Payroll Taxes, Social Insurance and Business Cycles

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Abstract
Payroll taxes represent a major distortionary influence of governments on labor markets. This paper examines the role of time-varying payroll taxation and the social safety net for cyclical fluctuations in a nonmone-
tary economy with labor market frictions and unemployment insurance, when the latter is only imperfectly related to search effort. A balanced social insurance budget renders gross wages more rigid over the cycle and strengthens the model’s endogenous propagation mechanism. For conventional calibrations, the model generates a negatively-sloped Beveridge curve and countercyclical unemployment as well as substantial volatility and persistence of vacancies and unemployment.

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1 Introduction

Payroll taxes represent a major influence of governments on labor markets. In 2005, OECD member governments collected about $3 trillion from employers and employees, representing 9.2 percent of GDP and, given a wage share of two-thirds, roughly 15 percent of the total wage bill. In some European countries, the share of “contributions to social insurance” in total compensation is as high as 40 to 45 percent.¹ Payroll taxes drive a wedge between hiring decisions of firms and labor supply decisions of households, and are likely to spur the untaxed, informal economy. A less-studied aspect is the effect of time-varying labor taxation on intertemporal decisions of employers and employees. Not only do payroll taxes impact the long-run functioning of labor markets and the macroeconomy, but they may also affect the magnitude and persistence of business cycle fluctuations.

This paper investigates the interaction of payroll taxes, the social insurance system and the business cycle. We begin with an empirical examination of the cyclical behavior of payroll taxation in advanced economies. We find that the payroll tax burden is countercyclical in a number of countries: employer and employee contributions to social insurance, measured relative to the total wage bill, tend to fall in recoveries and rise in recessions. This countercyclical labor tax burden arises for at least two reasons. First, most OECD governments rely on payroll taxation to fund their social welfare systems, sometimes on a near-balanced budget basis. Second, payroll taxation is usually capped, implying a relatively higher effective rate of taxation for low-productivity workers at the extensive margin.

We study the effects of countercyclical payroll taxation in an equilibrium business cycle model with labor market frictions. We show that in this class

of models, the elasticity of search activity on both sides of the market is influenced by the intertemporal path of the wedge between labor costs paid by firms and income received by households. The sensitivity of the tax burden to cyclical conditions reinforces the intertemporal response of labor market activity and increases the endogenous propagation of shocks in the model economy. By distinguishing between search and leisure, we account for the possibility that non-working time is not used for active search and create an additional margin for time use. There are two other features central to the model: unemployment benefits are financed by payroll taxation on a balanced budget basis and unemployment benefit provision is only imperfectly related to search effort. This latter is due to social welfare payments in the model economy, which can also be thought of as ”Type II” classification error – paying unemployment benefits to individuals who are in fact enjoying leisure. Combined with the endogeneity of labor taxation, these effects significantly distort the labor-search-leisure decision and increase the internal propagation of the model economy.

Models with labor market frictions have proliferated in recent years, but exhibit a number of shortcomings in matching real data. Tripier (2003), Veracierto (2008), and Ravn (2008) show that with endogenous participation, the search model predicts a counterfactually positively-sloped Beveridge relation and procyclical unemployment. Shimer (2005) and Hall (2005) showed that such models generally do not generate sufficient volatility and persistence of labor market quantities, i.e. vacancies and unemployment. Moreover, Gartner, Merkl and Rothe (2009) point out that for Western European economies, in particular Ger-

\[2\] Tripier (2003), Ravn (2008) and Ebell (2009) examine similar setups, but they do not examine the impact of unemployment benefit on the search-leisure margin and do not consider unemployment benefits financed by distortionary payroll taxation.

\[3\] Wage rigidity, high fallback positions, low workers’ bargaining power and overlapping Nash-bargained wage contracts have been proposed to solve the puzzle (see Hagedorn and Manovskii, 2008, Cole and Rogerson, 1999, and Gertler and Trigari, 2009). However, Hornstein, Krusell and Violante (2005) and Costain and Reiter (2008) show that despite their successes, these models continue to exhibit a number of unwanted properties.
many, the Hall-Shimer labor market puzzles are even more pronounced than in the US.

The central finding of this paper is that the interaction of endogenous payroll taxation with social insurance system increases the stability of gross labor costs in a real equilibrium business cycle model, thereby better matching key macro stylized facts, which include high cyclical volatility of labor market quantities, persistence in vacancies and unemployment, and negative correlation of vacancies and unemployment (the Beveridge curve). Time-varying payroll tax burdens affect the both cost of labor and the value of vacancies to the firm, as well as the value of time spent by workers in search. This intertemporal effect of payroll taxation on equilibrium models of unemployment is also a novel finding.

