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Structural and Cyclical Effects of Tax Progression☆

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Abstract

In a real business cycle model with labor market frictions, we find that a more progressive tax schedule reduces structural unemployment as it fosters long-run incentives for job creation. Because there exists an optimal level of unemployment in a matching environment ("*Hosios condition*"), tax progression improves steady-state welfare up to a certain threshold and harms it beyond that. However, tax progression increases the costs of business cycles for those consumers who can save and borrow, while it reduces the business cycle costs for households with limited asset market participation ("*rule-of-thumb*" consumers). Our analysis suggests that business cycle effects dominate steady-state effects. On the aggregate level, tax progression is welfare-enhancing up to a certain threshold and always shifts relative utility from optimizing to *rule-of-thumb* consumers. These findings are quite robust to alternative calibrations of our model.

Keywords: Tax Progression, Business Cycles, Automatic Stabilizers, Welfare (JEL: H2, J6, E32, E62)

1. Introduction

Tax progression is an important attribute of present-day tax systems. While top rates of income taxes have declined since the 1980s and the number of tax brackets has generally decreased, the overall progressivity of public tax and transfer systems has not necessarily been on a downward trend (see Bastagli et al., 2012, Diamond and Saez, 2011, and Piketty et al., 2011). Furthermore, top rates have been raised again as part of a number of recent consolidation packages, which has been seen as a new tendency towards higher tax progression (see, for example, European Commission, 2012). While progression may have negative incentive effects, it is sometimes argued that it may play

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a major positive role in the game of automatic stabilizers (see, for example, Auerbach and Feenberg, 2000, Dolls et al., 2010, Martinez-Mongay and Sekkat, 2005, and Attinasi et al., 2011). This issue is attracting renewed interest given the stronger calls for countercyclical fiscal policy and the shortcomings of ad-hoc fiscal interventions compared to automatic stabilization in practice.

In this paper, we assess the business cycle and welfare effects of tax progression in a standard real business cycle model augmented by a search and matching labor market in line with Pissarides (2000). Additionally, we assume that a fraction of households can neither save nor borrow and consumes all income each period in line with Galí et al. (2007). This household type has become known as *rule-of-thumb* consumer. The matching labor market-augmented real business cycle setup allows us to assess what implications tax progression has for structural output, consumption, employment as well as welfare and compare these implications to those in the earlier literature. The business cycle dimension enables us to assess how tax progression affects the cycle and how the conclusions from a purely structural analysis have to be modified when taking into account the cycle. The inclusion of *rule-of-thumb* consumers further allows us to analyze the possibility that consumers' preferences for tax progression may differ depending on whether or not they participate in asset markets.

We find that a more progressive tax schedule reduces structural unemployment as it fosters long-run incentives for job creation due to its dampening effect on wage claims. As established earlier in the literature, tax progression improves steady-state welfare up to a certain threshold and harms it beyond that because there exists an optimal level of unemployment in a matching environment ("*Hosios condition*"). However, we also show that tax progression always increases the costs of business cycles for optimizers who can save and borrow, while it always reduces the business cycle costs for *rule-of-thumb* households. The latter is due to less volatile net wages and less volatile employment. The former follows from, first, progressivity-induced tax rate volatility and intertemporal consumption shifting of optimizers ("intertemporal substitution effect"). Second, given that output volatility is virtually independent of tax progressivity, but employment is less volatile, tax progression reduces volatility of vacancy posting and, hence, makes optimizers' disposable income more volatile ("income effects").

Our analysis suggests that the business cycle effect dominates the steady-state effect when the technology shock process is calibrated to match plausible output volatility. Overall, tax progression seems welfare-enhancing up to a certain threshold and always shifts relative utility from optimizers to *rule-of-thumb* consumers. These findings are quite robust to alternative calibrations of our model.[1]

Much of the earlier theoretical literature on tax progressivity focussed on the effects tax progression has on structural, i.e. steady-state unemployment, output and welfare.

[1] Only when unemployment is already too low in terms of the Hosios condition (for example, as a result of too low workers' bargaining power or unemployment benefits) does tax progression immediately harm welfare.

A comprehensive overview of earlier studies from the 1990s and early 2000s is given by Røed and Strøm (2002). In a model with a matching labor market, Pissarides (1998) and Sørensen (1999) show that a more progressive tax schedule increases employment when wages are Nash-bargained over. Our analysis confirms their finding in a real business cycle framework taking into account the feedback of the labor market to the rest of the economy.

Steady-state welfare gains from higher employment are, generally, ambiguous in a matching labor market framework, as shown by Hosios (1990). The *Hosios condition* states that there exists an optimal level of unemployment because the individually rational vacancy posting decision of a single firm causes a congestion externality for others (see Pissarides, 2000, for a more detailed discussion). Our analysis also confirms this. However, the mechanism is different and potential welfare gains are smaller for *rule-of-thumb* consumers. Their sole source of income are wages and unemployment benefits and, since firms are owned by optimizers, they are less directly affected by the congestion externality. Generally, higher progressivity decreases both net wages and unemployment. Only when the latter decrease overcompensates the former, which is the case for low to intermediate progressivity, do *rule-of-thumb* consumers gain from progression.[2]

Hairault et al. (2010) and Jung and Kuester (2011) show that the welfare costs of business cycles are significantly augmented by the presence of a search labor market because of employment fluctuations. Focusing on the dynamic effects of tax progression, Zanetti (2011) shows that, in the standard matching framework, progressive labor income taxation decreases the reaction of vacancies and unemployment to shocks. Hence, tax progression stabilizes employment. In our analysis, we confirm this finding. Additionally, we show that tax progression stabilizes consumption of *rule-of-thumb* households owing to employment and net wage stabilization. However, consumption of optimizing households becomes more volatile. There are two effects responsible for this. First, tax progression increases the volatility of optimizers' disposable income because the volatility of output is virtually independent of tax progressivity, while employment and, thus, vacancy costs are stabilized through higher progression. Hence, there is a direct "income effect". Second, as productivity shocks die out over time, the effects they have on wages decrease over time, too. Future tax rates are, therefore, less affected by current productivity shocks. After a positive (negative) productivity shock, optimizing households bring forward (postpone) some of the expected relative progressivity-induced net income gains (losses) to today. Hence, there is additionally an "intertemporal consumption substitution effect".[3]

[2]When taking into account endogenous job destruction and a workers' participation decision, Hungerbühler et al. (2006) also show that average tax rates are optimally increasing in wages. Again, they focus exclusively on steady-state effects.

[3]As productivity shocks die out over time, consumption smoothing, of course, generates the incentive to save (borrow) today in the case of a positive (negative) productivity shock. This effect is dominated by the effects described in the main text, however.

These effects imply that, from a costs-of-business-cycle perspective, optimizers always lose from tax progression while *rule-of-thumb* consumers always win. The steady-state effects described are dominated by these business cycle effects for plausible values of the volatility of the productivity shock in our model. Arseneau and Chugh (2012) show that volatile labor income tax rates – introduced in our model through progressivity – can be welfare-enhancing up to a certain threshold.

