R_t \right\} \quad (3)$$

where the first condition determines the household’s labor supply and where the second condition is a standard consumption Euler equation. We can see from equation (2) that the progressive labor tax mitigates the response of hours worked to a change in the real wage holding consumption constant. Put differently, the labor supply schedule becomes steeper as an increase in hours implies a stronger increase in real wages because an increasing fraction of the gross real wage is taxed away.

Another way at looking at optimality condition (2) is to re-write it in terms of the first best allocation which equates the marginal rate of substitution between consumption and hours

worked to the real wage:⁶

$$\frac{(N_t^A)^\varphi (C_t^A)^\sigma}{\left(\frac{W_t}{P_t}\right)} = \eta \left(\frac{\frac{W_t N_t}{P_t}}{\frac{W N}{P}} \right)^{-\phi_n} = 1 - \tau_t. \quad (4)$$

In the first best allocation, the left hand side equals one and the optimal income tax rate is zero. With a flat tax on wages an efficiency wedge opens up and the marginal rate of substitution is suboptimally low, implying that the household consumes too little given hours worked and the real wage compared to the first best. When taxes are progressive, the average wedge is determined by both the level and the volatility of the real wage income. The wedge falls in the degree of tax progression ϕ_n because the tax rate is a concave function in the fluctuations of the real wage income. The economic intuition is that a rise in income has a weaker effect on the tax rate than a fall in income rendering the average tax rate and thereby the average wedge smaller. The wedge rises in the average level of income because the average tax take rises with income. A priori it is unclear whether tax progression reduces or increases the wedge. It will turn out that the average wedge decreases in all specifications with productivity shocks but only in some for demand shocks so that it may or may not constitute a welfare gain in a stochastic environment.

Further note that progressive taxation also affects the steady state labor supply (and thus aggregate output) according to equation (2). A higher degree of tax progression implies lower labor supply. Since in this paper we are interested in the business cycle properties of tax progression, we eliminate the steady state effect of tax progression through the use of an appropriate employment subsidy for the firm sector when we simulate the model subsequently.⁷ This considerably facilitates the analysis, especially when the degree of tax progression differs between countries (but symmetry in the steady state is still maintained).

⁶We use an employment subsidy that eliminates the steady state distortion of progressive taxes to arrive at this equation, see below.

⁷The subsidy (per unit of labor employed) would correspond to the value of the coefficient ϕ_n . To see this, note that firm optimization implies $\frac{W}{P} = \frac{MPL}{M_p} = \frac{A}{M_p}$ where MPL denotes the marginal product of labor and $M_p \equiv \frac{\epsilon_p}{\epsilon_p - 1}$ is the price markup. With an employment subsidy τ^s , the optimality condition would read $\frac{W}{P}(1 - \tau^s) = \frac{A}{M_p}$ instead. Setting $\tau^s = \phi_n$, it follows that $\frac{W}{P} = \frac{A}{M_p}(1 - \phi_n)^{-1}$ which implies that household labor supply is independent of the value of ϕ_n .

2.1.2 Rule-of-thumb households

Rule-of-thumb households have the same preferences with respect to consumption and hours worked as Ricardian households but lack access to financial markets. The representative rule-of-thumb household's labor supply is thus governed by an equation equivalent to (2) while its consumption expenditures are fully pinned down by its current disposable income:

$$P_t C_t^N = (1 - \tau_t^N) W_t N_t^N. \quad (5)$$

It is important to note that the progressive labor tax has an immediate stabilizing effect on rule-of-thumb households' consumption through dampening the fluctuations of disposable income. Due to the presence of credit constrained households the progressive tax system thus also acts as an automatic stabilizer on the demand side of the economy.

2.1.3 The consumption basket

Both types of households consume an identical consumption aggregate which combines home and foreign consumption baskets according to

$$C_t^A = C_t^N = \left[(1 - \omega^H)^{\frac{1}{\theta}} (C_t^H)^{\frac{\theta-1}{\theta}} + (\omega^H)^{\frac{1}{\theta}} (C_t^F)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{1-\theta}}$$

where ω^H determines the import share of household consumption and θ the elasticity of substitution between home (C_t^H) and foreign (C_t^F) baskets. These baskets are aggregators given by

$$C_t^H = \left[(1 - n)^{-\frac{1}{\epsilon}} \int_n^1 (C_t^H(i))^{\frac{\epsilon-1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon-1}}$$

$$C_t^F = \left[n^{-\frac{1}{\epsilon}} \int_0^n (C_t^F(i))^{\frac{\epsilon-1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon-1}}$$

where $C_t^H(i)$ denotes the good produced by firm $i \in [n, 1]$ located in country H and $C_t^F(i)$ the good produced by firm $i \in [0, n]$ located in country F . The elasticity of substitution between goods i produced within the same country is given by ϵ .

Cost minimization results in standard demand functions for all goods (not shown here for

convenience) and the following price indices for the consumption baskets:

$$\begin{aligned}
P_t &= \left((1 - \omega^H)(P_t^H)^{1-\theta} + \omega^H(P_t^F)^{1-\theta} \right)^{\frac{1}{1-\theta}} \\
P_t^H &= \left((1 - n)^{-1} \int_n^1 P_t^H(i)^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}} \\
P_t^F &= \left(n^{-1} \int_0^n P_t^F(i)^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}}.
\end{aligned}$$

2.2 The Government

2.2.1 Fiscal policy

Fiscal policy is set at the national level. We assume, for simplicity, that the government follows a balanced budget rule. The fiscal authority finances an exogenous stream of government consumption G_t by way of taxing household wage income, by imposing lump-sum taxes on Ricardian households, and by taxing (away) the steady state profits of firms.⁸ Accordingly, the period budget constraint of the government is given by

$$P_t G_t = (1 - \lambda)W_t N_t^A \tau_t^A + \lambda W_t N_t^N \tau_t^N + T_t + \Pi.$$

2.2.2 Monetary policy

Monetary policy is set at the union-level. We consider both Ramsey-optimal monetary policy and a Taylor-type interest rate rule (Taylor 1993). The Taylor-type rule targets a weighted average of home and foreign price inflation and is given by

$$R_t^U = \beta^{-1} \left(\left(\frac{P_t^H}{P_{t-1}^H} \right)^{1-n} \left(\frac{P_t^F}{P_{t-1}^F} \right)^n \right)^{\phi_\pi} \quad (6)$$

where $\phi_\pi > 1$.

⁸ G_t is defined analogously to the private consumption aggregate C_t . Analogous government demand functions for the individual goods i thus apply.

2.3 The Firm Sector

2.3.1 Production

Monopolistically competitive firm i produces the differentiated good $Y_t(i)$ according to

$$Y_t(i) = A_t N_t(i)$$

where $N_t(i)$ is the labor input of firm i and A_t the (stochastic) level of technology common to all firms (within the same country). The production function implies that nominal marginal cost MC_t and real marginal cost RMC_t (defined here in terms of the aggregate C_t^H) are equalized across firms within the same country, i.e.

$$RMC_t(i) = RMC_t = \omega_t \frac{P_t}{P_t^H} A_t^{-1} \quad (7)$$

where the real wage ω_t is defined in terms of the aggregate C_t . As discussed above, the progressive income tax implies a larger real wage increase for any given increase in employment. This in turn raises marginal costs more. Hence, the marginal cost curve, just like the labor supply curve, becomes steeper when taxes are progressive. Below we will see that, the marginal cost curve also becomes more convex with progressive taxes thereby crucially influencing incentives for price setting.