In Section 2, we document the level and intertemporal behavior of payroll taxation in the major OECD countries. For a number of Western European economies (Finland, France, and Germany in particular), effective payroll taxes are significantly countercyclical; in the United States, a similar pattern has emerged since the late 1980s. Section 3 presents a nonmonetary dynamic stochastic general equilibrium economy with a social insurance system, unemployment benefits and endogenous search. The model is calibrated in Section 4, while Section 5 presents our central finding: a productivity-driven real equilibrium economy with search frictions can account for labor market facts and generate a pattern of countercyclical payroll tax burdens observed in many OECD countries. Robustness checks and more detailed interpretation of the results are laid out in Section 6. Section 7 concludes.
2 Payroll taxes in the OECD

2.1 Magnitude of payroll taxes

Payroll taxation represents a significant, yet frequently overlooked intervention in labor markets in developed economies. In 2008, the total contribution of households and enterprises to social security (i.e. payroll taxes) represented 33.7 percent of total compensation in Germany and 25.2 percent in Sweden, as compared with 11.3 percent in the United States (OECD Main Economic Indicators). Table 1 provides a longer-term perspective on payroll taxation. The payroll tax rate, $\tau$, is defined as the ratio of "contributions to social insurance" divided by total compensation of employees, and represents the average burden posed by payroll taxes and similar payments as a fraction of total labor costs paid by firms. Contributions to social insurance consist of payments by firms or employees for pension, health, unemployment and disability insurance, and related programs. Total compensation is defined as gross wages, salaries and other payments by employers on behalf of their employees. Our data are taken from the OECD Economic Outlook and Main Economic Indicators databases. The first two columns of the table document levels and trends of payroll taxation in countries for which longer time series are available.

The average effective payroll tax rate varies widely in OECD countries, ranging from 5-15% of the wage bill in Canada, the US and Finland to 30% or more in France, Germany and Sweden. As evident from Figures 1 and 2, they also vary over time. Over the four decades of data available, average taxes have risen secularly in almost all countries. At the same time, they fluctuate around their respective trends, with standard deviations of less than 0.2 percentage points in the US and Canada to more than 0.6% in Sweden, France, Finland, Greece, and the Netherlands. Such fluctuations of tax burdens are likely to important for labor markets, not only in continental Europe, but also in the United States.
Table 1: Payroll taxes in OECD countries, 1970-2008

<table>
<thead>
<tr>
<th>Country</th>
<th>Ratio of payroll taxes to total compensation (τ)</th>
<th>Correlation of payroll tax rate with GDP*</th>
</tr>
</thead>
<tbody>
<tr>
<td>US</td>
<td>0.10</td>
<td>0.12</td>
</tr>
<tr>
<td>Germany</td>
<td>0.28</td>
<td>0.34</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.29</td>
<td>0.29</td>
</tr>
<tr>
<td>UK</td>
<td>0.23</td>
<td>0.26</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.25</td>
<td>0.32</td>
</tr>
<tr>
<td>France</td>
<td>0.37</td>
<td>0.41</td>
</tr>
<tr>
<td>Japan</td>
<td>0.17</td>
<td>0.24</td>
</tr>
<tr>
<td>Canada</td>
<td>0.06</td>
<td>0.09</td>
</tr>
<tr>
<td>Finland</td>
<td>0.14</td>
<td>0.17</td>
</tr>
</tbody>
</table>

Source: OECD, authors’ calculations based on quarterly data
*Real GDP and tax rates are HP-filtered with smoothing parameter λ=1600.

Payroll taxes are primarily used to fund social insurance systems. Social insurance dates back to reforms in late-nineteenth century Germany, which served as a model for many industrial countries, including the United States. "Bismarkian" social insurance systems are characterized by a relatively low level of explicit redistribution; health, pension, and unemployment insurance programs honor entitlements based on past service or accrued eligibility. Contributions by workers and firms fund programs on a balanced budget basis, at least at the margin. Budgets of such programs are susceptible to business cycle fluctuations, with cyclical adjustments often required to bring contributions in line with outlays. In contrast, Beveridge’s notion of social insurance was based on a notion of minimum benefit funded in part or entirely by the general public budget. In many European countries, deficits in social security programs are

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4 In Germany about two-thirds of all social transfers in 2008 were financed by social contributions (payroll taxes); the corresponding figure in the United States was about one-half (OECD National Accounts, General Government Accounts, 2010).