Another strand of the literature deals with tax progression in heterogeneous agent models, see, among others, Heer and Trede (2003), Conesa and Krueger (2006) or Krueger and Perri (2011). They analyze the effects tax progression has on the insurance of income risks and income distribution. Our analysis treats distributional issues only in a highly stylized way by introducing *rule-of-thumb* consumers to an otherwise standard real business cycle model. The stylized model shows that the more people can insure against income fluctuations – i.e. the less impaired / more capable insurance markets are and, in terms of our model, the lower the share of *rule-of-thumb* consumer is –, the less welfare-enhancing tax progression is with a view to the business cycle costs and the more relevant the Hosios condition becomes for determining overall welfare effects. Still, redistributive effects of tax progression certainly warrant additional attention and we leave a thorough analysis of these aspects for further research. A recent step in this direction is the analysis by Heathcote et al. (2012).

The rest of the paper is organized as follows. Section 2 describes the model. In section 3, we conduct the business cycle and welfare analyses including some robustness checks and discuss our results. Section 4 concludes.

2. The model

In this section, we describe a standard real business cycle model incorporating search and matching frictions in line with Pissarides (2000) and credit-constrained consumers in line with Galí et al. (2007). The latter implies that we assume that there is a continuum of households indexed by $i \in [0,1]$, of which a fraction $\mu \in [0,1)$ can neither save nor borrow. This consumer type has become known in the literature as *rule-of-thumb consumer* (RoT consumer). The remaining fraction $(1-\mu)$ shifts consumption intertemporally. Our simultaneous integration of a search labor market and RoT households follows Boscá et al. (2011) and Moyen and Stähler (*forthcoming*).[4] All households consume and work; optimizing households additionally save in non-state contingent securities. Each agent can be employed or unemployed, while receiving a wage income when employed and enjoying unemployment benefits when unemployed. Job matching is governed by a linear homogenous matching function of degree one and job separation is assumed to be exogenous. The simultaneous inclusion of RoT con-

[4] For the discussion of RoT consumers, see, for example, Campbell and Mankiw (1989), Mankiw (2000) or Galí et al. (2007). Among the large body of the DSGE literature including matching frictions, see Andolfatto (1996), Merz (1995), Moyen and Sahuc (2005), Walsh (2005), Trigari (2006, 2009), Krause and Lubik (2007) and Christoffel et al. (2009).

sumers and involuntary unemployment can be considered a short cut for an imperfect unemployment insurance system because RoT consumers are not able to smooth consumption intertemporally and, thus, face a true consumption risk from unemployment. The higher the share of RoT consumers, the less efficient the unemployment insurance is (see also Moyen and Stähler, *forthcoming*, for a further discussion).

2.1. Households

We assume that households maximize their expected lifetime utility

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t u_t \left(c_t^i \right) \right\}, \tag{1}$$

where E_0 is the expectations operator at $t = 0$, c_t^i denotes the agent's consumption of final goods, $i = o, r$ stands for optimizing and RoT consumers, respectively, and $u_t(.)$ is the instantaneous utility function given by

$$u\left(c_t^i\right) = \begin{cases} \frac{\left(c_t^i\right)^{1-\sigma_c} - 1}{1-\sigma_c}, & \sigma_c > 0, \sigma_c \neq 1, \\ log\left[c_t^i\right], & \sigma_c = 1 \end{cases} . \tag{2}$$

As in Boscá et al. (2011) and Moyen and Stähler (*forthcoming*), consumers of type i each live in a type-i family and pool their income to insure themselves against individual unemployment risk. The elasticity of consumption σ_c can be interpreted as a risk-aversion parameter.

When employed, households receive a type-specific real gross wage w_t^i. This wage is taxed at a progressive rate τ_t^i specified below. The employment rate of type-i households is given by N_t^i. Wages, employment and unemployment are determined on the labor market. When unemployed, household members are entitled to unemployment benefits κ^B. Their share is given by U_t^i. Since there are $(1-\mu)$ optimizing and μ RoT consumers, economy-wide employment and unemployment can be written as $N_t = (1-\mu)N_t^o + \mu N_t^r$, $U_t = (1-\mu)U_t^o + \mu U_t^r$ and $N_t^i = (1 - U_t^i)$.

The sequence of real budget constraints for **optimizing households** reads as

$$c_t^o + b_t = (1 - \tau_t^o) w_t^o \cdot N_t^o + U_t^o \cdot \kappa^B + R_{t-1} b_{t-1} + \Pi_t - T_t, \tag{3}$$

where b_t denotes a non-state contingent security that pays off R_t units of consumption one period later, Π_t are real firm profits and T_t are lump-sum taxes levied on optimizers. We will discuss their use below. Optimizing households thus choose the set of processes $\{c_t^o, b_t\}_{t=0}^{\infty}$ taking as given the set of processes $\{w_t^o, \tau_t^o, R_t, N_t^o, U_t^o\}_{t=0}^{\infty}$ and the initial wealth b_0, so as to maximize (1), given (2), subject to (3). Defining the Lagrangian multiplier on constraint (3) as λ_t^o , the following optimality conditions must hold

$$\text{for } c_t^o: \quad \lambda_t^o = (c_t^o)^{-\sigma_c}, \tag{4}$$

$$\text{for } b_t\text{:}\quad \lambda^o_t = \beta E_t \left\{ \lambda^o_{t+1} R_t \right\}. \tag{5}$$

Equation (4) is the marginal utility of consumption and equation (5) is the consumption Euler condition.

Given that we assume that **RoT consumers** also live in a family and pool their income, but that they cannot save or borrow, their budget constraint is given by

$$c^r_t = (1 - \tau^r_t) w^r_t \cdot N^r_t + U^r_t \cdot \kappa^B. \tag{6}$$

The marginal utility of consumption for RoT consumers is given by

$$\lambda^r_t = (c^r_t)^{-\sigma_c}. \tag{7}$$

Total economy-wide consumption is given by $c_t = (1 - \mu) c^o_t + \mu c^r_t$.

Following Guo (1999), Guo and Lansing (1998) and Mattesini and Rossi (2012), we postulate that τ^i_t takes the form

$$\tau^i_t = 1 - \rho \left(\frac{\bar{w}^{bm}}{w^i_t} \right)^{\phi}, \tag{8}$$

where $\phi \in [0, 1]$ determines tax progressivity. For $\phi = 0$, there is no tax progression and the tax rate equals $1 - \rho$. For $\phi > 0$, progression increases in ϕ. ρ determines the level and ϕ the slope of the tax schedule. $\bar{w}^{bm}$ is the wage level around which the (average) tax rate circulates. We assume that $\tau^i_t \in [0, 1]$ always holds and impose the necessary restrictions on the parameters of the tax code for this condition to hold. To better understand the taxation scheme, note that

$$\tau^{m,i}_t = \frac{\partial \left[\tau^i_t \cdot w^i_t \right]}{\partial w^i_t} = \tau^i_t + \phi \rho \left(\frac{\bar{w}^{bm}}{w^i_t} \right)^{\phi} = 1 - \rho (1 - \phi) \left(\frac{\bar{w}^{bm}}{w^i_t} \right)^{\phi}$$

is the marginal tax rate, which is always above the average tax rate τ^i_t for $\phi > 0$. Possible alternative ways of specifying tax progressivity in line with, for example, Pissarides (1998, 2000), Sinko (2007) or Zanetti (2011), do not alter the results we shall derive below qualitatively.

