Distortionary taxation, international business cycles and real wage: explaining some puzzling facts

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August 23, 2010

Abstract

In this paper, we show that fluctuations in distortive taxes can account for most puzzling features of the U.S. economy. Namely, the observed real wage rigidity, the international correlation of investment and labor inputs, and the so-called quantity puzzle (according to which cross-country correlation of outputs is higher than the one of consumptions). This is done in a two-country search and matching model with fairly standard separable preferences, extended to include a tax/benefit system.

JEL: E32, E62, H24, J41.

Keywords: Distortive taxes, real wage rigidity, international business cycles, search and matching.

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Introduction

Traditional real business cycle models (Kidland and Prescott 1982) assume that technological change is the driving force behind growth and fluctuations observed in developed economies, in particular the U.S.. While these models have been successful in accounting for a large fraction of the variability and comovements of the aggregate time series, they do not do well along some dimensions. As is well known, relative to the data, the variability of consumption, hours of work, and output is too low, and the variability of investment is too high. But maybe the main failure is the predicted correlation of real wages with both hours worked and output (the Dunlop-Tarshis puzzle). In such a models, variations in technology shift the labor demand curve but not the labor supply curve, thus inducing a strong positive correlation between wages and hours. Similarly, the open economy versions of these models (Backus, Kehoe, and Kydland 1994) appear to be insufficient to account for key features of the international business cycles. Namely, the international comovement of investment and labor inputs, and the so-called consumption correlation puzzle (according to which cross-country correlations of output are higher than the cross-country correlations of consumption). Moreover, they have the same limitations as their closed-economy counterpart regarding the dynamics of the real wage, the labor productivity and the total hours.

The introduction of search and matching in the labor market (Andolfatto 1996) outperforms the model predictions along several dimensions. Regarding the international fluctuations, the combination of the search and matching hypothesis with the non separability (between consumption and leisure) in the agents' preferences in a two-country framework (Hairault 2002), lets solve the consumption correlation puzzle. On the other side, results from the search hypothesis suggest that to improve the predictions from the real business cycle models, concerning the real wage rigidity, one must include something that shifts labor supply. If both labor demand and labor supply shift, then the strong positive correlation between hours and wages can probably be reduced.

Several candidate labor supply shifters have already been considered, such as home production (Benhabib, Rogerson, and Wright 1991) or government consumption (Christiano and Eichenbaum 1992). The inclusion of a public sector has the potential to improve some of the predictions of the standard real business cycle model. In particular, Christiano and Eichenbaum (1992) study a real business cycle model in which government purchases affect the agents' utility. The expenditures are financed through lump-sum taxes. In this case, shocks to expenditures shift the labor supply curve. However, they predict that while the hours and wage correlation comes closer to that observed, it is significantly positive. But they do not allow for distortionary taxation.

Intuitively, like government expenditures, shocks to income and payroll taxes can be interpreted as shocks to labor supply, as opposed to technology shocks which may be interpreted as shocks to labor demand. Thus, taxes would provide another mechanism for explaining the observed correlation between hours and wages. On the empirical side, most studies assessing the effects of tax shocks on the US economy conclude that unanticipated tax increases have strong negative effects on output and other real economy variables. This is true for studies using the sign-restrictions approach (Mountford and Uhlig 2005) or a narrative approach (Romer and Romer 2007). Similarly, (Caldara and Kamps 2008) find estimated effects of tax shocks ranging from non-distortionary to strongly distortionary, depending on the identification approach chosen. Moreover, Burnside, Eichenbaum, and Fisher (2004) and McDaniel (2007) document large changes in the tax rates.

On the theoretical side, in the Keynesian tradition, fiscal policy, and therefore taxation, is one of the main instruments to stabilize the economy. However, in the 1990s, several pioneering works considered taxation as a source of business cycle fluctuations. This feeds the criticisms about the possibility to use taxes as stabilization tool. These former articles have shown that stochastic fiscal policy improves the performance of real business cycle models. McGrattan (1994) finds that a significant portion of the variance of the aggregate consumption, output, hours worked, capital stock, and investment can be attributed to the factor tax (*i.e.* on capital and labor income) and government spending processes. Similarly, Braun (1994) shows that modelling fluctuations in personal and corporate income tax rates increases the model's predicted relative variability of hours and decreases its predicted correlation between hours and average productivity. Finally, using Swedish data, Jonsson and

Klein (1996) find that the empirical fit of a simple stochastic growth model is significantly improved when it is amended to include imperfectly predictable fluctuations in payroll taxes, consumption taxes and government consumption.[1]

In all cases, the basic mechanisms at work are as follows. Taxes to labor alter the leisure/labor supply decision, highlighting the volatility of hours worked. In plain words, if income and payroll taxes fluctuate over time, it is optimal to work hard when taxes are relatively low and to take time off when they are relatively high. Then, as labor taxes fluctuate, so do hours worked. Similarly, a temporarily high tax rate on consumption provides an incentive to postpone consumption to a later date, when the tax rate is likely to be lower. Hence, as the consumption tax fluctuates, so does consumption. Consequently, the inclusion of such a taxes should increase the predicted volatility of hours and consumption, bringing the implications of theory closer to the facts. Finally, the variability in investment and capital increases either because of increases in the capital tax, or indirectly by the complementarity of capital and labor, and even through the agents' trade-off between consumption and saving following a consumption tax shock.

In quantitative terms, these models yield to predictions for the correlation between hours and real wages, as measured by average productivity, close to the empirical correlation. Likewise, the predicted variability of hours worked and consumption are much closer to their empirical values when fiscal policy is included (even if in general the relative volatility of aggregate hours is overstated). Nevertheless, these former papers show two drawbacks. The first one is that all of them consider a closed economy, so that the possible variability in the macro aggregates passing through the international trade is not accounted for, whereas the international facts are obviously left unexplained. The second one is that the theoretical real wage is measured by average productivity, which prevents from analyzing other features of the US labor market, such as the lower volatility of the real wage than the one of the labor productivity.

Then, in this paper we develop an unified framework to show that fluctuations in distortive taxes can simultaneously account for most major puzzling features of

[1]Moreover, they find that for large sets of conventional moments, models with stochastic fiscal policy cannot be statistically rejected, whereas a model without it is always rejected.

the U.S. business cycles. Namely, the observed real wage rigidity, the international comovement of investment and labor inputs, and the so-called consumption correlation puzzle. This is done in a two-country search and matching model with fairly standard preferences, extended to include a tax/benefit system. In this context, the *tax side* is represented by average tax rates on labor income, employment (payroll tax) and consumption, whereas the *benefit side* is resumed by the unemployment benefits and the worker's bargaining power.

The main departures from the former literature on taxation as a source of business cycle fluctuations are twofold. First, we consider a two-country general equilibrium model, so that we are able to discuss the effects of shocks to taxes on the observed international fluctuations. Second, we assume search and matching in the labor market. Our model is close to the Hairault (2002)'s one. However, in his framework the non-separability of preferences, together with the variation in the relative price of goods leads to slightly more procyclical real wages than with conventional additively separable preferences. Our model is also close to the Chéron and Langot (2004)'s model, who explain the real wage rigidity in a closed-economy search model by means of a particular set of non-separable preferences, which have the property that, from an ex post perspective, employed agents are actually better off than unemployed agents, and can take more advantage of an economic boom. This depresses the outside options, in putting a downward pressure on the real wage.

Either in the Hairault (2002)'s paper or in the Chéron and Langot (2004)'s paper, the non-separability of preferences plays a main role. However, as was said before, this hypothesis is unable to simultaneously account for the real wage rigidity and for the observed international fluctuations. Conversely, in this work we show that all those facts can be accounted in a single framework with fairly standard preferences. On the one side, an economic boom accompanied of a positive shock to the labor taxes leads to countercyclical outside options, which dampens the procyclicality of the real wage. On the other side, under the national specialization hypothesis, the equalization of consumptions across countries following a productivity shock does not hold anymore, (even in presence of separable preferences), and the gap between domestic and foreign consumption increases as long as the consumption tax is shocked too.