5 In an effort to deflect criticism of rising inequality in a time of rapid growth, Bismarck initiated wide-reaching reforms during the 1880s, in particular the Health Insurance Act of 1883 (Gesetz betreffend die Krankenversicherung der Arbeiter), the Accident Insurance Act of 1884 (Unfallversicherungsgesetz) and the Old Age and Disability Insurance Act of 1889 (Gesetz betreffend der Invaliditäts- und Altersversicherung). These were important first pillars of the current German social insurance system, which were augmented in 1927 by the Law on Employment and Unemployment Insurance (Gesetz über Arbeitsvermittlung und Arbeitslosenversicherung).
regularly covered by budgetary transfers. The social security system of old-age benefits in the United States combines Bismarckian and Beveridgean elements. It is funded by payroll taxes, with employers withholding 6.2% of employee gross wages and matching that amount in employer social security taxes until total earnings reach a fixed earnings base (ceiling) for the year, above which no further tax is levied.

Figures 1 and 2 about here

2.2 Cyclical behavior of payroll taxes

For at least two reasons, the average payroll tax rate $\tau$ - and thus the tax burden for the representative worker moving from unemployment into employment - is likely to be countercyclical. In recessions, budget shortfalls are difficult to close, especially when social expenditures involve entitlements. As a result, tax rates may be raised in recessions and cut in expansions. While we focus on unemployment insurance and welfare benefits, countercyclical funding issues arise in systems of health services, public pensions and social programs in general. A second reason for countercyclical effective payroll tax rates is the cap on contributions in most OECD countries, which limits total annual tax liability of employers for a given employee.\(^6\) In expansions, when overall wages and productivity are rising, more workers will earn gross pay exceeding the contributions cap, while in recessions, new jobs tend to pay less, raising the effective tax burden on new employer-employee matches.

Figures 3 and 4 and the last three columns of Table 1 document that the average effective payroll tax rate ($\tau_1$) is not constant. To remove low frequency movements in the data, we applied the HP-filter to the payroll tax and real

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\(^6\)In the United States, the ceiling on social security contributions, which is adjusted annually for inflation, was $102,000 in 2008. This represents the roughly the 85th percentile of the annual gross household income distribution in the US. In Germany, the ceiling was 5500 Euro per month in 2008.
GDP series ($\lambda = 1600$). The overall contemporaneous correlation of the payroll tax rate and the business cycle in the period 1990-2008 was $-0.56$ in Germany, $-0.39$ in France, and $-0.48$ in Finland. While payroll taxation is acyclical in the United States over the longer sample period, it has become increasingly negatively correlated with the cycle over the last two decades; this is consistent with Romer and Romer (2009), who document that before the 1980s US Social Security tax increases tended to follow increases in benefits.\(^7\) Our finding for the US is consistent with the conclusion of the business cycle accounting literature and its concept of the "labor wedge" (see Chari, Kehoe and McGrattan, 2008), researchers in this area tend to stress those distortions originating in government regulation and other market imperfections. Rogerson and Shimer (2010) and Shimer (2009) argue that the labor wedge moves countercyclically, that is, in the same direction as our payroll tax measure.\(^8\)

**Figures 3, and 4 about here**

Policy can influence the sign of this correlation by breaking the link between payroll taxation and the business cycle which results from balanced budget policies. Already in the 1930s, Kaldor (1936) and Meade (1938) proposed setting payroll taxes to covary positively with the state of the economy, and their ideas were endorsed by Keynes (1942) and Beveridge (1944). In smaller, open OECD countries such as the Netherlands and Sweden, discretionary policy seems to have reduced the countercyclicality of the payroll tax rate or even rendered it procyclical. The increasing countercyclical behavior of the US payroll tax rate may also be due to increasing procyclicality in both levels and variance of

\(^7\)This finding is not an artifact of the detrending procedure. With first-differenced data, the correlation in the US over the two respective subperiods declines from 0.36 to -0.48. Moreover this correlation is becoming more negative over time, falling from 0.15 over the entire sample (1970-2008, Table 1) to -0.17 (1980-2008) to -0.36 (1985-2008) to -0.51 (1990-2008).

\(^8\)The correlation between HP-detrended versions of Shimer’s (2009) wedge measure for the US and the average payroll tax rate is 0.52 for the period 1990-2006 (for the period 1970-2006 it is only 0.10).
wages, given the contributions cap.\(^9\)

In the next section, we examine the effects of distortionary payroll taxation in a dynamic stochastic general equilibrium model of the business cycle with labor market frictions along the lines of Tripier (2003), Veracierto (2008), and Ravn (2008), to which we add a system of unemployment benefits and social assistance funded by distortionary labor taxation. We study the extreme case of a balanced-budget version of the model, in which the government sets payroll taxes to fund unemployment benefit and social assistance outlays due each period. In our representative agent setting presented below, the funding constraint is the sole cause of countercyclical labor taxation, leaving heterogeneity in the wage distribution to future research.