Lump-sum taxes will be used to close the government's budget constraint across the cycle. They are levied on optimizing households only to avoid introducing additional distortions, but they are assumed to be zero in steady state (see below).[5]

[5] Were RoT households also taxed, this would alter their consumption behavior and, thus, also generate distortions in the system.

2.2. *The production sector*

Firms sell their output in a competitive market. The sole production input is labor. Workers must be hired from the unemployment pool, and searching for a worker is time-consuming and involves costs. Wages are determined through Nash bargaining. In what follows, we shall describe the matching process, firms' behavior and the wage-setting process in more detail.

2.2.1. *Search and matching in the labor market*

To hire a worker, the representative firm must post a vacancy. All unemployed workers look for a job and we also assume no on-the-job search. The number of firm-worker matches in each period is determined by the number of searchers, U_t, and vacancies, V_t, according to a matching function

$$M_t(U_t, V_t) = \kappa^e U_t^{\eta} V_t^{1-\eta}, \tag{9}$$

where κ^e is a matching efficiency parameter. Defining labor market tightness $\theta_t = V_t/U_t$, firms meet with an unemployed worker at rate $q_t = M_t(U_t, V_t)/V_t = \kappa^e \theta_t^{-\eta}$. Unemployed workers find a vacant job at rate $p_t = \theta_t q_t = M_t(U_t, V_t)/U_t = \kappa^e \theta_t^{1-\eta}$. Matches are destroyed at an exogenous rate s. The number of employed people at time t is given by the fraction of employed people plus new matches in period $t-1$ for which the match continues

$$N_t = (1-s)\left[N_{t-1} + q_{t-1} \cdot V_{t-1}\right]. \tag{10}$$

Given the implicit assumption that, when posting a vacancy, firms cannot differentiate between posting vacancies for optimizers or RoT consumers, it holds that $N_t = N_t^o = N_t^r$ (see also section 2.1 for the labor market aggregation and Moyen and Stähler, *forthcoming*, for more details).

2.2.2. *The firm*

The representative firm operates a production technology which is linear in labor, $y_t = z_t \cdot N_t$, where z_t is a normally distributed aggregated technology shock which follows an AR(1) process with persistence ρ_z, and an $\epsilon_z \sim N(0, \sigma_z)$ i.i.d. random shock. $N_t = (1-\mu)N_t^o + \mu N_t^r$ is the (economy-wide) fraction of workers employed in the representative firm. The firm maximizes the following dynamic optimization problem

$$\max \Pi_t = E_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_{t+1}^o}{\lambda_t^o} \left\{y_t - (1-\mu) w_t^o N_t^o - \mu w_t^r N_t^r - \kappa^v V_t\right\}$$

by choosing the level of employment N_t and the number of vacancies V_t to post in order to generate future employment subject to equation (10).[6] Wages are taken as given

[6]As firms belong to optimizing households, we have used their marginal utility of consumption, λ_t^o, for discounting.

by the firm when determining employment. We derive them in the next subsection. Defining $\mathcal{J}_t^i$ as the Lagrangian multiplier on the employment law of motion of a type-*i* worker, first-order conditions are

$$\text{for } N_t^i\text{:} \quad \mathcal{J}_t^i = z_t - w_t^i + \beta E_t \left\{ \frac{\lambda_{t+1}^o}{\lambda_t^o}(1-s)\mathcal{J}_{t+1}^i \right\}, \tag{11}$$

$$\text{for } V_t\text{:} \quad \frac{\kappa^v}{q_t} = \beta E_t \left\{ \frac{\lambda_{t+1}^o}{\lambda_t^o}(1-s)\left[(1-\mu)\mathcal{J}_{t+1}^o + \mu \mathcal{J}_{t+1}^r\right] \right\}. \tag{12}$$

2.2.3. Wage setting and Bellman equations

The wage schedule is obtained through individual Nash bargaining between the firm and a worker. $\mathcal{J}_t^i$ of equation (11) is the firm's marginal value of a match with a type-*i* worker. Hence, it depends on marginal production minus wage payments plus the discounted continuation value. Furthermore, we note that equation (12) is an arbitrage condition stating that the expected value of a newly created job, not knowing which type of worker to meet *ex ante*, has to equal expected search costs. It is, thus, the standard *job creation condition* implying that the value of posting a vacancy must be zero in equilibrium due to the zero-profit condition and free market entry. The marginal value of a match to a type-*i* worker is given by[7]

$$\mathcal{W}_t^i = (1-\tau_t^i)w_t^i - \kappa^B + \beta E_t \left\{ \frac{\lambda_{t+1}^i}{\lambda_t^i}(1-s)(1-p_t)\mathcal{W}_{t+1}^i \right\}. \tag{13}$$

Given the bargaining power of workers $\xi \in (0,1)$, wages are determined by

$$\max_{w_t^i} \; S(w_t) = \left[\mathcal{W}_t^i\right]^{\xi} \left[\mathcal{J}_t^i\right]^{1-\xi}.$$

We assume that households take into account the tax structure given by equation (8), i.e. that demanding a higher wage will result in a progressively higher tax burden. The resulting sharing rule for a type-*i* household is given by

$$\mathcal{W}_t^i = \frac{\xi}{1-\xi} \cdot (1-\phi)(1-\tau_t^i)\mathcal{J}_t^i, \tag{14}$$

[7]The derivation follows standard procedures, i.e. households maximize utility, equations (1) and (2), with respect to N_t^i subject to the employment law-of-motion $N_t^i = (1-s)\left[N_{t-1}^i + p_{t-1}\cdot(1-N_{t-1}^i)\right]$. With λ_t^i and ω_t^i being the Lagrangians on the corresponding households' budget constraints and the employment laws-of-motion, respectively, this yields $\lambda_t^i\left[(1-\tau_t^i)w_t^i - \kappa^B\right] - \omega^i + \beta E_t\left\{(1-s-p_t(1-s))\,\omega_{t+1}^i\right\} = 0$. Defining $\mathcal{W}_t^i = \omega_t^i/\lambda_t^i$, we get equation (13); see also Moyen and Sahuc (2005).

which states that the share of the matching surplus the worker receives depends positively on his bargaining power, ξ, while it negatively depends on the tax progression parameter, ϕ, and the actual tax rate, τ_t^i. Hence, it is straightforward to show that increasing progressivity unambiguously decreases the after-tax wage in the steady state (see Sinko, 2007 and Section 3.1 below).