The remaining of the paper is organized as follows. In the first section we develop the model. In the second section we explore the implications form the model under several configurations. Last section gives the concluding remarks.

1 The Model

The world economy consists of two countries (country 1 or home country and country 2 or foreign country), each represented by a large number of identical consumers and a production technology. Population size is normalized to unity. Each country specializes in the production of a single good. The main source of fluctuations are persistent shocks to productivity that are internationally diffused. Additionally, both countries are affected by shocks to taxes on consumption and labor (*i.e.* , taxes on labor income and payroll taxes). The countries are linked either on the consumption and the production side since agents demand a CES basket of the two goods for consumption and investment purposes. Finally, agents participate in the trade on the labor market.

1.1 Labor market flows

Employment in country $i = 1, 2$ is predetermined at each time and changes only gradually as workers separate from jobs, at the exogenous rate s_i, or unemployed agents find jobs, at the endogenous hiring rate $M_{i,t}$. Let $N_{i,t}$ and $V_{i,t}$, respectively be the number of workers and the total number of new jobs made available by firms, then employment evolves according to

$$N_{i,t+1} = (1 - s_i)N_{i,t} + M_{i,t}, \quad M_{i,t} = \chi V_{i,t}^{\phi}[e_i(1 - N_{i,t})]^{1-\phi}, \quad 0 < \phi < 1, \quad \chi > 0.$$

In this expression $e_i > 0$ is the constant search effort and $0 < s_i < 1$ the exogenous separation rate of job-worker pairs.

1.2 Households

At any period, N_i agents are employed while the remaining $1 - N_i$ are unemployed. Unemployed agents are randomly matched with job vacancies. Employees work h_i

units of time at a wage rate of w_i. Unemployed workers devote e_i units of their time seeking employment and receive the unemployment benefits b_i. In both cases they pay a proportional labor income tax levied at rate τ_w^i. Markets are complete, so we can derive the intertemporal decision rules by solving the program of a representative household. This agent consumes a CES basket of the two goods (Hairault 2002):

$$C_i^{C,z} = \left[\gamma^{\frac{1}{\theta}} C_i^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_{j\neq i}^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}}, \quad for \quad z = n, u, \quad i = 1, 2$$

$C^{C,n}$ and $C^{C,u}$ respectively stand for the consumption of employed and unemployed agents. θ is the elasticity of substitution between the two goods, and γ is the share of the national good in the consumption basket. Consumption is subject to the consumption tax rate τ_c^i. The price index of the composite goods is defined as:

$$P_i^C = \left[\gamma P_i^{1-\theta} + (1-\gamma) P_{j\neq i}^{1-\theta}\right]^{\frac{1}{1-\theta}}, \quad for \quad i = 1, 2.$$

with P_i the production price of good i.

We assume perfect international risk sharing: households in the two countries have access to contingent claims $B_{i,t} = B_i(A_t)$ at prices $v_t = v(A_{t+1})$ providing one unit of good 1 if the state A occurs at $t+1$. That is, we take the good produced in country 1 as accounting unit, and we normalize its value to 1. Let $f(A) \equiv f(A_{t+1}, A_t)$ denote the density function describing the transition from the state A_t to the state A_{t+1}. Then, the representative household in country i is assumed to maximize the expected discounted sum of its utility flows,

$$\mathcal{W}^H(B_{i,t}) = \max_{C_{i,t}^{C,n}, C_{i,t}^{C,u}, B_{i,t}} \left\{ N_{i,t} U(C_{i,t}^{C,n}, 1-h_{i,t}) + (1-N_{i,t}) U(C_{i,t}^{C,u}, 1-e_i) + \beta \int \mathcal{W}^H(B_{i,t+1}) f(A) dA_{t+1} \right\} \tag{1}$$

subject to the labor constraint:

$$N_{i,t+1} = (1-s) N_{i,t} + \Psi_{i,t}(1-N_{i,t}), \quad \text{for i=1,2} \tag{2}$$

where $\Psi_{i,t} \equiv M_{i,t}/(1-N_{i,t})$ is the rate at which unemployed agents find jobs, and subject to the budget constraint:

$$(1+\tau_{c,t}^1)\left[N_{1,t}\mathcal{P}_{1,t}^C C_{1,t}^{C,n} + (1-N_{1,t})\mathcal{P}_{1,t}^C C_{1,t}^{C,u}\right] + \int v_t B_{1,t+1} dA_{t+1} \leq B_{1,t} + (1-\tau_{w,t}^1)[N_{1,t} w_{1,t} h_{1,t} + (1-N_{1,t}) b_{1,t}] + L_{1,t}, \quad \text{for i=1} \tag{3}$$

$$(1+\tau_{c,t}^2)\left[N_{2,t}\mathcal{P}_{2,t}^C C_{2,t}^{C,n} + (1-N_{2,t})\mathcal{P}_{2,t}^C C_{2,t}^{C,u}\right] + \int v_t B_{2,t+1} dA_{t+1} \leq B_{2,t} + (1-\tau_{w,t}^1) p_t [N_{2,t} w_{2,t} h_{2,t} + (1-N_{2,t}) b_{2,t}] + L_{2,t}, \quad \text{for i=2} \tag{4}$$

and given some initial conditions $(N_{i,0}, B_{i,0})$. $p_t \equiv \frac{P_{2,t}}{P_{1,t}}$, $\mathcal{P}^C_{i,t} \equiv \frac{P^C_{i,t}}{P_{1,t}}$ and $L_{i,t}$ are lump-sum transfers from the government to be defined below.

The contemporaneous utility function is assumed to be increasing and concave in its both arguments and exhibits conventional additive separability between consumption ($C^{C,z}_{i,t}$) and leisure ($L^z_{i,t}$):

$$U_{i,t}(C^{C,z}_{i,t}, L^z_{i,t}) = \log C^{C,z}_{i,t} + \Gamma^z_{i,t} \equiv U^z_{i,t}, \quad z = n, u \tag{5}$$

where $\Gamma^n_{i,t} \equiv \sigma \frac{(1-h_{i,t})^{1-\eta}}{1-\eta}$ with $\sigma, \eta > 0$ and $\Gamma^u_{i,t} = \Gamma^u_i$ $\forall t$. The parameter σ can be interpreted as reflecting differences in the efficiency of household's home production technology across different states of employment opportunities.

1.3 Firms

Each country specializes in the production of a single good. The representative firm in country $i = 1, 2$ has a constant returns-to-scale technology that uses composite capital and labor hours to produce output,

$$Y_{i,t} = a_{i,t} K^\alpha_{i,t} (N_{i,t} h_{i,t})^{1-\alpha}, \quad 0 < \alpha < 1 \tag{6}$$

The primary source of fluctuations are persistent shocks to aggregate productivity, represented by $a_{i,t}$. The stochastic productivity vector $a_t = [a_{1,t}, a_{2,t}]'$ is assumed to follow a $VAR(1)$ process in natural logarithms:

$$\ln a_{t+1} = \Omega \ln a_t + \vartheta \epsilon_{t+1} \quad \text{, where} \quad \epsilon_{t+1} \sim iid \;\; \mathcal{N}(0, \mathbf{I})$$

The vector $\epsilon_t = [\epsilon_1, \epsilon_2]'$ represents the innovations to productivity variables. The matrix Ω, defined as

$$\Omega = \begin{pmatrix} \rho_{1,1} & \rho_{1,2} \\ \rho_{2,1} & \rho_{2,2} \end{pmatrix}$$

describes the autoregressive component of the disturbance. Finally, the covariances between the elements are given by the matrix ϑ, defined as

$$\vartheta = \begin{pmatrix} 1 & \upsilon_{1,2} \\ \upsilon_{2,1} & 1 \end{pmatrix}$$

This matrix reflects the extent to which the shocks are idiosyncratic or global in nature.