3 An equilibrium business cycle model with payroll taxation

3.1 Labor market search

Subscripts refer to periods of discrete time \(t \geq 0\). The economy is populated by a large number of infinitely-lived, identical consumer-worker households of measure one. Each household consists of a large number of individuals who derive utility from consumption and leisure. Workers (or family members) can spend their nonworking time in active unemployment (i.e., searching) or in leisure. If non-sleeping time is normalized to unity, the representative agent faces the following time constraint:

\[
h_t + s_t + \ell_t = 1
\]

where \(h_t\), \(s_t\), and \(\ell_t\) are measures of the household’s working time, search time, and leisure (which could include home production). The threefold use of time

reflects our interest in the distinction between search and voluntary unemployment and its interaction with payroll taxes and social insurance. Income from employment is taxed and governments payroll tax receipts are used to subsidize search (unemployment benefits), leisure (social welfare payments), and finance some exogenous component of government expenditures.

Workers and jobs search for each other in a decentralized labor market. Matching is the result of workers’ search activities, $s_t$, and firms’ posted vacancies, $v_t$, and takes the form of a constant returns matching function, $M(s_t, v_t) = s_t^p v_t^{1-p}$. At the same time, filled jobs are broken up each period at an exogenous rate, $\delta^h$, with $0 < \delta^h < 1$. In the absence of on-the-job search, the vacancy-unemployment ratio $\theta_t \equiv v_t/s_t$ is a sufficient statistic of market tightness. The vacancy placement rate $q_t$, is linked to the job-finding rate among the searching unemployed $f_t$, by the relation $q_t = \frac{M(s_t, v_t)}{v_t} = M\left(\frac{s_t}{v_t}, 1\right) = \frac{M(1, s_t)}{v_t} = \frac{1}{\theta_t}$. Employment at the beginning of period $t$, $h_t$, is a state variable for the household. From the perspective of the individual searcher, $f_t$ is the probability that a match will occur. For the aggregate economy, employment obeys

$$h_{t+1} = s_t f_t + (1 - \delta^h) h_t. \tag{2}$$

Similarly, $q_t$ is the probability that an open vacancy will be matched in a period (the job matching rate per vacancy posted) so the following aggregate relationship also holds:

$$h_{t+1} = v_t q_t + (1 - \delta^h) h_t. \tag{3}$$

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10 Without loss of generality it is possible to modify this model to reflect more standard time use assumptions as well as costly labor market state switching.

11 See Merz (1995) and Andolfatto (1996) for the seminal contributions to this literature.

12 Shimer (2005) and Hall (2005b) argue that the cyclical variability of separations is dominated by that of outflows from unemployment.
3.2 Government and social insurance

The government collects social security contributions in this one-good economy from gross factor payments to labor, $w_t h_t$, at rate $\tau_t$. Revenues from payroll taxes are used to finance exogenous government purchases related to social insurance $g_s$, unemployment benefits $b$ paid to $s_t$ unemployed engaged in search, and $\varepsilon b$ paid to $(1-s_t-h_t)$ household members enjoying leisure.\(^{13}\) The parameter $\varepsilon \in (0, 1)$ can be interpreted alternatively as a measure of ”classification error”, malfeasance in the unemployment system, or overall generosity of the welfare state.\(^{14}\) A positive $\varepsilon$ means that household members not actively searching still receive some level of government transfers, a characteristic of many OECD social security systems. The government adjusts the payroll tax rate $\tau_t$ in each period to respect the budget constraint

$$g_s + bs_t + \varepsilon b(1-s_t-h_t) = \tau_t w_t h_t. \tag{4}$$

As $\varepsilon$ approaches 1, search time and leisure are ”rewarded” equally in terms of consumption goods. As $\varepsilon$ approaches zero, the system replicates the standard model, and leisure does not yield benefits to household beyond beyond its utility value to households. Writing the payroll tax rate as

$$\tau_t = \frac{g_s + (1-\varepsilon) bs_t + \varepsilon b(1-h_t)}{w_t h_t}, \tag{5}$$

we see that a sufficient condition for countercyclical $\tau_t$ is for $w_t$ and $h_t$ to be procyclical and $s_t$ countercyclical. The level of payroll taxation and thus distortion in the economy is driven by the level of social security spending in the system $g_s$, the generosity of unemployment insurance ($b$) and welfare benefits ($\varepsilon$) as well as endogenous labor market outcomes ($h_t$ and $s_t$). While the financing of social security in this parsimonious model is simple and excludes many aspects

\(^{13}\)Government purchases of goods and services include health care expenditures (excepting sick pay) and the overhead administration costs of the welfare, pension, and disability systems.