2.3. The government

The government needs to finance unemployment benefits, $\kappa^B U_t$, by the progressive wage taxes collected from employed workers, $[(1-\mu)\tau_t^o w_t^o + \mu\tau_t^r w_t^r]\, N_t$, and by lump-sum taxes collected from optimizers, T_t, to close the budget. Assuming a balanced budget each period, the government budget constraint is given by

$$[(1-\mu)\tau_t^o w_t^o + \mu\tau_t^r w_t^r]\, N_t + (1-\mu)T_t = \kappa^B U_t. \tag{15}$$

2.4. Market clearing

In equilibrium, aggregate production has to cover consumption demand and search costs, i.e.

$$y_t = c_t + \kappa^v V_t. \tag{16}$$

2.5. Benchmark calibration

Our benchmark is calibrated according to quarterly frequencies. We shall conduct robustness analyses to several parameters in Section 3.4 to show that our results are robust to alternative parameterizations of the model. We set $\phi = 0$ (no progression) in the benchmark and then analyze how the model reacts when increasing ϕ while leaving the other parameters described in this section unchanged. The calibration is much in line with Christoffel et al. (2009) and Moyen and Stähler (*forthcoming*). The parameter values are summarized in Table 1.

More precisely, the time-discount factor β is chosen to match an average annual interest rate of 4%, which implies $\beta = 0.99$. The value of the risk-aversion parameter is set to 1.5 as reported in Smets and Wouters (2003). Following Galí et al. (2007), we set the share of RoT consumers to $\mu = 0.33$. It should be noted that the literature offers quite an interval in which the share of liquidity-constrained consumers can be expected, ranging from lower values up to 50% (as in Forni et al., 2009).

Turning to the labor market, we set the matching elasticity η to 0.5 according to estimates by Burda and Wyplosz (1994), which is also in line with Petrolongo and Pissarides (2001) and Shimer (2005). The bargaining power of workers ξ is set to the conventional value of $\xi = \eta$, which is common in the literature. We set the quarterly separation rate $s = 0.06$. The equilibrium unemployment rate is calibrated to 8%. In the steady state, the number of matches must be equal to the number of separations, which allows us to calculate the number of vacancies. Following Christoffel et al. (2009), we target the steady-state vacancy-filing probability to be $\bar{q} = 0.7$, which allows us to solve for $\kappa^e = 0.717$. From the labor flow relations, we can solve for $\bar{p}$. The normalization $\bar{y} = 1$ allows us to calculate steady-state productivity $\bar{z}$.

We assume that the replacement rate for unemployment benefits equals $rrs = \kappa^B/[(1-\bar{\tau})\bar{w}] = 0.5$ in the steady state; see Nickell and Nunziata (2001). Using the sharing rule (see equation (14)), and the corresponding Bellman equations evaluated at their steady-state level, we are able to solve for the wages $\bar{w}^i$. Note that, in steady state, it holds that $\bar{w}^o = \bar{w}^r = \bar{w}$, which also implies that $\bar{\tau}^o = \bar{\tau}^r = \bar{\tau}$ must hold in steady state. We set $\bar{w}^{bm} = \bar{w}$ for defining the tax schedule. Assuming $\bar{T} = 0$ and solving the government budget constraint for $\bar{\tau}$ allows us to calculate η. Substituting wages into the job creation condition, we derive vacancy costs $\kappa^v = 0.45$. For the productivity shock, we assume high autocorrelation, $\rho_z = 0.807$ and a standard deviation of 0.475. This targets the measured standard deviation of output in the euro area, $\hat{y}_t \approx \log(y_t/\bar{y}) = 0.86$ (see Christoffel et al., 2009).

Parameter	Symbol	Europe
Preferences		
Discount factor	β	0.990
Risk aversion	σ_c	1.500
Share of RoT consumers	μ	0.330
Bargaining and production		
Matching elasticity	η	0.500
Bargaining power	ξ	0.500
Separation rate	s	0.060
Productivity (in SS)	$\bar{z}$	1.087
Policy		
Replacement rate	rrs	0.500
Tax schedule (benchmark slope)	ϕ	0.000
Tax schedule (benchmark level)	ρ	0.958
Tax schedule (benchmark wage)	$\bar{w}^{bm}$	1.039
Shock		
Autocorrelation	ρ_z	0.807
Standard deviation	σ_z	0.475

Table 1: Baseline calibration

3. Welfare and business cycle implications of tax progression

The welfare functions for both household types are calculated as the discounted sum of their utilities, i.e.

$$\mathbb{W}^i_{0,t} = E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \cdot u\left(c^i_t\right) \right\} = E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \cdot \frac{\left(c^i_t\right)^{1-\sigma_c} - 1}{1-\sigma_c} \right\}$$

Aggregate welfare can be expressed as $\mathbb{W}_{0,t} = (1-\mu)\mathbb{W}^o_{0,t} + \mu\mathbb{W}^r_{0,t}$. Ever since Lucas (1987), it is common in the RBC literature to conduct welfare comparisons in terms of consumption equivalents interpreted as the percentage of some baseline steady-state consumption that households are prepared to surrender in order to enter an alternative (policy) setup.[8] We shall do the same here and define the steady-state consumption level of our baseline calibration (no progression), which we label as $\bar{c}^{i,bm}$ for households of type i, as the benchmark against which we will compare the dynamic and steady-state welfare differences. Formally, we define an alternative welfare function

$$\widetilde{\mathbb{W}}^i_{0,t} = E_0 \left\{ \sum_{t=0}^{\infty} \frac{u\left((1+v^i_t)\bar{c}^{i,bm}\right)}{(1-\beta)} \right\} = E_0 \left\{ \sum_{t=0}^{\infty} \frac{\left((1+v^i_t)\bar{c}^{i,bm}\right)^{1-\sigma_c} - 1}{(1-\sigma_c)(1-\beta)} \right\}.$$

We then set $\mathbb{W}^i_{0,t}\left(c^i_t\right) = \widetilde{\mathbb{W}}^i_{0,t}\left((1+v^i_t)\bar{c}^{i,bm}\right)$ and solve for v^i_t. In the steady-state welfare comparison of different levels of progression, $\bar{v}^i$ indicates the percentage of baseline steady-state consumption (no progression) a household of type i would be willing to give up in order to live in the world with the corresponding progressivity in the tax schedule. For negative values, the household would have to be paid to prefer the progressive situation.

In a dynamic world, the stochastic mean of the second-order Taylor approximation of v^i_t gives the percentage of baseline steady-state consumption a household of type i is willing to give up in order to live in a non-stochastic world. We define the stochastic mean of the second-order Taylor approximation of v^i_t as $Taylor_2(v^i_t)$. Given that there are always costs for business cycles, we are interested in whether these costs increase or decrease in the progressivity of the tax code. Therefore, we define $\Delta^i_t = Taylor_2(v^i_t) - Taylor_2(v^{i,bm}_t)$ as the difference of business cycle costs between a situation with a certain tax progression, $Taylor_2(v^i_t)$, compared to no progression, which is our benchmark, $Taylor_2(v^{i,bm}_t)$.