2.3.2 Price setting

Firms set prices in a staggered fashion as in Calvo (1983) taking the demand functions for their good as given. Each period, a randomly drawn fraction of firms θ_p is not able to reset their prices while the remaining fraction $(1 - \theta_p)$ is able to do so. The first-order condition for readjusting firms with respect to the price chosen P_t^{Ho} is standard and given by

$$\sum_{k=0}^{\infty} \theta_p^k E_t \left\{ Q_{t,t+k} \left(\frac{P_t^{Ho}}{P_{t+k}^H} \right)^{-\epsilon-1} Y_{t+k}^H \left[\frac{P_t^{Ho}}{P_{t+k}^H} - \frac{\epsilon}{\epsilon-1} RMC_{t+k} \right] \right\} = 0 \quad (8)$$

$$(9)$$

where $Q_{t,t+k} = \beta E_t \left\{ \left(\frac{C_{t+k}^A}{C_t^A} \right)^{-\sigma} \frac{P_t}{P_{t+k}} \right\}$ is the Ricardian household's stochastic discount factor⁹ and $Y_t^H = \left[(1-n)^{-\frac{1}{\epsilon}} \int_n^1 (Y_t^H(i))^{\frac{\epsilon-1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon-1}}$ home gross domestic product (GDP).

2.4 Equilibrium and Aggregation

Equilibrium in the home labor market implies

$$N_t = \int_n^1 N_t(i) di$$

where $N_t = \lambda N_t^A + (1-\lambda)N_t^N$ is aggregate labor supply.

The home goods market is in equilibrium when supply equals demand for all goods $i \in [n, 1]$. Demand for good i is determined by home and foreign household and government demand and is given by

$$Y_t^H(i) = \left(\frac{P_t^H(i)}{P_t^H} \right)^{-\epsilon} \left((1-\omega^H) \left(\frac{P_t^H}{P_t} \right)^{-\theta} (C_t + G_t) + \omega^F \frac{n}{1-n} \left(\frac{P_t^{H*}}{P_t^*} \right)^{-\theta} (C_t^* + G_t^*) \right)$$

where ω^F determines the foreign country's import share.¹⁰ $C_t = \lambda C_t^A + (1-\lambda)C_t^N$ is aggregate household consumption.

In turn, home GDP is obtained by aggregating demand across all home firms i and can be expressed as

$$Y_t^H = (1-\omega^H) \left(1-\omega^H + \omega^H S_t^{1-\theta} \right)^{\frac{\theta}{1-\theta}} (C_t + G_t) + \omega^F \frac{n}{1-n} \left((1-\omega^F) S_t^{1-\theta} + \omega^F \right)^{\frac{\theta}{1-\theta}} (C_t^* + G_t^*) \quad (10)$$

where $S_t = \frac{P_t^F}{P_t^H}$ are the terms of trade.

The home aggregate supply side is summarized by

$$Y_t^H = s_t^{-1} A_t N_t \quad (11)$$

⁹Because firms are owned by Ricardian households they also use the same discount factor.

¹⁰Notice that the law of one price for individual goods and the existence of a common currency imply that $P_t^{H*} = P_t^H$, i.e. the price of the home goods basket in the foreign economy is equal to that in the home economy.

where $s_t \geq 1$ is given by the difference equation (see Schmitt-Grohé and Uribe 2006)

$$s_t = (1 - \theta_p)(\widetilde{p}_t^H)^{-\epsilon_p} + \theta_p(1 + \pi_t^H)^{\epsilon_p} s_{t-1}$$

with $\widetilde{p}_t^H \equiv \frac{P_t^{H_o}}{P_t^H}$. The variable s_t represents a resource cost induced by inefficient price dispersion across home firms if the value exceeds one. As these resource costs are related to the volatility of domestic inflation (see e.g. Woodford (2003) for the relationship between price dispersion and inflation), a reduction of this volatility has an effect like a permanent increase in productivity.

Under the Calvo mechanism the evolution of aggregate domestic prices is given by the law of motion

$$1 = \theta_p(1 + \pi_t^H)^{-1+\epsilon} + (1 - \theta_p)\widetilde{p}_t^H^{1-\epsilon}.$$

This last equation could be combined with the price-setting first order condition (8) to obtain the economy's Phillips curve. Progressive taxes, due to the stronger impact of an increase in employment on marginal costs discussed above, lead to a steeper Phillips curve. That is, a given positive (negative) deviation of output from its flexible price equivalent leads to a larger inflationary (deflationary) response. This was first shown by Mattesini and Rossi (2012).¹¹

Finally, the equilibrium real marginal cost function is important for understanding aggregate price dynamics. For our benchmark with correlated shocks (denoted "closed economy" in the calibration below) without rule-of-thumb households this can be derived by combining the real marginal cost function (7) with first order condition (2) and the aggregate demand and supply relations (10) and (11):

$$RMC_t = (s_t Y_t^H)^{\left(\frac{\varphi+\phi_n}{1-\phi_n}\right)} \left(\frac{Y_t^H}{1-\omega^H} - G_t - \frac{\omega^F}{1-\omega^H} \frac{n}{1-n} (C_t^* + G_t^*) \right)^{\frac{\sigma}{1-\phi_n}} A_t^{-\frac{1+\varphi}{1-\phi_n}} \text{const.} \quad (12)$$

The progressive tax system thus increases the degree of convexity of the marginal cost function in output and productivity. This will turn out to have implications for both the volatility and average level of prices as we will discuss in section 4.

¹¹Mattesini and Rossi (2012) derive the Phillips curve for the case of tax progression in a linearized model. We do not illustrate the Phillips curve as we are interested in a second order approximation of the model equations.

3 Calibration, Simulation, and Welfare Measure

The model is solved using Dynare++ (Kameník 2011). In order to avoid spurious welfare reversals we employ a second-order approximation of the equilibrium conditions (see Kim and Kim, 2003).¹² The exogenous processes considered are technology and government spending shocks.

3.1 Calibration

The calibration is based on the assumption that the relevant time period is one quarter. When not stated otherwise, the parameters of home and foreign take the same values. The baseline parameterization employed looks as follows: the household's subjective discount factor β is set to 0.99 which is consistent with a steady state value of the real interest rate of approximately 4 percent. The values $\sigma = 1$ (log utility of consumption) and $\varphi = 1$ (unitary Frisch elasticity of labor supply) for the household's utility function are standard in the literature. As in Galí et al. (2007) we set the share of rule-of-thumb households in the population to 50 percent ($\lambda = 0.5$). This value is within the range of estimated values found in the literature (see Mankiw 2000). The elasticity of substitution between goods produced within the same country ϵ takes a value of 6, implying a steady state gross price markup of size 1.2. The degree of price rigidity is given by $\theta_p = 2/3$, i.e. the average duration of prices is assumed to be 3 quarters. These last two parameterizations are commonly used in the business cycle literature (see e.g. Galí 2008).

Turning to the fiscal and monetary policy parameters, we assume that $\eta = 0.84375$ which amounts to a steady state average tax rate on wage income of roughly 16 percent. In our model economy this value is consistent with a government spending share of 25 percent in GDP if steady state profit income is entirely taxed away by the government. The tax progressivity parameter ϕ_n either takes the value 0 (flat tax) or 0.34 (the GDP-weighted average observed for the EA-12, based on the computations of Mattesini and Rossi 2012) for both countries (symmetric case) or the value 0.26 (bottom 50% of EA-12) for one country and 0.42 (top 50% of EA-12) for the other country (asymmetric case). For the Taylor inflation coefficient ϕ_π we

¹²The current version of Dynare (4.4.3) only allows a first order approximation of the equilibrium conditions when using the optimal policy command. We therefore use Dynare++ for all simulations. However, impulse responses for the specifications with Taylor rules were generated by Dynare 4.4.3, we checked and verified that this was inconsequential for results.

choose the standard value 1.5.¹³

Turning to the open economy parameters, the size of the foreign economy n is 0.5, i.e. we consider two equally large economies. In a robustness analysis presented in section 4.4 we also discuss results for the small open economy case. The elasticity of substitution between home and foreign consumption baskets is assumed to be $\theta = 2$ as in Obstfeld and Rogoff (2005) and Nakamura and Steinsson (2014). Finally, for the home bias we set $\omega^H = 0.2$ which implies $\omega^F = 0.2$ to guarantee balanced trade in the steady state.