\(^{14}\)See Burda and Weder (2002) for a similar formulation.
of the social security net, it sufficient to replicate countercyclical patterns of payroll taxation in the data.

To enhance the calibration below, we model the government as spending total $g$ in total, of which the remainder $g - g_{si}$ is financed by nondistortionary (lump-sum) taxation.

### 3.3 Household behavior

A representative household chooses labor and capital market activities to maximize expected utility. Labor services $h_t$ are compensated at net rate $(1 - \tau_t)w_t$. The household owns the capital stock used in production, $k_t$, and sells capital services deriving from it, $\kappa_t$, to firms in a competitive market. These capital services are the product of the capital stock and its utilization rate, $u_t$, i.e. $\kappa_t = u_t k_t$. The representative agent chooses $\kappa_t$ and $u_t$ subject to the dependence of depreciation on the latter:

$$\delta^k_t = \frac{\Psi}{\omega} \kappa_t^\omega$$  \hspace{1cm} (6)

where $\Psi > 0, \omega > 1$.\(^{15}\) Given sequences of market real wages, $\{w_t\}$, and rental rates for capital services, $\{r_t\}$, the household at $t = 0$ chooses sequences of consumption $\{c_t\}$, search time $\{s_t\}$, employment tomorrow $\{h_{t+1}\}$, capital tomorrow $\{k_{t+1}\}$ and capital utilization $\{u_t\}$ to maximize expected utility given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[ \ln c_t + A_t^{1+x} \right],$$

given initial stock of capital ($k_0$) and level of employment ($h_0$), the period-by-period budget constraint for $t = 0, 1, ..$:

$$k_{t+1} + c_t = (1 - \tau_t)w_t h_t + (1 + u_t r_t - \delta^k_t)k_t + bs_t + eb(1 - s_t - h_t),$$  \hspace{1cm} (7)

\(^{15}\)Modeling depreciation as a convex function of capacity utilization is common and follows Greenwood, Hercowitz and Huffman (1988) among others. This feature is included to match GDP behavior more closely and is not essential for generating our findings.
the evolution of employment (2) and the dependence of depreciation on utilization (6). It is assumed that $A > 0$, $0 < \beta < 1$, and $\chi \leq 0$.

Let $z_t$ stand for an exogenous stationary stochastic process which describes the state of productivity in the economy, to be made more precise below. The maximized value of expected utility given current employment, capital stock and the state of the economy, $V(h_t, k_t; z_t)$, is governed by the Bellman equation for $t = 0, 1, \ldots$

$$V(h_t, k_t; z_t) = \max_{c_t, s_t, \tau_t, k_{t+1}, h_{t+1}} \ln c_t + A \frac{(1 - s_t - h_t)^{1+x}}{1+x} + \beta E_t V(h_{t+1}, k_{t+1}; z_{t+1})$$

subject to (2), (6) and (7), taking initial levels of employment and capital as given. Optimality is characterized by the following first-order necessary conditions:

$$\frac{1}{c_t} = \beta E_t \left[ \frac{1 + w_{t+1} (1 - \tau_{t+1}) - \delta_{t+1}^k}{c_{t+1}} \right]$$

(8)

$$r_t = \Psi w_t^{\omega-1}$$

(9)

and

$$A (1 - s_t - h_t)^x - \frac{b}{e_t} (1 - \epsilon) = \beta f_t E_t \frac{w_{t+1} (1 - \tau_{t+1}) - eb}{c_{t+1}}$$

(10)

$$+ \beta f_t E_t \frac{(1 - \delta^h - f_{t+1}) A (1 - s_{t+1} - h_{t+1})^x - \frac{b (1 - \delta^h) (1 - \epsilon)}{c_{t+1}}}{c_{t+1}}.$$

Equation (8) is the typical Euler equation for consumption while (9) equates the marginal return from selling capital utilization today to its marginal costs. Equation (10) determines the optimal intertemporal search-labor supply sequence. The left-hand side denotes the net marginal utility of leisure time lost from shifting time from non-search leisure to search activities today. The right-hand side is the net expected discounted marginal gain from search, which consists of the expected utility of earning wages $w_{t+1} (1 - \tau_{t+1})$ tomorrow less $eb$, the loss of benefit which would result from spending that time in leisure (note
if $\epsilon = 0$, leisure is not subsidized), plus the net utility gain from not having to search tomorrow. Search activity today is also influenced by future taxes; higher expected taxes tomorrow reduces the net return from work and thus the incentive to search today.