In what follows, we shall, first, analyze the steady-state welfare effects of tax progression. Then, we will compare business cycle effects of different degrees of tax progression. Third, we shall address the welfare effects of tax progression when taking into account the business cycle. Last, we conduct a robustness analysis of our results.

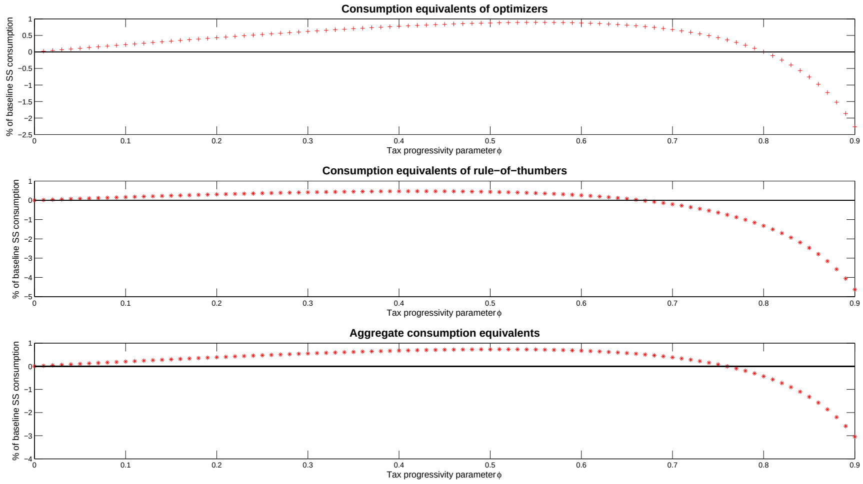
3.1. The steady-state welfare comparison

Figure 1 plots the steady-state consumption equivalents $\bar{v}^i$ as described in the previous section for optimizing households (upper panel), RoT households (middle panel) and the aggregate (lower panel). The latter is defined as $\bar{v} = (1-\mu)\bar{v}^o + \mu\bar{v}^r$.

By inspecting Figure 1, we see that higher tax progression increases steady-state welfare of optimizing households up to a certain threshold and harms it beyond that. They are willing to give up about 1% of their baseline steady-state consumption in order to move from a world without tax progression to a tax schedule with intermediate progression ($\phi \approx 0.55$). If progression it too high, however, they (strongly) prefer a world without progression (for $\phi \approx 0.8$ and beyond). The same holds for RoT households

[8]Among the large literature using consumption equivalents for welfare comparison, see, for example, Barro (2006), Cristoffel et al. (2009), Krebs (2003), Lucas (2003), Obstfeld (1994) and Otrok (2001).

Figure 1: Steady-state welfare comparison



Notes: Consumption equivalents $\bar{v}^i$ as described in the main text for different tax progressivity parameters ϕ. Aggregate consumption equivalents defined as $\bar{v} = (1-\mu)\bar{v}^o + \mu\bar{v}^r$.

qualitatively, albeit at a lower level and for lower thresholds. The aggregate welfare effects are simply a weighted average of the previous two.

How can we explain these steady-state welfare changes induced by tax progression? To answer this question, it is helpful to explicitly derive some steady-state relations of the model presented in Section 2. Noting that, in steady state, wages for optimizers and RoT households are the same, $\bar{w}^o = \bar{w}^r = \bar{w}$, which allows us to omit the indice i below, and using equations (11), (13), (14) and the fact that unemployment benefits are assumed to be a fraction rrs of the net steady-state wage, we can derive the steady-state wage as

$$\bar{w} = \frac{\xi(1-\phi)}{1-\phi\xi-(1-\xi)rrs} \cdot \left[\bar{z} + \kappa^v\bar{\theta}\right]. \tag{17}$$

Substituting this wage and equation (11) into the sharing rule, equation (12), evaluated at the steady state, yields

$$\frac{\left[(1-\xi)(1-rrs)\cdot\bar{z} - \xi(1-\phi)\kappa^v\cdot\bar{\theta}\right]}{(1-\phi\xi-(1-\xi)rrs)(1-\beta(1-s))} = \frac{\kappa^v}{\beta(1-s)\bar{q}} \tag{18}$$

as the steady-state job creation condition. Remember that $\bar{q} = \bar{M}/\bar{V} = \kappa^e\bar{\theta}^{-\eta}$ depends on $\bar{\theta}$, too (see Section 2.2.1). Hence, from equation (18), it is straightforward to see that market tightness, $\bar{\theta}$, which is the only endogenous variable in that equation, unambiguously increases in the tax progressivity parameter ϕ. This implies that job creation increases, yielding more aggregate employment (see equation (10) evaluated in steady state). Higher tax progression, hence, reduces structural – or steady-state – unemployment in a model with search frictions (see also Figure 2). We are able to explain this by the fact that higher marginal tax rates, an increase in the tax progressivity parameter ϕ, decrease the pre-tax wage $\bar{w}$ *ceteris paribus* (see also equation (17) and Figure 2 to confirm this result). Lower wage claims by workers, of course, increase the incentive for firms to create jobs. This, in turn, creates upward pressure on wages, but it cannot overcompensate the original wage reduction. Hence, our model confirms the finding in the earlier literature that, in matching labor markets with Nash bargaining over wages, higher progression in labor income taxes decreases structural unemployment; see also Pissarides (1998) or Sørensen (1999).

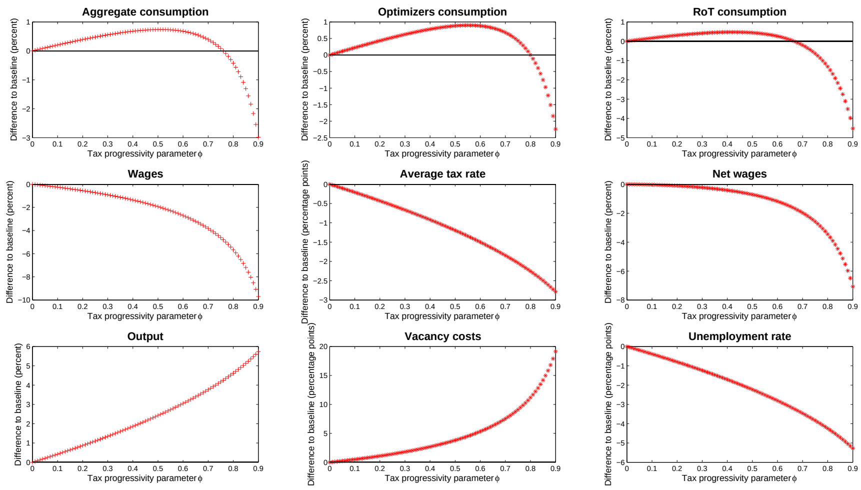
From the perspective of a pure search labor market, less unemployment implies ambiguous welfare effects ex-ante. The condition of Hosios (1990) states that there exists an optimal level of unemployment in matching markets. Lower unemployment indeed results in an increase in production, but higher job creation causes a congestion externality because it reduces the probability of finding a worker for each individual firm when the pool of unemployment becomes smaller. In terms of our model, we can relate this to equation (16). Evaluated at steady state, it is given by $\bar{c} = \bar{y} - \kappa^v \bar{V}$. Aggregate output, $\bar{y}$, indeed increases with increasing employment. However, this is also true for vacancy posting costs, $\kappa^v \bar{V}$. As the probability of filling a vacancy falls in higher employment levels, there must be more vacancies posted in the economy to keep employment at a higher constant level $\bar{N}$. This increases search costs. Hence, there is an optimal level of (un)employment that maximizes $\bar{c}$; see Pissarides (2000) for a further discussion.