3.2 Exogenous Processes

The exogenous processes considered in the following are technology and government spending shocks. The shocks are specified as AR(1) processes, i.e. $a_t = \rho_a a_{t-1} + \epsilon_{a,t}$ where $a_t = \ln(A_t)$ and $g_t = \rho_g g_{t-1} + \epsilon_{g,t}$ where $g_t = \ln\left(\frac{G_t}{G}\right)$. The autocorrelation coefficient ρ_a takes the value 0.95, ρ_g takes the value 0.66. The standard deviations of the innovations ϵ are chosen so as to match the observed volatility of GDP and government purchases in the Euro area. The values are 0.00365 (closed economy) and 0.00343 (open economy) for technology shocks and 0.0062 (closed and open economy) for government spending shocks. For each shock type we consider both perfectly correlated shocks across countries as well as uncorrelated shocks. The case of perfectly correlated shocks can be interpreted as the closed economy benchmark of our model. For each model specification, we ran 5 simulations with 200000 periods each.

3.3 Welfare Measure

For each simulated model path we compute home, foreign, and union-wide welfare as well as the welfare of Ricardian and rule-of-thumb households in each country. Our welfare measure is expected household lifetime utility (appropriately weighted) which is converted into a convenient consumption loss equivalent in the spirit of Lucas (1987). More precisely, for each combination of fiscal and monetary policy rules, we solve for the variable ξ^{rule} of the following equation:

$$E_t \sum_{k=0}^{\infty} \beta^k U(C(1 - \xi^{rule}), N) = E_t \sum_{k=0}^{\infty} \beta^k U(C_{t+k}, N_{t+k}).$$

¹³Estimating a reaction function for the ECB, Hayo and Hofmann (2006) find a Taylor inflation coefficient of roughly 1.5 for expected inflation.

$\xi^{rule} > 0$ represents the percentage reduction in average consumption in the non-stochastic steady state that makes households indifferent between living in this deterministic state of the world (with reduced average consumption) and the stochastic state of the world under the respective monetary and fiscal policy combination. For our model parametrization, this consumption equivalent is given by

$$\xi^{rule} = 100 (1 - \exp((W^{rule} - W)(1 - \beta)))$$

where W^{rule} is average welfare computed under one particular fiscal and monetary policy combination in a stochastic environment and W is welfare in the non-stochastic steady state.¹⁴

4 Progressive Taxation and Welfare under a Taylor Rule

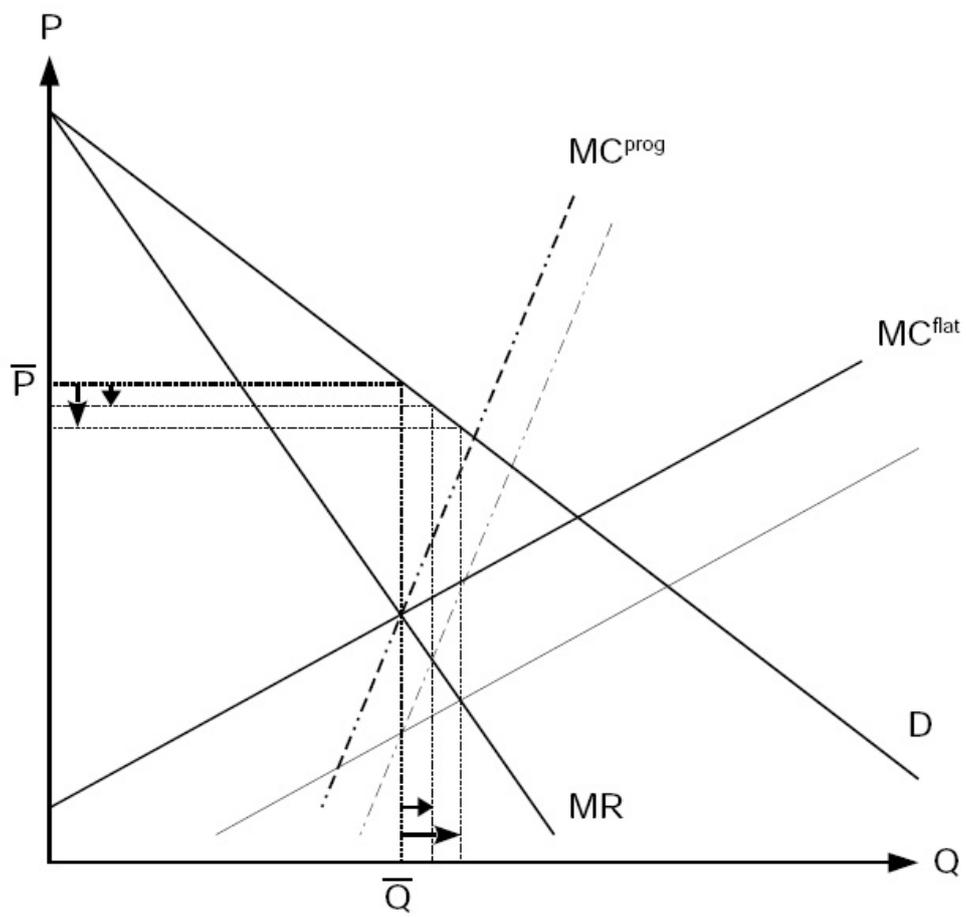
In the following, we assume that the common central bank follows a Taylor-type interest rate rule with a standard inflation coefficient of 1.5 and analyse the business cycle and welfare effects of progressive taxation. To build intuition, we sketch the macroeconomic effects of tax progression in a static closed economy setup first — taking the perspective of a representative monopolistic firm — before considering the fully-fledged dynamic model economy.

4.1 Intuition: Macroeconomic Effects of Progressive Taxation

How does the progressive tax system affect the cyclical behaviour of the most closely observed macroeconomic variables inflation, real GDP, and employment? To answer this question, let us consider the pricing and production decision of an arbitrary monopolistically competitive firm that has the possibility to adjust its price in the current period. Figure 1 first sketches, in a static setup, the (optimal) response of the firm to technology shocks and the resulting fluctuations of prices and real activity for a flat and a progressive tax system. Figure 2 does the same for a government spending shock. Two types of effects need to be differentiated: First, the influence of progressive taxes on the volatility of the relevant variables, and, second, the influence of tax progression on average prices. We will show that the volatility effects are different for the two shocks while the level effects are the same.

¹⁴See also Benes and Kumhof (2011) for a recent application.

Figure 1: Technology shocks and volatility of output and prices



As can be seen in Figure 1 (and as described above), progressive taxes imply, relative to flat taxes, that the firm's marginal cost curve is steeper. Holding demand D constant¹⁵, given fluctuations in technology will thus imply smaller movements of the marginal cost schedule MC along the marginal revenue schedule MR (the bold MC schedules in the figure apply when technology is at its steady state value).¹⁶ That is, the firm's output will fluctuate less around the steady state output \bar{Q} when the tax system is progressive. These smaller output fluctuations then translate into smaller fluctuations of the firm's price around the steady state price \bar{P} . Aggregating over all firms, we can conclude that progressive taxes dampen fluctuations of the overall price level (i.e. the volatility of inflation is reduced) and of real GDP when technology shocks hit the economy.

At the same time, the greater degree of convexity of the marginal cost curve causes price decreases in the presence of positive productivity shocks to be larger than the price decreases in the presence of negative productivity shocks. This implies that the average price level rises. The intuition is the following: When productivity rises, marginal costs fall at the current level of output and firms are induced to reduce prices to boost demand in order to restore the optimal markup. The opposite happens when a negative productivity shock hits the economy. In the former case, the real wage will rise and with it - more than proportionally - the marginal tax rate and marginal costs. In the latter case marginal costs will rise less than proportionally because of the progressive tax system. Price declines will thus be smaller than price increase in the presence of productivity shocks and average prices will thus be higher. This effect will matter in the dynamic setting discussed below where the interaction of inflation dynamics and monetary policy matter for equilibrium determination.