### 3.4 Firms

Firms maximize expected profits on behalf of their owners, the households. They produce output $y_t$ using a constant returns production technology

$$y_t = z_t \kappa_t^\alpha h_t^{1-\alpha}. \quad (11)$$

Periodic profits, $\Pi_t$, are given by

$$\Pi_t = y_t - w_t h_t - r_t \kappa_t - av_t. \quad (12)$$

We now assume that the logarithm of total factor productivity, $\ln z_t$, follows a stationary, first-order autoregressive stochastic process. Firms maximize the expected discounted value of profits, computed using the stochastic discount factor $\rho_{t+1} = \beta \lambda_{t+1}/\lambda_t$, by hiring capital services $\kappa_t$ from households, posting vacancies at $v_t$ at cost $a$ and, given the transition equation for employment, by choosing the volume of employment at the beginning of the next period, $h_{t+1}$.

The maximized value of the firm given current employment and the state of the economy, $W(h_t; z_t)$, solves the Bellman equation

$$W(h_t; z_t) = \max_{\{\kappa_t, v_t, h_{t+1}\}} \Pi_t + E_t [\rho_{t+1} W(h_{t+1}; z_{t+1})]$$

subject to (12) and the transition equation for employment from the firm’s perspective (3).

First-order conditions for the firm for $t = 0, 1, \ldots$ can be expressed as follows. Optimal choice of capital service input equates marginal product of capital services with the rental price:

$$\alpha \frac{y_t}{\kappa_t} - r_t = 0. \quad (13)$$
Optimal vacancy decisions are determined by

\[
\frac{a}{q_t} = E_t \rho_{t+1} \left[ \left(1 - \alpha\right) \frac{y_{t+1}}{h_{t+1}} + w_{t+1} + (1 - \delta^h) \frac{a}{q_{t+1}} \right]
\] (14)

which equates expected costs of posting a vacancy to the expected discounted value of profits of filling it (recursively, the marginal surplus of a match today plus vacancy costs saved if it survives to the next period).

### 3.5 Wage bargaining

The two surpluses derived above determine the joint surplus from a match between a worker and a firm. The surplus to a matched worker is \( V_{h_t} - V_n \), since the fallback position of a worker is to resume search or spend time in leisure. At the optimum, these two alternatives yield equal utility. Optimality implies that the marginal contribution to the value of the utility maximization program of an additional unit of time in search equals zero: \( V_n = 0 \). For firms, the surplus of an additional employed worker is \( W_{h_t} - W_n \). At the optimum, it must also be the case that \( W_n = 0 \). The joint surplus in the symmetric, free entry equilibria we will study in this model is therefore equal to \( W_{h_t} + V_{h_t} \).

The wage divides match surplus between worker and firm and is determined at the individual level (we abstract completely from collective bargaining). Individual workers are hired by a representative firm, which employs many workers. Labor’s bargaining power is summarized by \( \mu \in [0, 1] \), the Nash bargaining parameter which determines the split of the match surplus going to the worker. The surplus to the worker in terms of utility today is

\[
V_{h_t} = \frac{w_t(1 - \tau_t) - b}{c_t} + \beta (1 - \delta^h - f_t) E_t V_{h_{t+1}}.
\] (15)

Note that as the solution to a standard Nash bargaining problem, the gross (before tax) wage is continuously renegotiated and there are no \textit{ad hoc} real
rigidities. In each period it solves

$$\max_{w_t} \mu \ln(V_{h_t}/\lambda_t) + (1 - \mu) \ln W_{h_t}$$

subject to the definitions of $V_{h_t}$ and $W_{h_t}$ and taking $\lambda_t$ as given, which is the marginal utility of resources at the optimum. In the Appendix, we show that the wage which solves this problem is given by:

$$w_t = \frac{(1 - \mu) b}{1 - \tau_t} + \mu (1 - \alpha) \frac{y_t}{h_t} + \mu (1 - \delta^n) \frac{a}{q_t} - \mu (1 - \delta^n - f_t) \frac{a E_t (1 - \tau_{t+1})}{1 - \tau_t}.$$  

(16)

Three features of the wage equation (16) are noteworthy. First, a novel and central aspect is the explicit role of payroll taxation, and in particular, its intertemporal path. *Ceteris paribus*, expectations of higher future payroll taxes will raise the bargained gross-of-tax wage today. Similarly, falling expected payroll taxes tomorrow will cause the bargained gross wage to decline today. If taxes are constant ($\tau_t = \tau_{t+1} = \tau$), the wage equation reduces to

$$w_t = \frac{(1 - \mu) b}{1 - \tau} + \mu (1 - \alpha) \frac{y_t}{h_t} + \mu \theta_t a,$$

and if $\tau = 0$, it collapses to the wage equation derived by, for example, Ebell (2008) or Ravn (2008). To the extent that an expanding economy implies lower expected payroll tax rates tomorrow and more moderate gross wage demands today, the model thus opens the possibility of endogenous gross wage rigidity.