New capital goods are internationally mobile. Investment $I^c_{i,t}$ has the same CES structure (and then, the same price) as consumption and is subject to quadratic adjustment costs $\mathcal{C}_{i,t}$:

$$\mathcal{C}_{i,t} = \frac{\hat{\phi}}{2}(K_{i,t+1} - K_{i,t})^2$$

Let ω_i be the unitary cost of a vacancy job. Firms seek to maximize the discounted value of the dividend flows,

$$\begin{aligned} \mathcal{W}^F(K_{i,t}, N_{i,t}) &= \max_{V_{i,t}, I_{i,t}} \left\{ \pi_{i,t} + \int v_t \mathcal{W}^F(K_{i,t+1}, N_{i,t+1}) dA_{t+1} \right\} \\ \text{for } \pi_{i,t} &= P_{i,t} \left(Y_{i,t} - \omega_i V_{i,t} - (1 + \tau^i_{f,t}) w_{i,t} N_{i,t} h_{i,t} - \mathcal{C}_{i,t} \right) - P^C_{i,t} I_{i,t} \end{aligned} \quad (7)$$

subject to the constraints,

$$N_{i,t+1} = (1 - s_i) N_{i,t} + \Phi_{i,t} V_{i,t} \quad (8)$$

$$K_{i,t+1} = (1 - \delta) K_{i,t} + I_{i,t} \quad (9)$$

and given some initial conditions $(N_{i,0}, K_{i,0})$, where $0 < \delta < 1$ is the depreciation rate of capital. $\Phi_{i,t} \equiv M_{i,t}/V_{i,t}$ is the rate at which vacancies and workers are matched and τ^i_f stands for the country-specific payroll tax payed by firms.

1.4 Government

The government levies taxes to finance expenditures. We assume a balanced budget at each period, so that any revenue that is not used to finance current purchases is transferred to households in a lump-sum payment. Thus, real transfers to country i households are given by:

$$L_{1,t} = \tau^1_{c,t} \mathcal{P}^C_{1,t} [N_{1,t} C^{C,n}_{1,t} + (1 - N_{1,t}) C^{C,u}_{1,t}] + (\tau^1_{f,t} + \tau^1_{w,t}) w_{1,t} h_{1,t} N_{1,t} - b_{1,t} (1 - \tau^1_{w,t})(1 - N_{1,t}) \quad (10)$$

$$L_{2,t} = \tau^2_{c,t} \mathcal{P}^C_{2,t} [N_{2,t} C^{C,n}_{2,t} + (1 - N_{2,t}) C^{C,u}_{2,t}] + p_t (\tau^2_{f,t} + \tau^2_{w,t}) w_{2,t} h_{2,t} N_{2,t} - b_{2,t} p_t (1 - \tau^2_{w,t})(1 - N_{2,t}) \quad (11)$$

In order to be coherent with our estimations (appendix A), we assume that the stochastic process governing tax rate τ_j, for $j = c, w, f$, follows an AR(1) process in natural logarithms,

$$\log(\tau_{j,t+1}) = (1-\rho_j)\log\bar{\tau}_j + \rho_j \log(\tau_{j,t}) + \epsilon_{j,t+1}, \quad \text{with} \quad \epsilon_{j,t} \sim \mathcal{N}(0,\sigma_j) \tag{12}$$

with $\bar{\tau}_j$ denoting the mean value of the tax variable $\tau_{j,t}$, for $j = c, w, f$.

1.5 Nash bargaining

Wages and hours worked are derived from the generalized Nash-bargaining model (Pissarides 2000), with firm's relative bargaining power ϵ_i:

$$\max_{w_{i,t},h_{i,t}} (\lambda_{i,t}\mathcal{V}_t^F)^{\epsilon_i}(\mathcal{V}_{i,t}^H)^{1-\epsilon_i} \tag{13}$$

with $\mathcal{V}_{i,t}^F = \frac{\partial \mathcal{W}(\Omega_{i,t}^F)}{\partial N_{i,t}}$ the marginal value of a match for a firm, $\mathcal{V}_{i,t}^H = \frac{\mathcal{W}(\Omega_{i,t}^F)}{\partial N_{i,t}}$ the marginal value of a match for a worker, and $\lambda_{i,t}$ be the shadow price of the budget constraint.

It is worth stressing that, under the separability assumption, optimal households' decision rules imply

$$C_{i,t}^{C,n} = C_{i,t}^{C,u} \equiv C_{i,t}^C = (\mathcal{P}_{i,t}^C(1+\tau_{c,t}^i)\lambda_{i,t})^{-1} \tag{14}$$

$$U_{i,t}^u = U_{i,t}^n + \left(\Gamma_i^u - \Gamma_{i,t}^n\right) \tag{15}$$

For the home country ($i = 1$), this entails the following hours of work contracts[2]

$$\begin{aligned} \left(\frac{1-\tau_{w,t}^1}{1+\tau_{f,t}^1}\right)(1-\alpha)\frac{Y_{1,t}}{N_{1,t}h_{1,t}} &= \sigma\frac{(1-h_{1,t})^{-\eta}}{\lambda_{1,t}} \\ \Leftrightarrow (1-\alpha)\frac{Y_{1,t}}{N_{1,t}h_{1,t}} &= \sigma(1-h_{1,t})^{-\eta}TW_{1,t}\mathcal{P}_{1,t}^c C_{1,t}^c \end{aligned} \tag{17}$$

where $TW_{i,t} = \frac{(1+\tau_{f,t}^1)(1+\tau_{c,t}^1)}{1-\tau_{w,t}^1}$ stands for the tax wedge in this economy.

And the three following equivalent expressions for the wages contracts[3]

[2]Similarly, for the foreign country ($i = 2$) we have:

$$(1-\alpha)\frac{Y_{2,t}}{N_{2,t}h_{2,t}} = \frac{TW_{2,t}\mathcal{P}_{2,t}^C C_{2,t}^C}{p_t}\sigma(1-h_{2,t})^{-\eta} \tag{16}$$

Note that in this case the hours contracts are affected by the relative price of goods p.

[3]Similarly, for the foreign country ($i = 2$) we have:

$$(1+\tau_{f,t}^2)w_{2,t}h_{2,t} = (1-\epsilon_2)\left[(1-\alpha)\frac{Y_{2,t}}{N_{2,t}} + SC_{2,t}\right] + \epsilon_2\tau_{2,t}^n\left[\frac{\Gamma_2^u - \Gamma_{2,t}^n}{p_t\lambda_{2,t}} + (1-\tau_{w,t}^2)b_{2,t}\right] \tag{18}$$

Note that in this case the outside options are affected by the relative price of goods p.

Labor cost

$$(1+\tau_{f,t}^{1})w_{1,t}h_{1,t} = (1-\epsilon_1)\underbrace{\left[(1-\alpha)\frac{Y_{1,t}}{N_{1,t}} + SC_{1,t}\right]}_{\text{Bargained Surplus}} + \epsilon_1\left(\frac{1+\tau_{f,t}^{1}}{1-\tau_{w,t}^{1}}\right)\underbrace{\left[\frac{\Gamma_1^u - \Gamma_{1,t}^n}{\lambda_{1,t}} + (1-\tau_{w,t}^{1})b_{1,t}\right]}_{\text{Outside option}} \quad (19)$$

Net wage

$$(1-\tau_{w,t}^{1})w_{1,t}h_{1,t} = (1-\epsilon_1)\left(\frac{1-\tau_{w,t}^{1}}{1+\tau_{f,t}^{1}}\right)\left[(1-\alpha)\frac{Y_{1,t}}{N_{1,t}} + SC_{1,t}\right] + \epsilon_1\left[\frac{\Gamma_1^u - \Gamma_{1,t}^n}{\lambda_{1,t}} + (1-\tau_{w,t}^{1})b_{1,t}\right]$$

Gross wage

$$w_{1,t}h_{1,t} = \frac{1-\epsilon_1}{1+\tau_{f,t}^{1}}\left[(1-\alpha)\frac{Y_{1,t}}{N_{1,t}} + SC_{1,t}\right] + \frac{\epsilon_1}{1-\tau_{w,t}^{1}}\left[\frac{\Gamma_1^u - \Gamma_{1,t}^n}{\lambda_{1,t}} + (1-\tau_{w,t}^{1})b_{1,t}\right]$$

where, for $i = 1, 2$ the search costs SC are defined by:

$$SC_{i,t} = \omega_i \left\{ \underbrace{\frac{V_{i,t}}{1-N_{i,t}} E_t\left[\left(\frac{1+\tau_{i,t}^{f}}{1+\tau_{i,t+1}^{f}}\right)\left(\frac{1-\tau_{i,t+1}^{w}}{1-\tau_{i,t}^{w}}\right)\right]}_{\mathbf{a}=\text{Outsiders}} + \underbrace{\frac{1-s_i}{\Phi_{i,t}}\left(1 - E_t\left[\left(\frac{1+\tau_{i,t}^{f}}{1+\tau_{i,t+1}^{f}}\right)\left(\frac{1-\tau_{i,t+1}^{w}}{1-\tau_{i,t}^{w}}\right)\right]\right)}_{\mathbf{b}=\text{Insiders}} \right\} \quad (20)$$

where SC_i denotes the average search and matching costs per hiring incurred by firms.