Relating this discussion to the welfare findings presented in Figure 1, we note by inspecting Figure 2 that this mechanism is much in line with the welfare effects for optimizing households. Higher employment, induced by higher tax progression, increases output $\bar{y}$ and also vacancy costs $\kappa^v \bar{V}$. As long as the former increase dominates the latter, aggregate consumption and, hence, consumption of optimizing households rises. This implies a rise in welfare even though wages fall. For our model calibration, optimizers prefer a progression parameter $\phi \approx 0.55$ and an optimal unemployment rate of $\bar{U} \approx 5\%$. For values beyond $\phi \approx 0.8$ and an unemployment rate below $\bar{U} \approx 3.75\%$, optimizers start being worse off than in a situation with a flat tax.

The picture looks similar for RoT consumers, but the explanation is different. RoT households consume what they earn each period. In Figure 2, we see that, when tax progression increases, pre-tax wages fall, which is generally not overcompensated by a fall in the marginal tax rate, i.e. also net wages fall in general. On the other hand, RoT households could benefit from higher employment levels overcompensating the loss in net wages. This is indeed the case for low to intermediate levels of tax progression. However, the reduction in net wages dominates the positive employment effect for values of $\phi > 0.65$. Hence, after this threshold, RoT consumers no longer prefer tax progression over a flat tax either.

The above analysis suggests that, from a steady-state perspective, optimizing and RoT households benefit from tax progression compared to a flat tax up to certain thresh-

Figure 2: Steady-state comparison of selected variables



Notes: The figure pictures percentage (point) deviation of the steady-state outcome of selected variables compared to the outcome in the baseline calibration for alternative ϕ. The heading of each panel indicates which variable is plotted.

old. They benefit most from intermediate progression. These principle findings are quite robust to alternative parametrization of the model (of course, the precise optimal value for ϕ varies with changing parametrization).

3.2. Impulse response analysis

So far, the analysis has focussed on structural effects of tax progression and the corresponding steady-state welfare implications. However, tax progression also affects the cyclical behavior of the economy and welfare implications may be different. Before a more detailed look at the business cycle-induced welfare consequences in the next subsection, it first seems appropriate to consider the cyclical effects of tax progression. For this purpose, we compare impulse responses to a standard 1%-productivity shock of selected variables for a flat tax, $\phi = 0$, intermediate tax progression, $\phi = 0.4$, and high tax progression, $\phi = 0.8$. The findings are summarized in Figure 3. The lower right panel shows that we consider exactly the same productivity shock for all scenarios. The evolution of the average tax rate and net wages is plotted for optimizers, but they are virtually the same for RoT consumers. Differences in their discounting, see equation (13), are of basically no numerical importance.

Figure 3 shows that progressivity-induced differences in the evolution of output and aggregate consumption are very small.[9] Still, there are notable differences in the consumption paths of optimizing and RoT households, and tax progression affects optimizers' and RoT households' consumption behavior in opposite ways. Optimizers' consumption volatility increases in the progressivity of the tax schedule, while the opposite is true for RoT consumers. The latter is due to the fact that higher tax progressivity makes net wages and (un)employment less volatile. Given that RoT households consume their entire labor income each period, this also makes their consumption less volatile when tax progression is higher.

The increase in consumption volatility for optimizers can be attributed to intertemporal consumption shifting and the more volatile "disposable income" of optimizers. Regarding the latter, we observe that output volatility itself is virtually independent of tax progressivity, while employment and, thus, vacancy costs are stabilized through higher progression. Hence, there is a direct "income effect" which induces optimizers to consume more erratically. Regarding intertemporal consumption smoothing, we can note that, as productivity shocks die out over time, the effects they have on wages decrease over time, too. Hence, future tax rates are less affected by current productivity shocks due to tax progression. After a positive (negative) productivity shock, optimizing households therefore expect decreasing (increasing) tax rates in the future and, therefore bring forward (postpone) some of the expected relative progressivity-induced net income gains (losses). Both effects increase consumption volatility of optimizers.

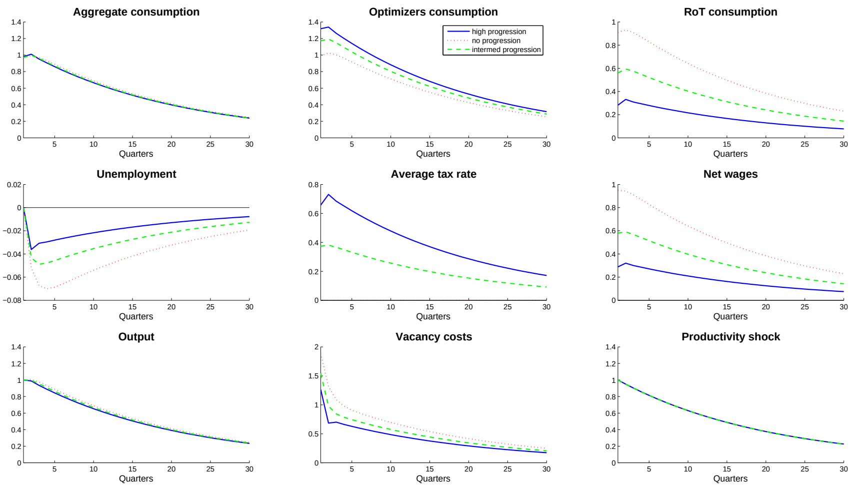
3.3. The dynamic welfare effects

In this section, we shall analyze the welfare differences of tax progression when taking into account the business cycle. The results are summarized in Figure 4. The left column of Figure 4 plots the overall differences in the stochastic mean of the second-order Taylor approximation as explained at the beginning of this Section 3. However, this stochastic mean of a second-order Taylor approximation also takes into account the changes in the steady-state starting position, which we described in Section 3.1. Hence, in order to calculate the pure costs of the business cycle for different levels of tax progressivity, we also plot the stochastic mean of the second-order Taylor approximation minus the progressivity-induced steady-state differences (as described in Section 3.1) in the right-hand column of Figure 4.

Building on the analyses of the previous two subsections, it is actually straightforward to explain what happens. On the one hand, the left-hand column of Figure 4

[9] Here, a word on the disconnect of wages and output in matching labor markets may be in order. In the presence of a matching labor market in which firms and workers bargain over wages, the link between wages and output is not so strict as it is in a Walrasian labor market. The reason for this is that, in principle, there is a huge range of wages that workers and firms would be willing to accept in a matching environment (see also Arseneau and Chugh, 2012). Hence, as wages have a distributive rather than an allocative role, even if output evolves quite similarly under two policy regimes, this is not necessarily the case for (net) wages. We see that this holds true for different levels of tax progression in our model.