Finally, due to the dampening effect on output, progressive taxes increase the fluctuations of employment in the presence of technology shocks.¹⁷

Figure 2 sketches the firm's (optimal) response to government spending shocks, or more

¹⁵This assumption seems plausible when rule-of-thumb households are absent. Note that in any given period, Ricardian households consume a fraction of their total expected lifetime resources. A temporary technology shock that changes their lifetime resources should thus only have a small effect on their current period consumption demand. In contrast, rule-of-thumb households base their consumption on current period resources. Their consumption demand should thus be significantly affected by technology shocks.

¹⁶For the sake of clarity, Figure 1 only shows the realization of a positive technology shock.

¹⁷This is due to the well-known fact that in the presence of technology shocks output and employment move inversely when prices are sticky. Progressive taxes imply a smaller increase (decrease) in output after a positive (negative) technology shock and thus a larger decline (increase) in employment.

generally, demand shocks.¹⁸ We see that for given marginal cost schedules, fluctuations in demand imply smaller deviations of output from its steady state value when the marginal cost curve is steeper, i.e. when taxes are progressive. The figure also shows that as a consequence, however, fluctuations of the optimally chosen price around its steady state value are larger when taxes are progressive. Aggregating over all firms, we infer that progressive taxes reduce the volatility of real GDP, relative to flat taxes, while increasing the volatility of inflation when demand shocks are present.

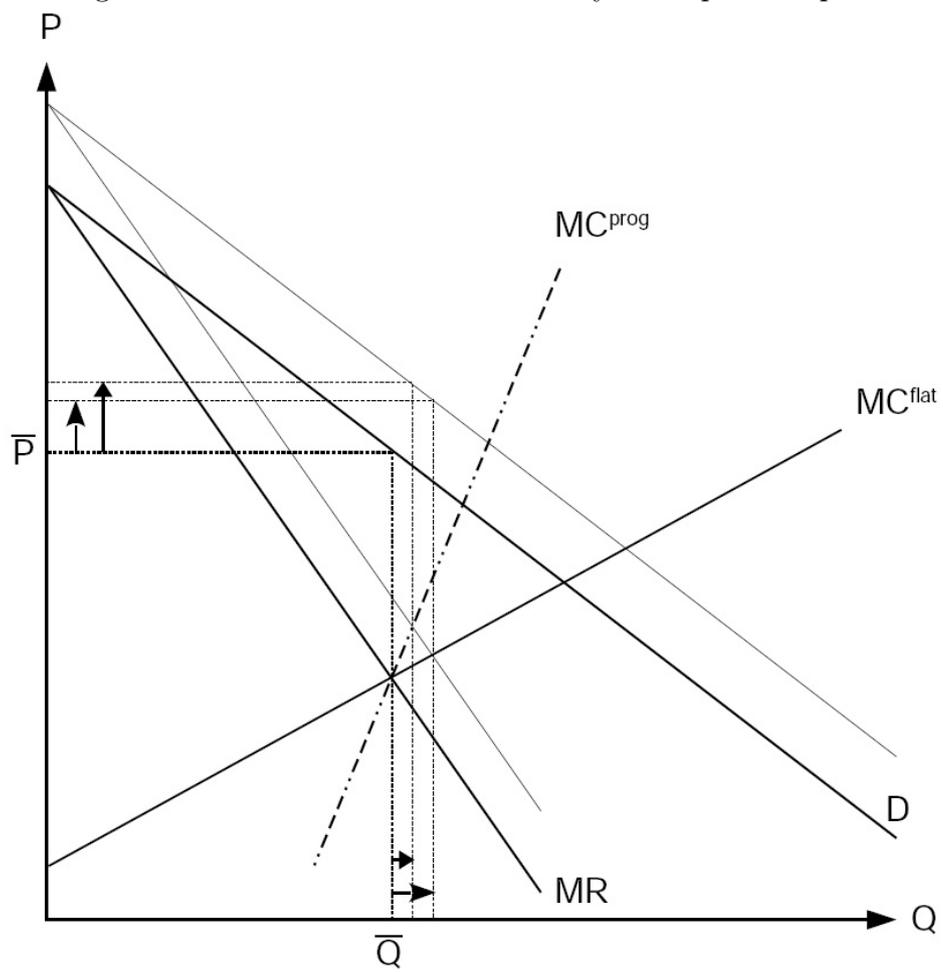
The convexity of the marginal cost schedule implies a higher average price level for demand shocks too. The shifts of the marginal revenue curve along the marginal cost curve imply price increases in response to positive demand shocks that are larger than the price decreases in response to demand reductions. The intuition for this is analogous to the case of productivity shocks. This average price level effect, again, will matter in the dynamic setting discussed below.

4.2 Progressive Taxation and Technology Shocks

Let us now turn to the fully-fledged dynamic model. Table 1 presents business cycle statistics and the welfare effects of the simulated model when technology shocks are the only type of disturbance. In the first column, results are shown for a specification where the shocks are assumed to be perfectly correlated across countries. We dub this a "closed economy" scenario as the terms of trade do not move at all and the net asset position does not change here. We did not remove domestic consumption of foreign goods here as we want to leave the specifications as close as possible to one another. Column two shows results for a closed economy where, in addition, rule-of-thumb households are included. Column 3 shows results for the currency union scenario where shocks are uncorrelated across countries and where the degree of tax progression is symmetric ($\phi_n = 0.34$ for both countries), in column 4 the tax progression is asymmetric ($\phi_n = 0.42$ for Home and $\phi_n = 0.24$ for Foreign). The table presents the percentage change of the welfare losses, ξ , the standard deviations of inflation, GDP, consumption and employment and the Home average aggregate levels of consumption and employment, compared to the flat-tax benchmark. A negative entry thus indicates a reduction in the respective variable. Figure 3

¹⁸Figure 2 shows the realization of a positive government spending shock.

Figure 2: Demand shocks and volatility of output and prices



shows impulse responses for an expansionary productivity shock for the four specifications.