As in the standard search framework, the wage bill turns to be some weighted average of (i) the worker's contribution to output plus the average costs per hiring, and (ii) the worker's endogenous outside options. Nonetheless, this time the search costs are affected by the dynamics of the labor tax rates. Likewise, the income and intertemporal effects that shape the outside opportunities (through variations in $\lambda_{i,t}$) depend not only on variations in the relative price of goods, but also on variations in the consumption tax. All this together could potentially lead to counter-cyclical wage dynamics, converse to the standard setting.

The impact of taxes on the labor supply

The impact of taxes on the number of hours worked and on wages is as follows:

- **Hours worked and taxes.** Equation (17) shows that the marginal productivity net of the labor taxes (payroll tax and labor income tax) is equal to the marginal disutility of labor. The introduction of these two taxes reduces the labor supply as households prefer leisure, because this good is not taxed. Moreover, the tax on consumption also decreases the number of hours worked because it increases the cost of consumption and then reduce the incentives to work.

- **Bargained wage and taxes.** In the bargaining process, either the firm or the worker try to incorporate their own tax burden in the wage (the payroll tax for the firm, and the labor income tax and the consumption tax for the worker). The three equations in (19) show that following a labor tax increase (τ_w or τ_f), the fraction of the bargained surplus distributed to the workers decreases. This clearly reduces the net wage, diminishing the labor supply. The gross wage equation provides another way to interpret the impact of the labor taxes on the labor supply: an increase of the payroll tax decreases the bargained surplus distributed to the workers, by decreasing the workers bargained power, whereas an increase of the labor income tax acts as an increase of the bargaining power of the firms. The consumption tax has an impact on wages through the higher cost of consumption, leading to a higher value of the outside options. This also reduces the labor supply.

- **Search costs and taxes.** Converse to the standard setting, the search costs take into account the intertemporal substitution of labor. If, for instance, the labor income tax increases tomorrow ($\tau^i_{w,t+1} > \tau^i_{w,t}$), the firm anticipates a higher bargaining power than today: the term **b** in equation (20) increases. This would increase the value of keeping an insider (the probability of keeping a job is $1 - s_i$ and the search costs saved in that case amounts to $\omega_i/\Phi_{i,t}$). At the opposite, this would reduce the value of hiring today an outsider: the term **a** in equation (20) decreases. Likewise, if $\tau^i_{f,t+1} > \tau^i_{f,t}$ the term **a** will increase, whereas the term term **b** will decrease. In this case the intuition is that insiders have lower salary vindication today because they anticipate a fall in their purchasing power tomorrow. Conversely, the outsiders accept lower wages today because they anticipate that their outside options will be lower tomorrow (remember that the income of unemployed workers is also taxed). Since in both cases the insiders effect and the outsiders effect offset each other, the total outcome on the search costs is ambiguous.

1.6 Equilibrium

The optimal households' choices of contingent bonds lead to: $v_t = \beta \frac{\lambda_{i,t+1}}{\lambda_{i,t}} f(A)$. Under the assumption that all households have the same initial wealth distribution, we deduce that $\lambda_{1,t} = \lambda_{2,t} = \lambda_t$. Then, the search equilibrium in country $i = 1, 2$ is characterized by the following system of equations:

$$N_{i,t+1} = (1 - s_i)N_{i,t} + V_{i,t}^{\phi}[e_i(1 - N_{i,t})]^{1-\phi} \tag{21}$$

$$((1 + \tau_{c,t}^i)\mathcal{P}_{i,t}^c C_{i,t}^c)^{-1} = \lambda_t \tag{22}$$

The equalization of consumptions across countries following an idiosyncratic shock does not hold anymore even in presence of separable preferences. This is due to the change in the relative price of goods. In addition, in the present case the consumption gap increases as long as the consumption tax is shocked as well.

$$\begin{aligned} \frac{(1-\alpha)Y_{1,t}}{(1+\tau_{f,t}^1)N_{1,t}h_{1,t}} &= \frac{\sigma(1-h_{1,t})^{-\eta}}{(1-\tau_{w,t}^1)\lambda_t} \\ \frac{(1-\alpha)Y_{2,t}}{(1+\tau_{f,t}^2)N_{2,t}h_{2,t}} &= \frac{\sigma(1-h_{2,t})^{-\eta}}{(1-\tau_{w,t}^2)p_t\lambda_t} \end{aligned} \tag{23}$$

The intertemporal allocation of consumption and leisure is such that the marginal contribution of one hour of labor for the firm is equal to the marginal cost of one worked hour for the worker. Remark that in the foreign country the number of hours worked is affected by variations in the relative price of goods (p_t).

$$\begin{aligned} w_{1,t}h_{1,t} &= \frac{1}{1-\epsilon_1\rho_1}\left\{\frac{1-\epsilon_1}{1+\tau_{f,t}^1}\left[(1-\alpha)\frac{Y_{1,t}}{N_{1,t}} + SC_{1,t}\right] + \frac{\epsilon_1}{1-\tau_{w,t}^1}\left(\frac{\Gamma_1^u - \Gamma_{1,t}^n}{\lambda_t}\right)\right\} \\ w_{2,t}h_{2,t} &= \frac{1}{1-\epsilon_2\rho_2}\left\{\frac{1-\epsilon_2}{1+\tau_{f,t}^2}\left[(1-\alpha)\frac{Y_{2,t}}{N_{2,t}} + SC_{2,t}\right] + \frac{\epsilon_2}{1-\tau_{w,t}^2}\left(\frac{\Gamma_2^u - \Gamma_{2,t}^n}{p_t\lambda_t}\right)\right\} \end{aligned} \tag{24}$$

These expressions for the wage contracts are obtained by assuming that, at equilibrium, the unemployment benefits b amount to a fraction ρ of the wage bill, with ρ given by the average replacement rate: $b_{i,t} = \rho_{i,t} w_{i,t} h_{i,t}$. With this we can now now complete the analyze of the effects on the wage bill of the tax/benefit system: higher replacement rates imply unemployment benefit, which yields to higher wages because they now must compensate the higher outside options of the worker.