A second noteworthy aspect of (16) is the interaction of payroll taxation with worker bargaining power, parametrized by $\mu$. For a constant profile of tax rates, the gross Nash-bargained wage depends positively on the level of taxes, but the extent of this forward shifting depends on $\mu$; greater workers’ bargaining power implies more shifting of taxes forward onto firms. This also applies to the impact of the expected tax profile on wages; wages of more powerful workers are more likely to reflect intertemporal considerations. As workers’ bargaining power approaches zero, i.e., $w(1 - \tau_t) = b$, the gross wage only reflects the
amount necessary to achieve indifference with the unemployment benefit paid to searchers.

Finally, while the wage is influenced by the unemployment benefit paid to searching unemployed, it is independent of the social safety net parameter $\epsilon$, holding constant the marginal product of labor $(1 - \alpha) \frac{Y}{M}$, market conditions $(f_t$ and $q_t)$, and the expected intertemporal path of taxes $\frac{E_t(1 - \tau_{t+1})}{1 - \tau_t}$. The parameter $\epsilon$ does however play a central role by determining the size of the social safety net, the level and intertemporal nature of search intensity by workers ($s_t$) and firms ($v_t$), and the volatility of $\tau_t$ in general equilibrium. From (10), as $\epsilon$ approaches unity, search is not only less attractive, but the gains from intertemporal reallocation of search activity increase. The net effect of these forces on labor market quantities and prices can only be studied in general equilibrium, to which we now turn.

4 Equilibrium and calibration

An equilibrium in this decentralized economy is defined as a set of sequences of prices, quantities and payroll tax rates $\{w_t\}, \{r_t\}, \{\kappa_t\}, \{k_t\}, \{u_t\}, \{h_t\}, \{s_t\}$, $\{v_t\}, \{y_t\}, \{e_t\}$, and $\{\tau_t\}$ which satisfy optimality conditions of households and firms, resource and budget constraints as well as a transversality condition for the capital stock, given the current values of the state variables employment, technology, and capital stock.

We begin by specifying the non-stochastic stationary state of this economy and its calibration, which is summarized in Table 2. Given the findings of Table 1, the German economy is a natural benchmark and we calibrate our economy to its average over our sample period (1970-2008). The fundamental period is a quarter.

---

Table 2: Parameter values, baseline calibration

<table>
<thead>
<tr>
<th>Postulated/assumed:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount factor, $\beta$</td>
<td>0.99</td>
</tr>
<tr>
<td>Steady state capital depreciation rate, $\delta^k$</td>
<td>0.025</td>
</tr>
<tr>
<td>Job separation rate, $\delta^n$</td>
<td>0.06</td>
</tr>
<tr>
<td>Frisch supply elasticity of nonleisure time, $-1/\chi$</td>
<td>0.20</td>
</tr>
<tr>
<td>Matching function elasticity, $\eta$</td>
<td>0.50</td>
</tr>
<tr>
<td>AR coefficient of log TFP process $\rho$</td>
<td>0.95</td>
</tr>
<tr>
<td>Vacancy cost share $av/y$</td>
<td>0.005</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Calibrated/matched to data:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor share, $wh/y$</td>
<td>0.67</td>
</tr>
<tr>
<td>Replacement rate, $b/w$</td>
<td>0.60</td>
</tr>
<tr>
<td>Unemployment rate $s/(s + h)$</td>
<td>0.07</td>
</tr>
<tr>
<td>Time working and searching, $h + s$</td>
<td>0.50</td>
</tr>
<tr>
<td>Labor taxation rate $\tau$</td>
<td>0.30</td>
</tr>
<tr>
<td>Consumption share $c/y$</td>
<td>0.58</td>
</tr>
<tr>
<td>Government purchases paid by soc.sec. $g_s/y$</td>
<td>0.08</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Calculated:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Elasticity of output wrt capital $\alpha$</td>
<td>0.3241582</td>
</tr>
<tr>
<td>Elasticity of depreciation to utilization $\omega$</td>
<td>1.4040</td>
</tr>
<tr>
<td>Vacancy cost $a$</td>
<td>0.30362775</td>
</tr>
<tr>
<td>Social transfer (misclassification) rate $\epsilon$</td>
<td>0.20992537</td>
</tr>
<tr>
<td>Bargaining power of workers $\mu$</td>
<td>0.56978009</td>
</tr>
<tr>
<td>Utility scale parameter $A$</td>
<td>0.04431910</td>
</tr>
<tr>
<td>Unemployment benefit $b$</td>
<td>1.16757537</td>
</tr>
<tr>
<td>Scale parameter for depreciation function $\Psi$</td>
<td>0.03510100</td>
</tr>
<tr>
<td>GDP share of government purchases $g/y$</td>
<td>0.19412470</td>
</tr>
</tbody>
</table>