4.2.1 Closed economy

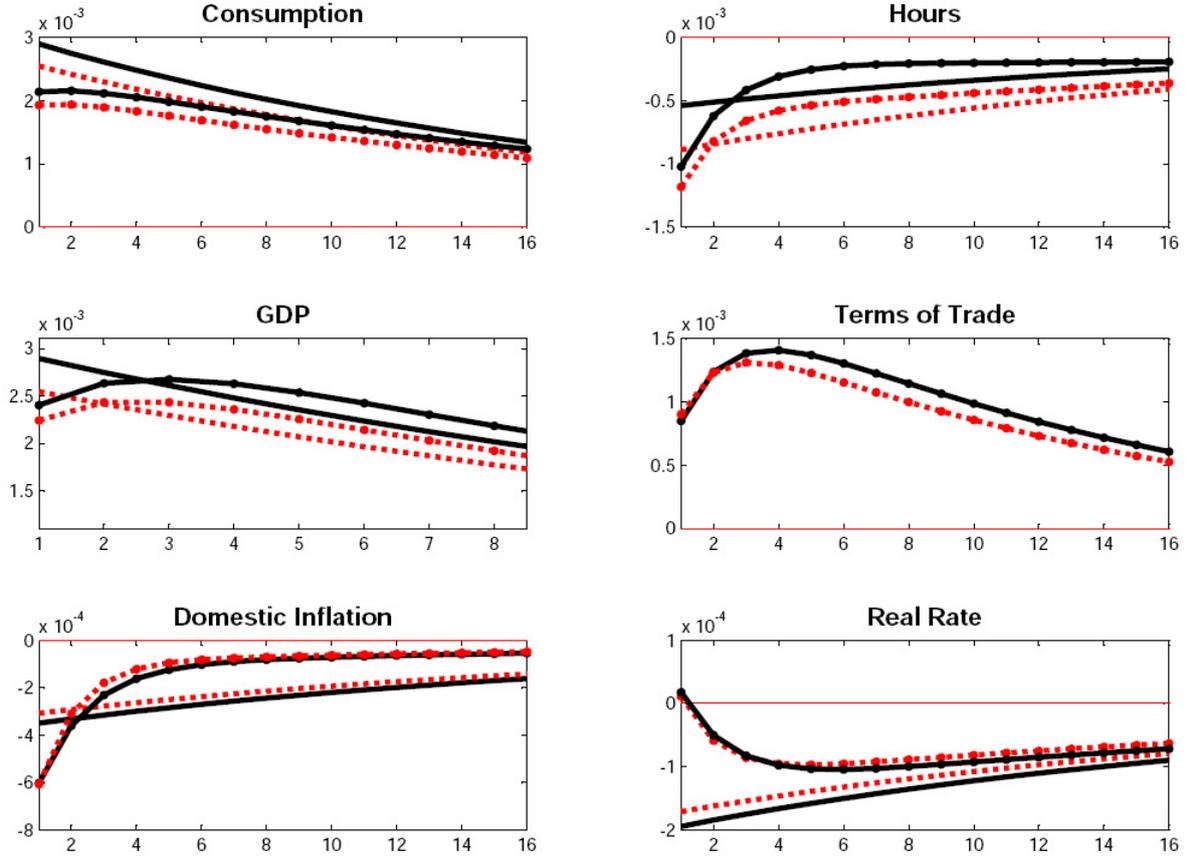
As can be seen in Table 1, welfare rises when the progressive tax is introduced in the closed economy, the consumption equivalent falls by 14.3 percent. To understand this result, we first look at figure 3 which provides important insights and complements the discussion in the static model. An expansionary productivity shock causes an increase in potential output and a fall in prices. This induces the central bank to lower the interest rate (not shown) and thereby the real rate to boost aggregate demand as it follows a Taylor-type rule. But this response will not be aggressive enough to raise consumption demand up to the point where the gap is closed and prices are perfectly stabilized. Hence, those firms that can adjust their prices will reduce them. Lastly, hours fall, which is a typical property in New Keynesian models.

Table 1: Moments and welfare losses with technology shocks

	Closed economy		Currency Union	
	<i>w/o RoT</i>	<i>w RoT</i>	<i>symm.</i>	<i>asymm.</i>
ξ^H	-14.3	+15.7	-6.0	-2.0
ξ^F				-10.0
ξ^A		+32.0		
ξ^N		-29.0		
$\sigma(\pi^H)$	-12.1	+4.4	-8.2	-3.3
$\sigma(\pi^F)$				-8.2
$\sigma(Y^H)$	-12.1	-12.1	-10.9	-13.1
$\sigma(Y^F)$				-8.5
$\sigma(C^H)$	-12.1	-12.1	-11.3	-13.4
$\sigma(C^F)$				-9.0
$\sigma(N^H)$	+64.0	+63.5	+42.7	+52.8
$\sigma(N^F)$				+32.4
\bar{C}	-0.0004	-0.001	-0.0002	-0.0004
\bar{N}	+0.0002	+0.001	+0.0006	+0.0007

Notes: Results are changes compared to the flat-tax benchmark in percent.

Figure 3: Responses to Positive Productivity Shock - Closed Economy and Currency Union



Note: Black solid (red dotted) lines indicate flat (progressive) taxes; circles (no circles) indicate currency union (closed economy) setting.

As noted above, with a progressive income tax, the household labor supply curve and thus firms' marginal cost curves become steeper. It has been shown in the static setup that this implies that the positive productivity shock leads to a smaller decrease in marginal costs and therefore also to smaller price decreases by those firms that have the ability to adjust their prices in the current period. The central bank then reduces the policy rate and the real rate by less so that consumption and output increase more while the reduction in hours worked rises. All other things equal, the deflationary impact of the shock is thus lower while the increase in output and consumption is dampened. This is confirmed in figure 3.

More generally, i.e. taking account of an entire history of positive and negative shocks to productivity, the volatilities of inflation, output and consumption are smaller and the volatility of hours rises when taxes are progressive as can be seen in Table 1. The standard deviation of domestic price inflation, output and consumption falls by about 12 percent each while the standard deviation of hours rises by 64 percent.

In the last two rows of Table 1, the changes in the average level of consumption and hours worked are shown. Consumption falls a little bit by 0.0004 percent while hours increase by 0.0002 percent. This is related to the effects of progressive taxes on the curvature of the real marginal cost function and its implications on the average inflation rate and real rate of interest. As shown above, given productivity, the marginal cost function (12) doesn't only become steeper in output, it also becomes more convex, i.e. an increase in labor input needed to produce an additional unit of output incurs increasing marginal effects on real wages when taxes are progressive. This implies that an increase in prices in response to declining productivity will be greater than a decrease in prices in response to an increase in productivity. The net effect is that prices will be set higher on average and the average inflation rate rises. We denote this as the *curvature effect* of progressive taxes.

The higher average inflation rates, in turn, result in higher average real rates as the central bank follows the Taylor type rule, and a lower average consumption level.¹⁹ This lower average consumption level increases the incentive to work more hours. Hence average hours worked increase.²⁰ increases the incentive to work more hours. Hence average hours worked increase.²¹

The aggregate effect of progressive taxes on welfare is determined by both the effects on the volatility and the levels of consumption and hours. The level effects and the increased volatility of hours reduce welfare but these effects are dominated by the reduction in consumption volatility. The consumption equivalent falls by 14.3 percent in the closed economy benchmark model. Tax progression thus causes a reduction in the welfare loss that is related to the stochastic environment that is equivalent to 14 percent of steady state consumption. Interestingly, the

¹⁹The level of consumption in any period of time can be computed by solving the consumption Euler equation forward. This results in an equation that relates current consumption to the entire history of future real interest rates which, taken together, can be interpreted as a long-term real interest rate. When this long-term real interest rate rises, consumption falls.

²⁰A further effect of progressive taxes in our model is a direct consequence of the assumed concavity of the average tax schedule. In the presence of (real) wage income volatility, a concave average tax schedule will reduce the household's average wage income tax rate (relative to a flat tax) since the additional tax burden resulting from above-average income realizations is smaller than the tax relief due to below-average realizations. All other things equal, the progressive tax thus reduces the average tax distortion when wage income is stochastic and thus further increases the incentive to work. However, this effect is negligible in our model. Our results do not change when using a linear progressive tax schedule instead.

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mechanism behind this result looks similar to the traditional Keynesian macroeconomic motivation of progressive taxes in that aggregate demand would be stabilized by stabilizing disposable income. Here, however, it is not the stabilization of disposable income that causes consumption and aggregate demand to be stabilized but the slope of the marginal cost function that changes the average inflation rate and the real rate of interest.

Interestingly, the increased efficiency that is related to the smaller wedge between the marginal rate of substitution and the real wage is associated with a lower level consumption and a higher level of hours worked. This suggests, that the progressive tax provides, at best, a second best improvement in welfare. We will see below that, indeed an optimal monetary policy stance will improve welfare even more and render tax progression useless for that purpose.

But first we look at the role of rule-of-thumb households and thereby introduce the more traditional Keynesian channel of disposable income stabilization just mentioned. We will see this indeed improves welfare for rule of thumb households remarkably but we will also see that the above mechanisms that improved welfare for Ricardians breaks down and that their welfare therefore falls.