Given these contracts on the hours worked and wages, the labor demand is summarized by:

$$\xi_{1,t} \equiv \frac{\omega_1}{\Phi_{1,t}}, \quad \xi_{2,t} \equiv \frac{p_t \omega_2}{\Phi_{2,t}} \tag{25}$$

$$\xi_{1,t} = \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \left((1-\alpha) \frac{Y_{1,t+1}}{N_{1,t+1}} + (1-s_1)\xi_{1,t+1} - (1+\tau^1_{f,t+1}) w_{1,t+1} h_{1,t+1} \right) \right] \tag{26}$$

$$\xi_{2,t} = \beta E_t \left[\frac{p_{t+1}\lambda_{t+1}}{\lambda_t} \left((1-\alpha) \frac{Y_{2,t+1}}{N_{2,t+1}} + (1-s_2)\xi_{2,t+1} - (1+\tau^2_{f,t+1}) w_{2,t+1} h_{2,t+1} \right) \right]$$

$$q_{1,t} \equiv \mathcal{P}^c_{1,t} + \hat{\phi}(I^C_{1,t} - \delta K_{1,t}), \quad q_{2,t} \equiv \mathcal{P}^c_{2,t} + p_t \hat{\phi}(I^C_{2,t} - \delta K_{2,t}) \tag{27}$$

$$q_{1,t} = \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \left(\alpha \frac{Y_{1,t+1}}{K_{1,t+1}} - \delta \mathcal{P}^c_{1,t} + q_{1,t+1} \right) \right] \tag{28}$$

$$q_{2,t} = \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \left(\alpha p_{t+1} \frac{Y_{2,t+1}}{K_{2,t+1}} - \delta \mathcal{P}^c_{2,t} + q_{2,t+1} \right) \right]$$

The firm optimal choices of employment (equations (25) and (26)) are very similar to those of capital (equations (27) and (28)) because finding new workers takes time and effort, so that the existing labor force is viewed by the firm as an capital asset. Nonetheless, the firm's tends to reduce the number of vacancies as the payroll tax increases. Moreover, either the capital or the employment decisions are affected by the consumption tax trough λ_t.

The equilibrium on the goods market is given by the accounting equations for output,

$$\begin{aligned} Y_{1,t} &= C^1_{1,t} + C^2_{1,t} + I^1_{1,t} + I^2_{1,t} + \mathcal{C}_{1,t} + \omega_1 V_{1,t} \\ &= \gamma \left(\mathcal{P}^c_{1,t}\right)^\theta (C^c_{1,t} + I^c_{1,t}) + (1-\gamma)\left(\mathcal{P}^c_{2,t}\right)^\theta (C^c_{2,t} + I^c_{2,t}) + \mathcal{C}_{1,t} + \omega_1 V_{1,t} \end{aligned} \tag{29}$$

$$\begin{aligned} Y_{2,t} &= C^1_{2,t} + C^2_{2,t} + I^1_{2,t} + I^2_{2,t} + \mathcal{C}_{2,t} + \omega_2 V_{2,t} \\ &= (1-\gamma)\left(\frac{\mathcal{P}^c_{1,t}}{p_t}\right)^\theta (C^c_{1,t} + I^c_{1,t}) + \gamma \left(\frac{\mathcal{P}^c_{2,t}}{p_t}\right)^\theta (C^c_{2,t} + I^c_{2,t}) + \mathcal{C}_{2,t} + \omega_2 V_{2,t} \end{aligned} \tag{30}$$

$C^i_{j,t}$, $I^i_{j,t}$ respectively denote the demands for good j from country $(i = 1,2,\ j = 1,2)$

for consumption and investment. The job filling probability is given by

$$\Phi_{i,t} = \left(\frac{V_{i,t}}{e_i(1 - N_{i,t})}\right)^{\psi-1} \tag{31}$$

Finally,

$$Y_{i,t} = a_{i,t} K_{i,t}^{\alpha} (h_{i,t} N_{i,t})^{1-\alpha} \tag{32}$$

$$K_{i,t+1} = (1 - \delta) K_{i,t} + I_{i,t}^{c} \tag{33}$$

2 Empirical results

As we aim to shed new light on old debates, for numerous parameters, as well as for the stylized facts, we use standard values. The most are taken from the Backus, Kehoe, and Kydland (1994)' and Andolfatto (1996)' works. We also adopt a symmetric calibration of the two countries with a null net exports steady state. This facilitates the comparison of our results with a bulk of previous literature on international fluctuations. For the additional parameters, in particular those regarding taxes, the calibration procedure is quite traditional. However, matter of consistency, estimations and average values are based on the 1970:1-1986:4 period, as in Backus *et al.*(1994).

2.1 Parameterization

The technology parameters are calibrated as follows (Backus *et al.*(1994)). The autocorrelation parameter $\rho_{1,1} = \rho_{2,2} = \rho$ is set at 0.906. The cross-country diffusion parameter $\rho_{1,2} = \rho_{2,1} = \rho^*$ is fixed at 0.088 and $\upsilon_{1,2} = \upsilon_{2,1} = \upsilon$ is calibrated in order to get a correlation between technology innovations of 0.258. The depreciation rate δ is set at 0.025. α, which no longer corresponds to the labor share of output, is calibrated in order to get a labor share of 64%. And the discount factor β is set at 0.99.

The elasticity of substitution between domestic and foreign goods, θ, is set at 1.2, while the value of the home bias γ is set at 0.75. The capital adjustment cost parameter, $\hat{\phi}$ is calibrated in order to replicate the volatility of investment in each model configuration.

For the labor-market parameters, the calibration is symmetric across countries and rely mostly on Andolfatto (1996). The elasticity of the matching function with respect to vacancies and the firm's bargaining power are set to $\epsilon = \psi = 0.6$. The value of χ is chosen to be consistent with the stationary values (in the non-taxation economy) for the probability that a vacancy position becomes a productive job, the employment ratio and the fraction of time spent working: $\Phi = 0.9$, $N = 0.57$ and $h = 1/3$. The ratio of aggregate recruiting expenditures to output is fixed at $\omega V^*/Y^* = 1\%$, and the average fraction of time that nonemployed households devote to search to $e = h^*/2$. Following Hairault (2002), we choose $\eta = 5$ and the quarterly rate of transition from employment to non-employment equal to $s = 0.10$. Lastly, parameters σ and Γ^u are computed to be consistent with steady-state restrictions.

The last set of values concerns the evolution of the tax rates. We take as benchmark the US estimates to be found in table 3 (appendix A).

The equilibrium can now be computed numerically.

2.2 Models evaluation

The equilibrium decision rules are used to simulate the time paths for the variables of interest. The statistical properties of these simulated time series are then compared to the statistics summarizing the cyclical properties of the US and the model economies. Statistics are reported in Table 1. Models include our tax/benefit, international search model with standard separable preferences under four configurations: (i) fluctuations are only driven by productivity shocks (LMS1), (ii) fluctuations are driven as well by consumption tax shocks (LMS2), (iii) fluctuations are also driven by labor income tax shocks (LMS3), and (iv) fluctuations are also driven by payroll tax shocks (LMS4). That is, in last model fluctuations are driven by simultaneous shocks to technology and to all tax rates. In explaining the instantaneous responses of variables, we shall focus primarily on the home economy (country 1).