Figure 3: Impulse response functions of selected variables



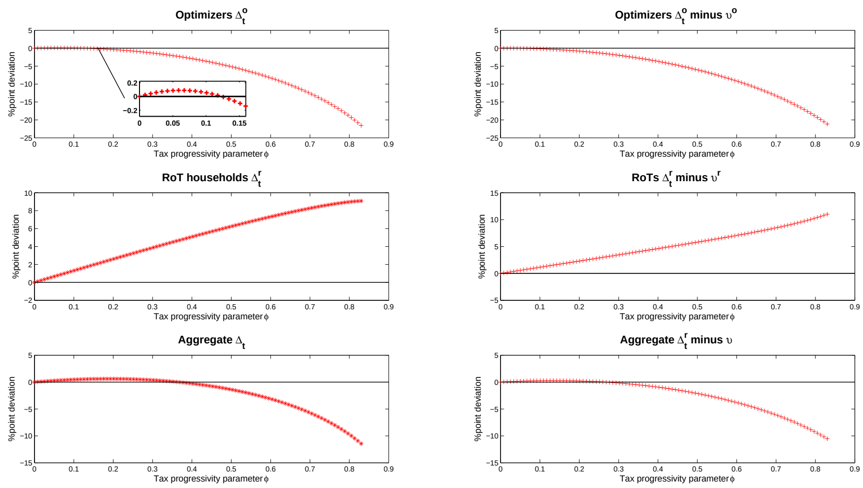
Notes: The figure plot IRFs of selected variables to a persistent 1% productivity shock. It shows percentage deviations from steady state (percentage point deviations for tax and unemployment rates). The bold blue lines indicate high tax progression, the green dashed lines are intermediate progression and the dotted red lines are the IRFs of a flat tax system.

reveals that aggregate welfare differences taking into account business cycle fluctuations are broadly in line with what we already found in the pure steady-state analysis in Section 3.1. On the other hand, the right-hand column highlights a notable difference showing that, from a pure costs of business cycles perspective, optimizers *always* lose and RoT households *always* win from higher tax progression relative to our benchmark. For RoT consumers, the business cycle effects clearly dominate the steady-state welfare effects, which implies that they always benefit from tax progression. For optimizers, it is also true that the business cycle effect dominates. This implies, however, that they lose from tax progression.

Using the results of Section 3.2, we can easily explain why optimizers lose and RoT consumers win. As we have seen in Figure 3, volatility of consumption increases for optimizers, while it decreases for RoT households when tax progression increases (remember that the latter results from less volatile net wages). Because risk-averse households dislike volatility in consumption, tax progression thus increases the costs of business cycles for optimizers and reduces these costs for RoT households.

Hence, we can conclude from the analysis in this section that, when evaluating the virtue and harm of tax progression, it indeed makes a difference whether we consider pure costs of business cycles or whether we talk about structural, i.e. steady-state, effects. Our analysis suggests that the steady-state welfare effect is dominated by the

Figure 4: Dynamic welfare comparison



Notes: The left-hand column shows overall welfare differences Δ_t^i as explained at the beginning of Section 3 for optimizers, RoT households and on an aggregate level. The right-hand column shows the pure welfare differences resulting from business cycle fluctuations corrected for differences in steady state, i.e. $\Delta_t^i - \bar{\upsilon}^i$, again for optimizers, RoT households and on an aggregate level.

business cycle effects and that progressivity significantly affects the costs of business cycles.

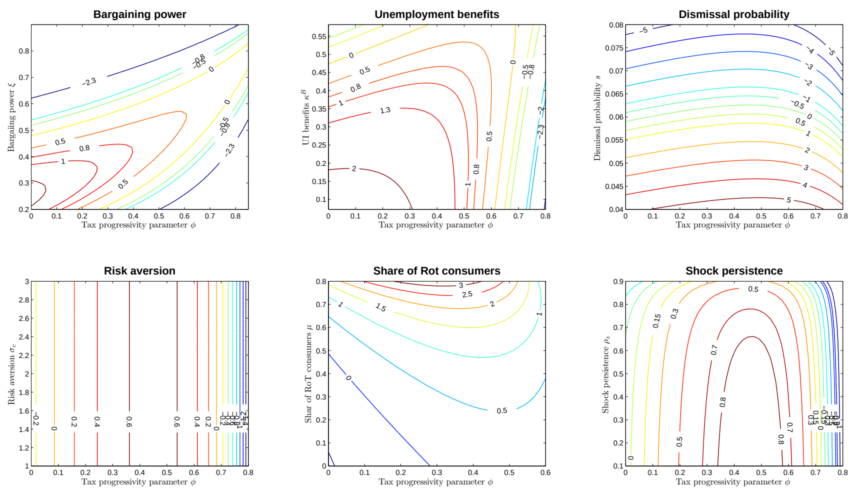
3.4. Robustness and discussion of the results

In this section, we dig a little deeper to investigate how robust our welfare results are to changes of selected model parameters. To do so, we conduct the the same experiments as described in the previous subsection 3.3 varying different model parameters. We differentiate between optimizers' welfare, Δ_t^o, RoT welfare, Δ_t^r, and total welfare, Δ_t. The results are depicted in Figures 5 to 7 for optimizers, RoTs and the aggregate, respectively.

We present the results as contour plots, where each level curve represents a parameter combination (selected parameter "x" and tax progressivity ϕ) that yields the same consumption equivalent. In order for the qualitative results presented above to be robust to the parametrization of the model, the graphs would have to show the following characteristics. For optimizers and aggregate welfare, we shall have to "climb the mountain" from the west to the east up to a certain threshold of ϕ and "descend" it beyond for all values of the selected parameter "x". For RoTs, we will always have to "climb the mountain" over the entire range. To verify this, compare the left column of

Figure 4 to the resulting line-plot of fixing parameter "x" in Figure 5, 6 and 7, respectively, and moving from $\phi = 0$ up. In what follows, we shall analyze the effect of the different parameters in more detail.

Figure 5: Robustness: Optimizers' welfare Δ_t^o

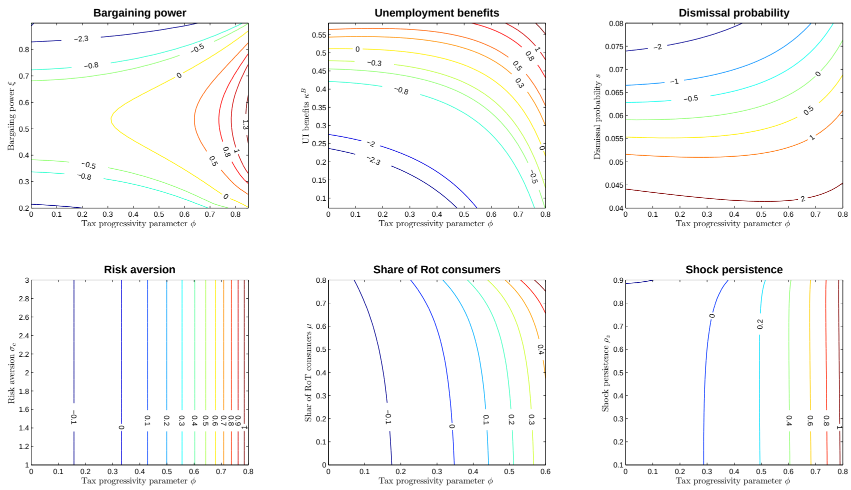


Notes: Contour plots of consumption equivalents for a combination of selected variables "x" (as indicated in the title of the corresponding subplot) and the tax progressivity parameter ϕ for optimizers.