4.2.2 Rule-of-thumb households

As can be seen in Table 1, once rule-of-thumb households are considered, the welfare gains from progressive taxes no longer exist at the aggregate level, the consumption loss equivalent rises by 15.7 percent. This result is driven by the influence of the progressive taxes on rule-of-thumb households' consumption demand and thereby aggregate demand: The tax progression significantly reduces the volatility in disposable income and in consumption of these households and thereby dampens aggregate demand fluctuations and increases the inflation volatility. The central bank, in turn, adjusts the real rate by more and causes a greater volatility in the Ricardian household's consumption. The rule-of-thumb household's consumption volatility thus falls while the Ricardian household's consumption volatility increases. At the same time, the volatility of hours is zero for rule-of-thumb households, no matter how progressive the tax system is²² as income and substitution effects cancel for the log utility case that we consider here. The Ricardian household, in contrast, suffers from a higher employment volatility when progressive taxes are

²²Only lump-sum taxes would result in changes in hours over the cycle but in our model set-up we abstract from them for rule-of-thumb households.

introduced like in the benchmark specification without rule-of-thumb households. And, because the effects on average inflation and consumption demand are small here too, the volatility effects again dominate the welfare effects of tax progression: The Ricardian household's consumption equivalent rises by 32 percent while the rule-of-thumb household's welfare rise is equivalent to 29 percent of his steady state consumption. We thus observe a huge distributional effect in favor of rule-of-thumb households.²³

It remains to be noted that the above result of a negative net welfare is due, to some extent, to the assumed identical consumption and employment levels in the deterministic steady state. When we would, alternatively, increase the Ricardian household's steady state consumption level relative to the rule-of-thumb household's consumption, the redistribution might well end up with an aggregate welfare gain as the Ricardian's welfare losses induced by higher volatility might hurt less at a higher average consumption level while the rule-of-thumb household's welfare gains from lower volatility might increase welfare more at a lower average consumption level.

After having discussed the effects of progressive taxes in a closed economy, we now turn to the currency union setting. We will see that the main mechanisms are still at play and welfare increases but that these gains are smaller than in the closed economy.

4.2.3 Currency union

In the currency union setting, Home and Foreign are hit by shocks that are uncorrelated to one another. Results are shown in column 3 of Table 1 and impulse responses in Figure 3. The main difference compared to the closed economy results from the different reaction by the central bank to the shocks. As a typical shock will hit only one of the economies and as their respective inflation rates are only weighted according to their relative size in the currency union, the central bank's reaction to the shock is muted compared to the closed economy setting (it even rises slightly in the shock period). The deflationary impact of an expansionary productivity shock is thus followed by a smaller reduction of the real rate and a smaller increase in consumption. Overall, the volatility of consumption is significantly lower than in the closed economy even without progressive taxes. At the same time, output is stabilized to a smaller

²³In our calibration both types of households are of equal size. Whether increasing the fraction of rule-of-thumb households would result in an aggregate welfare gain cannot be verified as the model becomes indeterminate once we reduce the fraction of Ricardian households far below the 50 percent threshold.

extent than consumption as the terms of trade depreciate and net exports increase in the presence of positive productivity shocks and vice versa for negative shocks, thereby moving aggregate demand in the same respective directions as consumption. As prices adjust only in a staggered fashion, the terms of trade depreciate for several quarters after a positive shock causing output to increase in a hump shaped manner. This causes employment to rapidly return towards the initial level after a sharp initial drop. The main difference between the reaction of hours in the closed economy and the currency union setting is therefore the time path, the aggregate volatility is only slightly higher in the currency union.

When progressive taxes are introduced, the central bank's reaction is muted when compared to the closed economy setting. The reason is, again, that the smaller weight in the central bank's Taylor rule implies a smaller impact of a tax change. The percentage reduction in the volatilities of the variables reported in column 3 are thus smaller and the welfare impact is smaller. However, the consumption equivalent still falls by 6 percent. The progressive tax system thus raises welfare also in a currency union.

This result may appear surprising as one could have expected the benefits of a progressive tax system to be the larger the less correlated business cycles are in a currency union and that such a system could have offset, to some extent, the lower stabilization due to the lack of an independent monetary policy. However, it turns out that the effectiveness of a progressive tax system depends on its interaction with monetary policy and that the gains from it are relatively modest in a currency union for productivity shocks and the assumed Taylor type rule.

The last column of Table 1 shows that this important result also holds for the asymmetric case where the Home tax progression parameter is increased to 0.42 while it is reduced in to 0.26 for the foreign economy thereby mimicking the observed differences in tax progression across the eurozone. The welfare losses are almost identical at the aggregate eurozone level for asymmetric and symmetric tax progression parameters. The asymmetry observed in European income tax systems thus does not incur any further costs to the average European consumers, the consumption equivalent falls by 6 percent on average. However, the region with the higher tax progression harms itself slightly while its neighbor benefits. The reason for this is a positive externality of tackling one's own volatility more aggressively the benefits of which are not internalized: By reducing the effect on aggregate inflation volatility of a domestic productivity

shock more strongly, the more progressive tax incurs a weaker reaction of the common central bank to such a domestic shock. This implies a smaller welfare reducing spillover effect for the other region while the home economy suffers from less support from the central bank.

4.3 Progressive Taxation and Government Spending Shocks

Table 2 shows the results when government spending shocks are the only disturbance in the economy for the same specifications as above. We see that in this case, there is no specification in which welfare rises.

Table 2: Moments and welfare losses with spending shocks

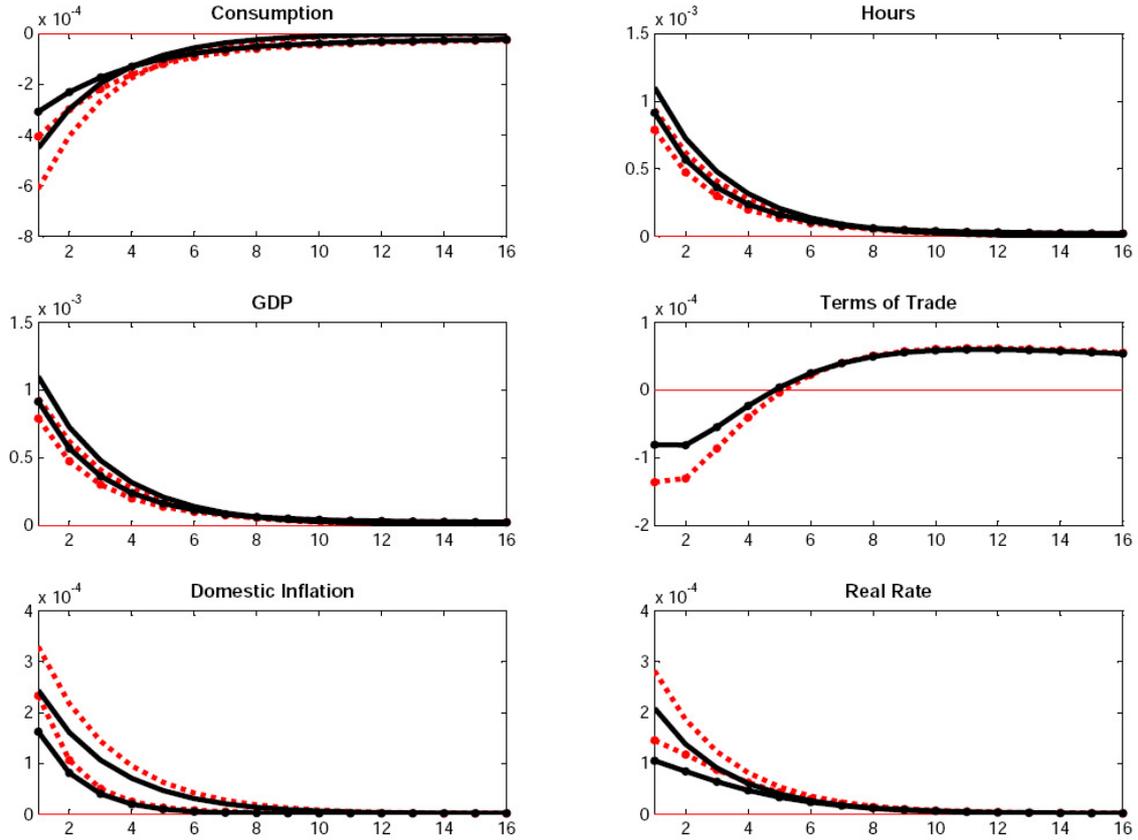
	Closed economy		Currency Union	
	<i>w/o RoT</i>	<i>w RoT</i>	<i>symm.</i>	<i>asymm.</i>
ξ^H	+20.2	+40.7	+14.4	+16.6
ξ^F				+12.7
ξ^A		+53.0		
ξ^N		+10.0		
$\sigma(\pi^H)$	+35.3	+31.0	+37.6	+42.7
$\sigma(\pi^F)$				+33.4
$\sigma(Y^H)$	-14.5	-17.3	-14.4	-18.0
$\sigma(Y^F)$				-10.8
$\sigma(C^H)$	+35.3	+239.3	+28.4	+32.5
$\sigma(C^F)$				+28.4
$\sigma(N^H)$	-14.5	-17.3	-14.4	-18.0
$\sigma(N^F)$				-10.8
\bar{C}	-0.00026	-0.001	-0.0002	-0.0002
\bar{N}	+0.00004	+0.001	+0.00001	+0.00002