Table 1: Cyclical properties

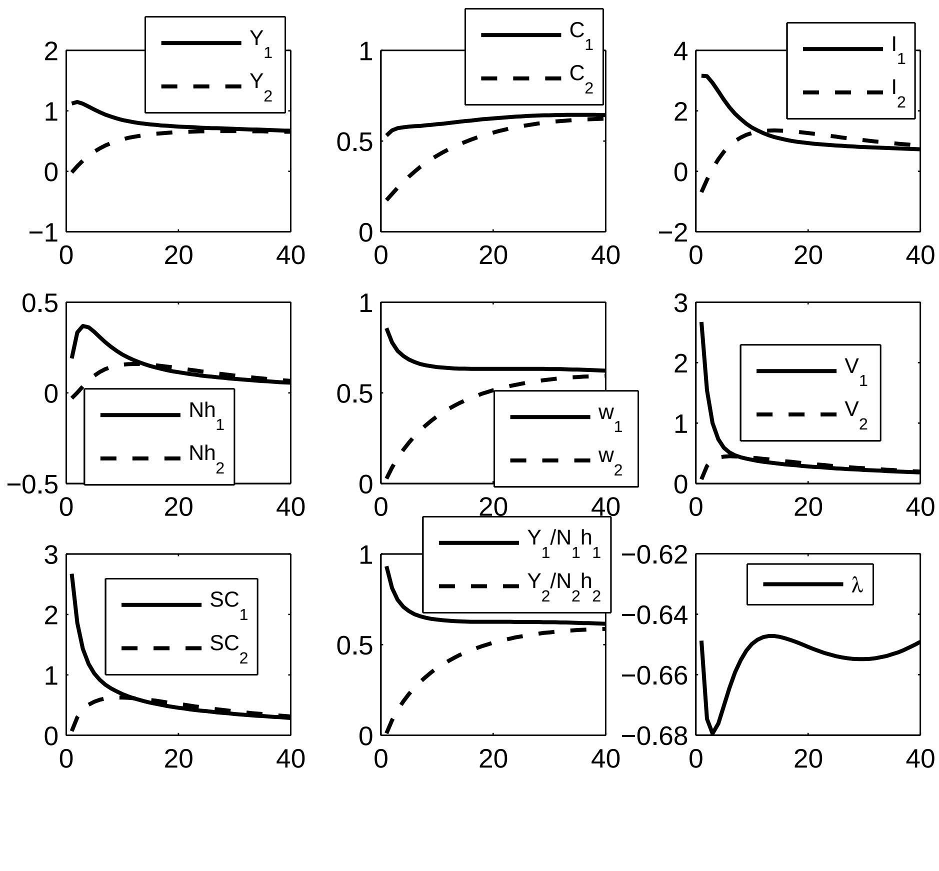
	Data	LMS1	LMS2	LMS3	LMS4
shock to:		a	a, τ_c	a, τ_c, τ_w	$a, \tau_c, \tau_w, \tau_f$
		$\phi = .165$	$\phi = .175$	$\phi = 0.21$	$\phi = 1.63$
International[a,e]					
$\rho(Y_1, Y_2)$	0.51	0.57	0.57	0.57	0.57
$\rho(C_1, C_2)$	0.40	0.95	0.46	0.48	0.49
$\rho(H_1, H_2)$	0.36	0.63	0.69	0.68	0.69
$\rho(I_1, I_2)$	0.38	-0.16	-0.08	0.06	0.12
USA[c,e]					
σ_Y (in %)	1.91	1.30	1.27	1.51	1.54
σ_C/σ_Y	0.40	0.45	0.62	0.56	0.55
σ_H/σ_Y	0.86	0.36	0.40	0.90	0.93
σ_I/σ_Y	3.07	3.06	3.07	3.05	3.05
σ_{LP}/σ_Y	0.57	0.70	0.71	0.67	0.67
σ_W/σ_Y	0.45	0.64	0.65	0.69	0.71
$\rho(Y_t, Y_{t-1})$	0.85	0.75	0.75	0.78	0.78
$\rho(C_t, C_{t-1})$	0.86	0.75	0.71	0.74	0.74
$\rho(H_t, H_{t-1})$	0.84	0.87	0.87	0.88	0.85
$\rho(I_t, I_{t-1})$	0.81	0.75	0.73	0.76	0.74
$\rho(LP_t, LP_{t-1})$	0.52	0.60	0.60	0.64	0.64
$\rho(Y, C)$	0.83	0.98	0.76	0.79	0.80
$\rho(Y, H)$	0.82	0.89	0.81	0.75	0.76
$\rho(Y, I)$	0.97	0.98	0.95	0.96	0.96
$\rho(Y, LP)$	0.51	0.97	0.94	0.47	0.43
$\rho(Y, W)$	0.28	0.99	0.95	0.37	0.33
$\rho(H, LP)$	-0.07	0.76	0.57	-0.21	-0.24
$\rho(H, W)$	0.03	0.81	0.60	-0.28	-0.28

The moments reported are computed from Hodrick-Prescott filtered artificial time series. [a] Backus, Kehoe, and Kydland (1995). [b] Hairault (2002). [c] Chéron and Langot (2004). [d] Baxter and Crucini (1993). [e] Hairault (1995).

Only technological shocks (LMS1).

Responses to productivity shock to country 1 are displayed in figure 1. On the demand side, the trade in the labor market, together with the international diffusion of technological shocks, makes firms of two countries start posting vacancies simultaneously. Then total hours rise slowly in the two countries. Since capital productivity increases, so do investment in both countries at impact. On the supply side, the wealth effects in the household's labor decisions is reduced by the deterioration of both the exchange rate and the terms of trade of country 1: E and p increase, as showed in the top left panel of figure 5. This leads to a slight dissociation of national consumption from foreign consumption.

Figure 1: IRF - Idiosyncratic shock to technology



Country 1 receives a positive 1% shock to productivity ($\rho_{12} = \psi = 0$).

Let us turn now to the analysis of the effects from shocks only to taxes. This is useful to understand the aggregate effect of simultaneous (positive) shocks to both productivity and taxes.

Consumption tax shock (LMS2).

An increase in the consumption tax reduces the demand for consumption. A temporarily high tax rate on consumption provides an incentive to postpone consumption to a later date, when the tax rate is likely to be lower. Hence, as the consumption tax fluctuates, so does consumption. Furthermore, because such a tax lowers the purchasing power of an hour worked, it also reduces the labor supply.

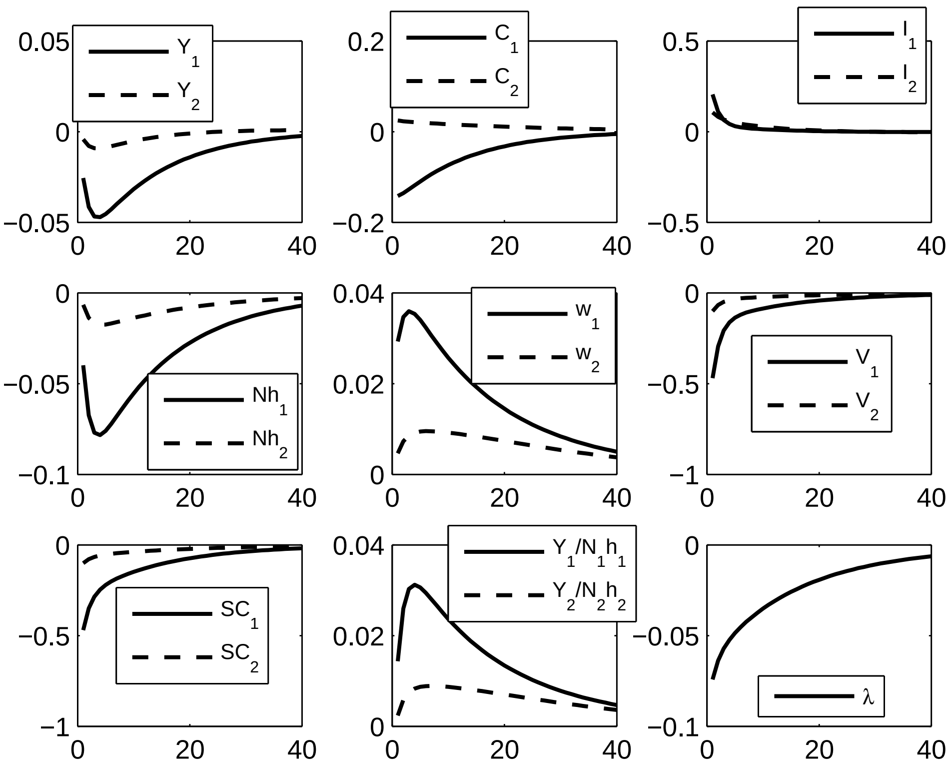
The increase in saving raises the agent's wealth and then her outside option. This reduces the incentives to post vacancies. Remark that converse to what one may expect from the analysis of the wage equation, the consumption tax shock largely dampens the search costs. Nevertheless, the dynamics of the outside options through the decrease in λ (figure 2) dominate, so that the real wage rate responds positively in the two countries. This reduces too the incentives to post vacancies. Aggregate hours of work go down in both countries, bringing output down below trend. This explains the positive international correlation of labor input.

Then, an additional positive shock to consumption tax in country 1 diminishes the cross-country correlation of consumption, so that it is even lower than the cross-correlation of outputs. This also enhances both, the volatility and the procyclicality of consumption. Looking at the IRF in figure 2 we see that, since the consumption tax encourages saving, this motivates the accumulation of capital, producing a positive response of investment in the first periods, which allows for a slightly positive response of output few periods later. Thereafter the economy slowly goes back to the steady state. This increases the predicted volatility of hours and consumption, bringing the implications of theory closer to the facts.