From a qualitative point of view, we see that the welfare result of optimizers is quite robust to an alternative parametrization of the model. As Figure 5 reveals, in most cases, we "climb the mountain" from the west to the east up to a certain threshold and descend it thereafter. Hence, the welfare consequences that we described above can be considered robust. This is especially true for the risk aversion parameter, σ_c and shock persistence, ρ_z. For the dismissal probability, s, unemployment benefits, κ^B, and the share of RoT consumers, μ, the results also hold qualitatively. However, the slope of the line graph would differ. We inspect a noteworthy difference for the bargaining power of the union, ξ, however. Whenever the bargaining power is below some threshold of around $\xi \approx 0.25$, we see that an increase in tax progression reduces optimizers' welfare, while in the left-hand column of Figure 4, we saw that optimizers, too, benefit mildly from tax progression at the very beginning.

This is, however, a straightforward issue to explain. As we know from the literature (see Hosios, 1990, and Pissarides, 2000) and the earlier discussion, the optimal level of unemployment in a labor market matching environment is achieved whenever the bargaining power of workers is equal to the firms' job-finding elasticity when there is no policy intervention (here: no unemployment benefits). Given that we assume a positive level of unemployment benefits in our baseline calibration, this condition is fulfilled in our model at $\eta = 0.5 > \xi \approx 0.25$. At this point, the level of unemployment is optimal from the optimizers' perspective. Any policy measure decreasing unemployment – which, as we have seen above, higher tax progressivity does –, harms welfare. In our baseline calibration with $\eta = \xi = 0.5$, the optimal level of unemployment according to the *Hosios condition* results when there is no policy intervention (here: $\kappa^B = 0$). This can be confirmed by the corresponding contour plot of Figure 5.

Figure 6: Robustness: RoT consumers' welfare Δ_t^r



Notes: Contour plots of consumption equivalents for a combination of selected variables "x" (as indicated in the title of the corresponding subplot) and the tax progressivity parameter ϕ for RoT consumers.

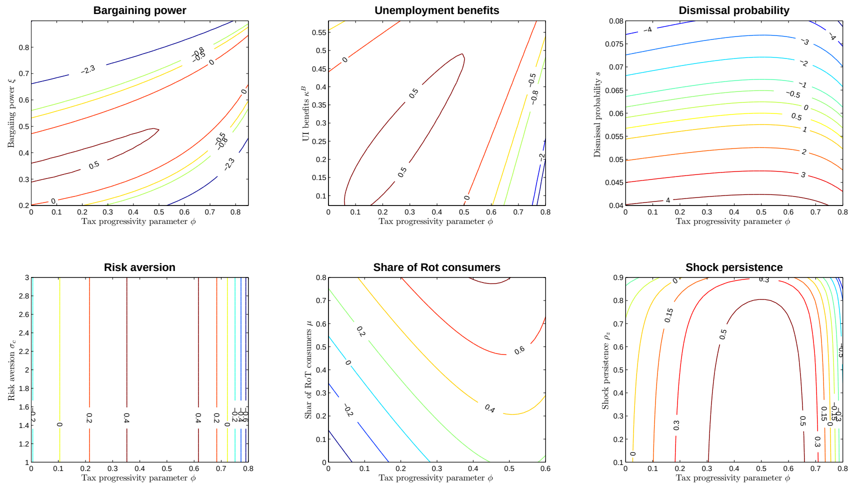
For RoT consumers, we see that, for nearly all parameters plotted in Figure 6, we constantly "climb the mountain" from the west to the east. It is only when the dismissal probability s is relatively low that welfare for RoT consumers may initially decrease in increasing progressivity.[10] Hence, the welfare results that we presented above are quite robust to alternative parameterizations for RoT consumers, too.

There are some additional interesting observations to make. For any given level of tax progressivity, RoT consumers always prefer higher unemployment benefits. As

[10]In this case, the positive steady-state employment effect no longer overcompensates the steady-state decrease in net wages such that there is a steady-state loss for RoT consumers. Given that both low dismissal probability and high progressivity stabilize employment and (net) wage fluctuation, the welfare gains in a dynamic environment are decreased when dismissal probability falls. If the dismissal probability is relatively low, the steady-state welfare losses can then overcompensate dynamic welfare gains, which we see happening for $s < 0.05$ in the upper right-hand panel of Figure 6.

they dislike consumption fluctuations and as they consume all their income each period, they prefer income differences between being employed and unemployed to be small. They also like higher bargaining power for any given level of tax progressivity up to a certain threshold. Whenever bargaining power is too great, however, aggregate unemployment (in the steady state and across the cycle) is so, too. Beyond this bargaining power threshold, RoTs would prefer a lower level, too.

Figure 7: Robustness: Aggregate welfare Δ_t



Notes: Contour plots of aggregate consumption equivalents for a combination of selected variables "x" (as indicated in the title of the corresponding subplot) and the tax progressivity parameter ϕ.

Not surprisingly, Figure 7 shows that the welfare results we presented above are also robust on an aggregate level. This must be true given that aggregate welfare is a weighted average of optimizers' and RoTs' welfare. The larger the percentage of RoT consumers in the economy, the more aggregate welfare will be influence by them and vice versa.

4. Conclusions

In this paper, we assess the business cycle and welfare effects of tax progression in a standard real business cycle model augmented by a search and matching labor market. We also assume that a fraction of households can neither save nor borrow. They have been called *rule-of-thumb* consumers in the literature. We find that a more progressive tax system reduces structural unemployment as it reduces wages and, thus, fosters long-run incentives for job creation. Because there is an optimal level of unemployment in a matching environment ("*Hosios condition*"), tax progression improves steady-state welfare up to a certain threshold and harms it beyond that. In a cyclical environment, however, tax progression always increases the costs of business cycles for those consumers who can save and borrow, while it always reduces the business cycle costs for *rule-of-thumb* households who cannot. The latter is due to less volatile net wages, while the former follows from higher volatility in optimizers' disposable income as well as progressivity-induced tax rate volatility and the resulting increase in consumption volatility. Our analysis suggests that the business cycle effect dominates the steady-state effect. Overall, tax progression seems welfare-enhancing up to an intermediate threshold and always shifts relative utility from optimizers to *rule-of-thumb* consumers. These findings are quite robust to alternative calibration of our model.

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