Notes: Results are changes compared to the flat-tax benchmark in percent.

4.3.1 Closed economy

To understand this result for the closed economy we first look at Figure 4 which displays impulse response functions to an expansionary spending shock. The shock increases aggregate demand and thus hours worked. This additional labor demand incurs an increase in marginal

Figure 4: Responses to Positive Spending Shock - Closed Economy and Currency Union



Note: Black solid (red dotted) lines indicate flat (progressive) taxes; circles (no circles) indicate currency union (closed economy) setting.

costs, inflation and the real rate of interest which induces a reduction in private consumption. Over the cycle, this volatility in consumption and hours clearly reduces welfare compared to the deterministic steady state.

With a progressive tax system, the steeper marginal cost curve implies for a given increase in demand by the government an even larger increase in marginal costs and consequently stronger inflationary pressure and a higher real interest rate and more crowding-out of private consumption. With a smaller increase in output, hours rise less. Over the cycle, this implies that a lower volatility of hours is traded off against a higher volatility of consumption. At the same time, the same curvature effects of the progressive tax system on the marginal cost function imply a higher average inflation rate and lower consumption level. The lower average consumption level increase the incentive to work more hours implying more hours worked on average. The two level effects and the increased volatility of consumption thus dominate the lower volatility of hours and cause aggregate welfare to fall. Hence, as under productivity

shocks, the welfare effects are mainly driven by the effect of progressive taxes on the volatility of consumption.

4.3.2 Rule-of-thumb households

When the rule-of-thumb household is added, the inflationary pressure induced by an expansionary government spending shock can only be countered by the central bank by raising the real interest rate and thereby lowering the Ricardian household's consumption. In contrast, the rule-of-thumb household does not react to a higher real rate. Instead, it reacts to the higher income he receives because of the increase in labor demand and real wages and therefore increases his consumption. Demand is thus reduced to a lower extent for a given change in real rates, inflation rises more and the real rate needs to be increased more too. The Ricardian thus needs to bear a bigger burden of the adjustment and sees his consumption fall by more than in the scenario without the rule-of-thumb household. His consumption volatility rises. Furthermore, as the rule-of-thumb household's hours are constant over the cycle, the Ricardian's hours also fluctuate more compared to the scenario without rule-of-thumbers.

The progressive tax system reduces the increase in the rule-of-thumb household's demand after the shock and thereby reduces the inflationary pressure, but this effect is more than offset by the effects of the steeper and more convex marginal cost curve. The central bank needs to raise the real rate more to achieve more crowding-out of the Ricardian's consumption. His consumption volatility thus rises and his welfare falls. But also the rule-of-thumb household suffers from lower welfare as the reduction of his consumption volatility is not sufficient to offset his reduced average consumption level.

4.3.3 Currency union

In the open economy, like under productivity shocks, the central bank's reaction to inflationary or deflationary pressure due to home government spending shocks is muted when compared to the closed economy because the home inflation rate has a smaller weight in the Taylor rule. Consumption therefore is less volatile and the respective changes in the terms of trade reduce the volatility of hours. When progressive taxes are introduced, the inflationary and deflationary pressures increase here too due to the steeper real marginal cost function. This, in turn, leads to stronger consumption volatility and a reduction in the volatility of hours. The

average consumption level is reduced here too while hours rise, just as in the closed economy, but these changes are slightly smaller which is due to the flatter Phillips-curve in the open economy which mainly results from price competition from abroad which reduces the optimal price changes. The net effect for welfare is a somewhat smaller increase of the consumption equivalent compared to the closed economy.

We can thus conclude that welfare always falls in this setting when demand shocks hit the economy.

4.4 Robustness

We report results of two robustness checks, for the degree of risk aversion in consumption, σ , and the size of the home economy, n . Results are robust to both of these parameters.²⁴ In the following we briefly explain the intuition for the result for the relative size of the economy.

The positive welfare effects of the progressive tax schedule for the productivity shock scenario were smaller in the currency union compared to the closed economy in our two-country setting. However, a priori it is not clear whether this still holds for a small open economy that is part of a currency union. The interaction between the tax schedule and the response of the central bank mattered for the effects of tax progression in the above specifications, but the interest rate response of the central bank will be negligible because the small open economy's weight is negligible in a currency union.

It turns out that the result is indeed robust to that specification, even with negligible changes of the nominal rate of interest in response to domestic productivity shocks. This is mainly due to two effects. First, the long-run real rate of interest also falls in the small open economy so that consumption also rises when productivity increases. However, this is not due to a change in the nominal rate but almost entirely related to the path of inflation. After the initial deflationary shock, prices need to return to their old level because the purchasing power parity holds in the long-run and because the foreign price level is unchanged. Hence, after the initial deflation, prices increase after a few quarters and the real rate declines. But as the short-run real interest rate rises due to the deflationary impact of the shock, the immediate consumption increase is muted when compared to the currency union scenario above. And just

²⁴Welfare results and impulse responses are available from the authors upon request. They are not shown here because they do not add much to the discussion.

like in the scenarios discussed above, the progressive tax schedule causes a muted price response and thereby reduces the volatility of the real rate and consumption and increases utility.

Second, a small open economy in a currency union is much more exposed to productivity shocks in the rest of the union than a large economy because the central bank's response will be much stronger to that shock. But when the foreign economy's prices change less because of the progressive tax schedule, the negative spillover effects will be smaller and welfare falls less in the small open home economy.

4.5 Discussion

In particular the results on progressive taxes in the presence of productivity shocks lead us to a few interesting interpretations. However, our model set-up needs some more discussion at least with respect to one crucial assumption.

First, a currency union can benefit from progressive taxes from bigger macroeconomic stabilization. Second, there is a strong incentive for a race to the bottom in that a country would benefit from reducing its degree of tax progression unilaterally and that this would constitute a beggar-thy-neighbour policy, i.e the country would harm its neighbour. Third, based on the first two points in conjunction, one can make the case for a coordination of tax policies because a harmonization of the degrees of tax progression across the eurozone would result in an equal distribution of its macroeconomic benefits and because a welfare reducing race to the bottom can be avoided.

However, we have seen that in our model calibration, distributional effects between Ricardian and rule-of-thumb households were considerable and resulted in an aggregate welfare loss. This result was based on the assumption of identical utility levels in the deterministic steady state. It is, however, conceivable that the result of a negative effect on aggregate welfare under productivity shocks can be overturned for a higher consumption and utility level of Ricardian households than of rule-of-thumb households. The reason is that a higher steady state consumption level might reduce the impact on welfare by the increase in the Ricardian's consumption volatility caused by the progressive tax when rule-of-thumb households are present.