Labor income tax shocks (LMS3).

A positive 1% shock to country 1 labor income tax leads to a non-negative international correlation of consumptions, and to a higher volatility of aggregate hours, that now is very close to data. But the striking effect is the reduction of the correlation of real wage with both output and labor input. The IRF functions to a positive orthogonal 1% shock to labor income tax are plotted in figure 3. This shock produces a large response in aggregate hours, which falls about 1%. This is due to

Figure 2: IRF - Idiosyncratic consumption tax shock to country 1

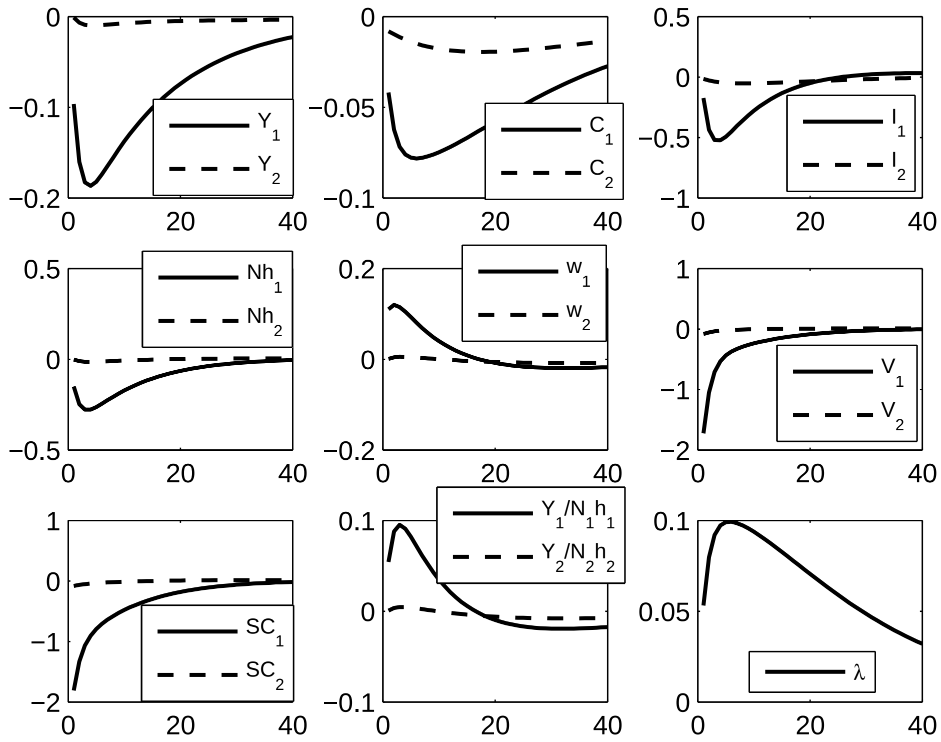


Country 1 receives a positive 1% shock to consumption tax.

the deeper rise in the real wage. Indeed, the direct impact of the labor income tax on wages is larger than the indirect adjustments of productivity and wealth: the labor income tax increases the real wage through the bargaining process. This higher tax also decreases labor input, implying higher productivity and lower reservation wage, due to the lower agent's wealth (λ increases). Then, we observe a sharper fall in vacancies and in the search costs than with a consumption tax shock. Basically, the leisure/labor supply decision is affected by an instantaneous substitution effect which induces households to reduce current consumption and work effort. The fall in aggregate hours, in turn, raises the average productivity in the early periods.

Finally, the larger instantaneous response of the hourly wage is also explained by the stronger effect on the outside options due to the fall in the relative prices of goods (p and E, figure 5), which offsets in part the increase in wealth (the fall in λ).

Figure 3: IRF - Idiosyncratic labor income tax shock to country 1



Country 1 receives a positive 1% shock to labor income tax.

Payroll tax shocks: all shocks at work (LMS4).

The effects of a positive shock to payroll tax in country 1 are plotted in figure 4. Apart from the real wage, the instantaneous responses of variables are qualitatively similar to those produced by the shock to the labor income tax. However, this additional shock produces higher volatility of hours, as well as higher international correlation of labor inputs. But now the international correlation of investment is positive and the correlation of real wage with output decreases by more.

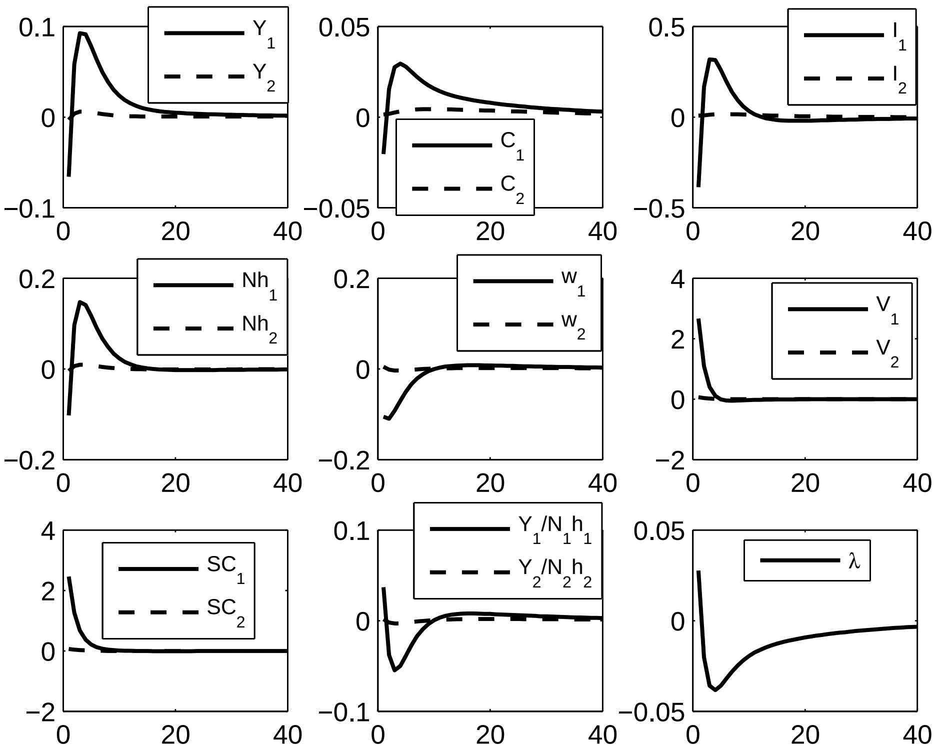
Converse to the previous scenario, the instantaneous response of the real wage to the payroll tax shock is negative in country 1. This shows that part of the tax burden of firms is supported by workers. The lower purchasing power of an hour worked implies a fall in both consumption and saving (investment). But even if the gross wage decreases, the labor cost increases. This explains the fall in aggregate hours. From the employment equation (equations (25 and 26) we see the direct negative effect of the higher payroll tax on the firm's employment decision. This adds to the larger fall in vacancies and in the search costs. With the retained calibration, all this reduces the real wage in country 1.

Furthermore, the volatility of aggregate hours is enhanced. In plain words, if income and payroll taxes fluctuate over time, it is optimal to work hard when taxes are relatively low and to take time off when they are relatively high. Then, as labor taxes fluctuate, so do hours worked.

To sum up, by adding the effects of all four shocks we better understand the quantitative implications of our economy. In this case the model reproduces quite well the facts regarding the international comovements: the international correlation of consumption is reduced, whereas the cross-country correlation of labor input, as well as that of investment is now positive, converse to the model with only technological shocks.

Concerning the labor market dynamics, the introduction of fiscal shocks allows to a significant reduction in the correlation of wages with both output and aggregate hours. The model also match the relative volatility of real wages. However, the relative standard deviation of hours is slightly overstated. Nevertheless, results are encouraging.

Figure 4: IRF - Idiosyncratic payroll tax shock to country 1



Country 1 receives a positive 1% shock to payroll tax.

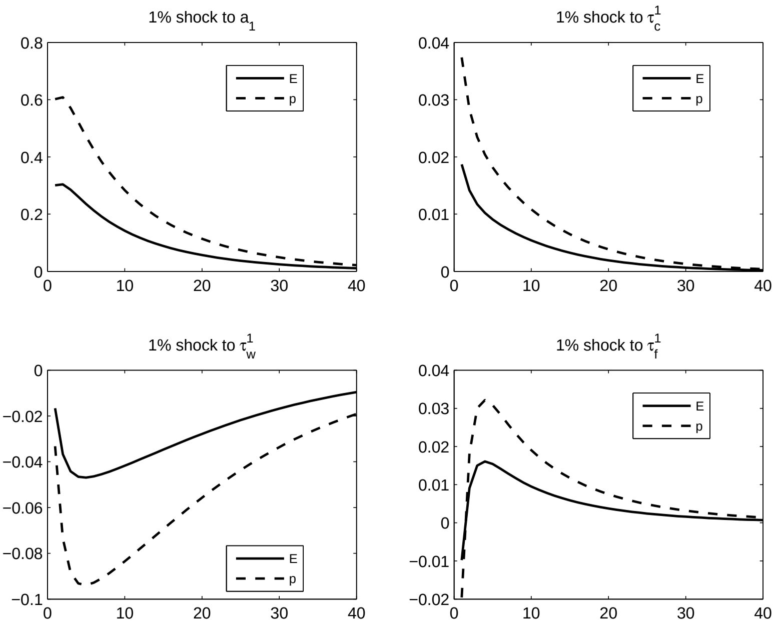
3 Conclusion

In this paper the effects of distortionary taxation are studied in the context of a two-country general equilibrium model with search and matching on the labor market. We show that distortive taxes on labor and consumption have important effects on the quantitative properties of the model, allowing to outperform the predictions from the model without taxation in several lines. In particular, we show that the fluctuations in distortive taxes provide a plausive explanation from the three empirical puzzles concerning the real wage dynamics and the international fluctuations.

Moreover, our framework reconciliate the standard separable preferences with either the observed U.S. real wage rigidity and the international fluctuations, by taking into account the tax/benefyt system. This provides simultaneously an explanation to the real wage rigidity puzzle, alternative to that of Chéron and Langot (2004); and an explanation to the quantities puzzle (concerning the ranking of the outputs correlation relative to the consumptions correlation), alternative to the Hairault (2002)'s one. In the two cases, the authors base their explanations on the non-separability of agents' preferences between consumption and leisure. However, this hypothesis is unable to simultaneously account for the real wage rigidity and for the observed international fluctuations.

Nevertheless, the problem of modelling income taxes has not been resolved in a fully satisfactory way. The volatility of labor input is exaggerated, whereas the persistence of output and the other macro aggregates is underestimated. Despite our model's shortcomings, it is striking how much we are able to explain by amending a basic two-country search model with fairly standard preferences to include fiscal policy variables.

Figure 5: IRF - Relative prices



IRF of the relative prices of goods E and p to the several shocks. a: tax/benefit economy when country 1 receives a positive 1% shock to productivity ($\rho_{12} = \psi = 0$).

A Tax rates

As in Ohanian *et al.*(2006), we use the series, comparable across countries and time, of average tax rates on consumption and labor income provided by McDaniel (2007). These series are deduced from the national accounts statistics and the method is the same as in Mendoza *et al.*(1994). The method is also close to the one in Prescott (2004). However, Prescott makes an adjustment to account for a progressive tax system and no such adjustments are made by McDaniel. Lastly, the payroll taxes are deduced deduced from the ratio of the compensation of employees (CoE) to the wage and salaries (WS). All these taxes should then be interpreted as average, not marginal. The estimated processes for taxes are showed in table 3.

However, in dealing with taxation, it is important to distinguish the average tax rate from the marginal tax rate. Whereas the average rate is an indicator of the global volume of taxation, the marginal rate, which measures the increase in taxation on each extra unit of income or expenditure, is an indicator of the progressivity of taxes. In progressive systems of mandatory contributions the marginal rate exceeds the average rate.

Some authors, such as Joines (1981) or McGrattan, Rogerson, and Wright (1997) calculate average marginal labor income tax rates in the US utilizing data (from the *Statistics Income* published by the Internal Revenue Service) that allow the authors to classify income taxes paid by adjusted gross income. McDaniel makes a comparison of her average taxes with these marginal taxes and concludes that both series display similar trends, but the average rates are slightly below the marginal rates, evidencing some progressivity.

Similarly, Cahuc and Zylberbeg (2004) present figures for 1990 (see table 2) for the average rate, the marginal rate, and the coefficient η_e of residual income progression as they apply to taxation on the income of a single person with an income equivalent to 167% of that of an average worker in 1999 from some OECD countries. A unitary coefficient means that average taxes are equal to marginal taxes (no progressive system), whereas a coefficient lower (resp. higher) than unity corresponds to a progressive (resp. regressive) system. Note that France and the UK have marginal rates clearly lower than those of the other countries, and the gap between the average rate and the marginal rate is also relatively narrow there, which is a sing that they are less progressive. But in all countries the coefficient of residual income progression is lower but not far from unity, so that our search model with average taxes is a good approximation.

Table 2: Average rates and marginal rates for a single person with an income equivalent to 167% of that of an average worker in 1999.

Country	Average Rate	Marginal rate	η_e
Denmark	51.6	63.3	0.76
France	31.0	35.4	0.93
Germany	47.5	58.5	0.79
Japan	19.3	30.8	0.85
Netherlands	39.1	50.0	0.82
Sweden	40.3	50.6	0.83
United Kingdom	26.6	33.0	0.91
Unites States	31.9	42.9	0.84

Source: Cahuc and Zylberbeg (2004), table 12.8, pp. 756. (Original source: OECD (2001), Taxing Wages: Income Tax, Social Security contributions and Cash Family Benefits, 1999-2000, Paris: OECD).

Moreover, as Piketty and Saez (2006) show, the progressivity has declined substantially since 1970 in the countries with available data: France, United States and United Kingdom. The last argument to justify the use of average taxes in our search economy concerns data availability: as all these authors point out, producing data on progressive taxes is very difficult and costly.

A.1 Exogeneity of taxes

Here we test the Granger causality of each tax process and the Solow residual. The steps followed for this exercise are the following:

1. We compute the TFP according to the Cobb-Douglas technology.
2. We compute the residuals from the regression of the logarithm of the TFP on a linear tendency and a constant. These residuals are our Solow residual $\mathcal{SR}$.

Table 3: Tax rates stochastic processes, United States

	$\hat{\tau}^{us}_{c,t+1}$	$\hat{\tau}^{us}_{w,t+1}$	$\hat{\tau}^{us}_{f,t+1}$
$\bar{\tau}^i_j$	0.083	0.207	0.197
ρ^i_j	0.920	0.928	0.820
σ^i_j	0.041	0.040	0.031
R^2	0.818	0.938	0.583

OLS estimations.

Table 4: Granger-causality tests - United States

	$\mathcal{SR}_{us}$	$\log(\tau^c_{us})$
$\mathcal{SR}_{us}$	0.00	0.08
$\log(\tau^c_{us})$	0.76	0.00
	$\mathcal{SR}_{us}$	$\log(\tau^w_{us})$
$\mathcal{SR}_{us}$	0.00	0.02
$\log(\tau^w_{us})$	0.07	0.00
	$\mathcal{SR}_{us}$	$\log(\tau^f_{us})$
$\mathcal{SR}_{us}$	0.00	0.21
$\log(\tau^f_{us})$	0.67	0.00

Lecture: The solow residual Granger-causes the labor income tax rate at 93% confidence level.

3. Finally, we estimate a VAR(1) of the logarithm of each tax series and the Solow residuals to test the Granger causality.

Table 4 reports the marginal probabilities p associated with the Granger-causality test. The columns reflect the Granger-causal impact of the column-variable on the row variable. Inferences are drown on the basis of a $(1-p)\times 100\%$ confidence level.

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