The reason for choosing our simplifying assumption is that a lot of reasons, which are beyond the scope of this paper, could cause different utility and consumption levels among

individuals. Idiosyncratic productivity differences would be one such reason, another could be a higher net worth related to inheritances. However, these reasons would need to be related to the use of financial markets for the purpose of intertemporal optimization of utility in order to justify an imposition of differing steady states. It could well be that an individual has better access to financial markets because of a higher net worth related to either an inheritance or to high idiosyncratic productivity. In this case scale effects of or fixed entry costs to financial intermediation could be the reason for the lack of access to financial services for rule-of-thumb households. Alternatively, a better intellectual capacity by a high productivity individual could be a prerequisite to make intertemporal judgements. But these are a priori statements and would require more analysis that is beyond the scope of the present paper. In any case, it is unlikely that the Ricardian household's losses will fade so that it is difficult to justify a progressive tax system based on Pareto arguments when Ricardian and rule-of-thumb households are considered.

5 Progressive Taxation and Optimal Monetary Policy

In the previous section we have seen that tax progression matters for aggregate volatility and welfare. The analysis has been conducted under the assumption that the monetary authority follows a standard Taylor-type interest rate rule. We have seen that progressive taxes have a dampening effect on real GDP. The effect on inflation is ambiguous, depending on the type of shock hitting the economy. In this section, one of our goals is to analyse how optimal monetary policy is affected by the existence of a progressive tax system. Since monetary policy is about the stabilization of macroeconomic variables, mostly output and inflation, we are interested in whether the changed macroeconomic environment that a progressive tax system brings forth has implications for optimal monetary policy. Optimal monetary policy with progressive taxation has been analyzed before by Mattesini and Rossi (2012) in a closed economy using a linear-quadratic approach. We extend the analysis to a currency union setting relying on a second order approximation of the equilibrium conditions. Since the degree of tax progressivity differs widely across eurozone countries, the case of an asymmetric degree of tax progression between the two union members of our model is also of interest. Another goal of this section is to analyze whether a progressive tax system is a reasonable macroeconomic stabilization tool,

i.e. whether it improves economic welfare, once monetary policy is conducted optimally by the common central bank. In what follows, we consider technology shocks only as government spending shocks did not result in welfare improvements even under the Taylor rule. It should therefore be clear that a distortionary tax cannot improve welfare when monetary policy is conducted optimally so we do not show results for that specification.²⁵ Note that the central bank's objective function is the population-weighted average of Home and Foreign welfare and that this objective function is maximized taking the optimality conditions of households and firms as given.

Table 3: Moments and welfare losses with productivity shocks - Optimal Monetary Policy

	Closed economy		Currency Union	
	<i>w/o RoT</i>	<i>w RoT</i>	<i>symm.</i>	<i>asymm.</i>
ξ^H	+7.1	+38.2	+6.5	+3.9
ξ^F				+9.9
ξ^A		+38.8		
ξ^N		-40.4		
$\sigma(\pi^H)$	+256.7	+102.1	+1.4	-0.8
$\sigma(\pi^F)$				+3.4
$\sigma(Y^H)$	-12.7	-12.6	-11.2	-13.3
$\sigma(Y^F)$				-8.9
$\sigma(C^H)$	-12.7	-12.6	-11.7	-13.8
$\sigma(C^F)$				-9.5
$\sigma(N^H)$	+76.2	+77.1	+46.0	+55.7
$\sigma(N^F)$				+36.9
\bar{C}	-0.0019	-0.0015	-0.0008	-0.0008
\bar{N}	+0.00001	+0.0004	-0.0001	+0.0006

Notes: Results are changes compared to the flat-tax benchmark in percent.

To understand the subsequent results, it is important to first remember what the optimal monetary policy aims for in this model. The goal of an optimal monetary policy is to eliminate inflation and thereby the inefficient price dispersion. This is achieved by a much more aggressive reduction of the real rate in response to the productivity shock than under the standard Taylor

²⁵Results are available from the authors upon request, of course.

rule. The real rate and the Ricardian household's consumption are thus more volatile while the volatility of hours worked falls. The elimination of price dispersion increases aggregate productivity as can be seen from equation (11) and thereby average consumption. The higher average consumption level induces the household to work less hours. This increases welfare compared to the Taylor rule. But remember that the increase in welfare due to the introduction of the progressive tax schedule under the Taylor rule was caused by a *smaller* consumption volatility and a *higher* volatility of hours while the level of consumption fell and hours increased. However, the optimal policy strikes an optimal balance between the level of consumption and hours on the one hand and the volatility thereof on the other hand. By deviating from this optimal balance through the distortionary tax, welfare falls.

The qualitative effects of the progressive tax are still the same under the optimal monetary policy stance as under the Taylor rule: The steeper marginal cost schedule implies a smaller reaction of prices to the shocks and thereby a muted response of monetary policy causing a smaller consumption volatility and a bigger volatility of hours. Furthermore, the convexity of the marginal cost function increases average prices and real rates and thereby reduces average consumption and raises average hours. But in terms of welfare, the reduction in consumption volatility is not sufficient to compensate for the increased hours volatility and levels effects.

This result holds for all specifications shown in Table 3. Most strikingly, the results also show that the existence of a progressive tax system does not have any considerable effect on the conduct of optimal monetary policy in our currency union. Using a linear-quadratic approach, Benigno (2004) has shown that in a symmetric two-country currency union with sticky prices and flat taxes, optimal monetary policy ensures that union inflation is zero at all times. National inflation rates fluctuate inversely, i.e. inflation in one country implies an equal degree of deflation in the other country. This policy minimizes the convex costs of national price level adjustments. This policy prescription also holds in our model economy, independent of the tax system. The volatility of union inflation is practically zero in all cases, with a slightly higher volatility when rule-of-thumb households are present. National inflation rates have similar volatilities, i.e. the burden of adjustment is equally distributed among the members of the currency union. Even the case of an asymmetric degree of tax progression across countries, where we observe significant differences in terms of e.g. real GDP fluctuations, does

not change this result.

What can easily be verified is that the optimal monetary policy is well approximated by the strict inflation targeting regime with a value of the coefficient ϕ_π of 5 as both the volatility of the macroeconomic variables and the welfare effects are very similar.²⁶ This policy has been shown to be a very good approximation of optimal policy in standard business cycle models with sticky prices where a progressive tax system is absent (e.g. in Galí 2008) and also to be robust across a wide-range of model specifications (see e.g. Schmitt-Grohé and Uribe 2006). We thus also confirm the desirability of this simple policy regime in the case of tax progression. However, we find progressive taxes are not necessary in this environment any longer to maximize welfare.

6 Conclusion

In this paper we analyze the welfare implications of a progressive tax system in a monetary union in a DSGE model with Calvo pricing. We find welfare gains from the introduction of such a system for Ricardian households when we assume a standard Taylor rule, when we abstract from rule-of-thumb households and only for productivity shocks, but not for demand shocks. One potential caveat to our analysis and results needs to be mentioned and one main conclusion beyond that of possible welfare gains of progressive taxes.

We concentrate on macroeconomic effects of tax progression, i.e. we ignore the negative welfare effects in the steady state related to a reduced incentive to supply labor (the "microeconomic" effects of tax progression). One therefore needs to be aware of the fact that in order to compute the overall welfare effects one needs to subtract the negative microeconomic effects, unless a realistic subsidy scheme offsetting these microeconomic effects can indeed be implemented. This certainly merits further research.

The major conclusion from these simulations is that strict inflation targeting remains the prime objective in stabilizing business cycles. This is true for both closed economies and open economies that are members of a currency union. We confirm the robustness of this results for the presence of progressive taxes and that the latter have no beneficial impact on welfare in any calibration once monetary policy is conducted optimally. It then remains an empirical

²⁶Results are available from the authors upon request.

question whether monetary policy is indeed conducted in an optimal manner or whether a standard Taylor rule is followed and, in the latter case, which shocks dominate business cycle fluctuations.

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