While most parameter values are standard, our calibration and the implied steady state require more detailed discussion. At the steady state, the labor share is 67 percent and costs of posting vacancies ($av$) are half a percent of output; higher values of the vacancy share had no significant implications for our results. Our choice of $\beta$ implies an annual risk free rate of about four percent;
physical capital depreciates at 2.5 percent per quarter. We calibrate the share of private consumption in GDP at 0.58, the historic average 1990-2012 (OECD Main Economic Indicators), this allows us to compute $\alpha$ at 0.3242. By setting $\chi = -5$, we make individual labor supply less elastic than usually assumed in real business cycle models. The model is calibrated to match the replacement rate, $b/w$, at 60 percent. This value is significantly lower than that assumed by Hagedorn and Manovskii (2008) and it corresponds to values found in Western Europe. Steady state nonsleeping leisure time $1 - h - s$ is set to $1/2$ (Burda, Hamermesh, and Weil, 2008). The average unemployment rate is seven percent and $\tau$ is equated to the average of observed rate for Germany (30 percent). Our calibration also pins down overall government purchases $g$ at $g/y = 0.19$, which is close to the value given by the OECD (0.20). Government purchases financed by payroll taxes are calibrated as a share of GDP to 0.08, based on data from the Federal Statistical Office. The government’s steady state financing constraint $\tau w h = g_s + sb + \epsilon b(1 - s - h)$ pins down the "misclassification rate" at

$$\epsilon = \frac{\tau h}{h/w} - \frac{h(g_s/y)/(wh/y) - s}{1 - s - h} = \frac{(0.3)(0.465 - (0.08)/(0.67)}{(0.6)} - 0.035 = 0.20992537$$

The elasticity of the matching function with respect to searching unemployed is set to 0.5. The firm’s vacancies equation and the wage equation determine $A$ and the relative bargaining power at $\mu = 0.5698$. The elasticity parameter

---

17 This value is in line with micro studies of labor supply and reflects the usual criticism of the labor market in real business cycle models. We will show below that a high labor supply elasticity is not needed to induce high employment volatility.

18 While payroll taxation has increased in all countries over the sample period, this secular increase was relatively modest with the exception of Germany, which we address below. Table 1 suggests that most changes occurred with regards to payroll tax volatility. We therefore calibrate our model economy as if the steady state $\tau$ did not change.

19 Note that the last parameter does not coincide with the elasticity of the matching function,
\( \omega \) relating depreciation to capacity utilization is pinned down by the first order conditions for the household (7) and (8):

\[
\omega = \frac{1/\beta - 1 + \beta \kappa}{\kappa} = 1.4040.
\]

## 5 Cyclical properties of the artificial economy

In this section, we examine the central predictions of the model for macroeconomic and labor market variables. In particular, we are interested in artificial economies that exhibit cyclical behavior of payroll taxation as in Table 1. To do this, we simulate the artificial economy and compare the outcome to Germany, where the Hall-Shimer-Ravn labor market puzzles are even more pronounced than in the US (see Gartner, Merkl and Rothe, 2009). We begin by presenting key facts regarding the correlations of vacancies, unemployment, labor market tightness and labor productivity for the German economy in Table 3. All data are quarterly, Hodrick-Prescott detrended for the period 1970:1 to 2008:4.

We focus attention on three important empirical regularities in Table 3. The most well-known is the Beveridge curve, the empirical negative correlation between vacancies and unemployment. Second, the table features the inverse relationship of unemployment and labor market tightness, which is measured as the ratio of vacancies to unemployment. This measure of tightness rises in booms and declines in recessions. Third, unemployment and labor productivity, \( p \), are slightly negatively correlated; booms tend to be periods of higher labor productivity.

We first characterize the dynamics of our artificial economy in the absence of payroll taxes and thus in the absence of government spending financed by those taxes. This model is close in spirit to those studied by Tripier (2003), Ravn (2008), and Veracierto (2008), in which two distinct activities for nonemployed workers are possible, i.e. search versus leisure. All these authors were unable hence, the Hosios (1990) condition is not satisfied in this economy. Given the severe tax and other distortions already present, it seems inappropriate to assume the efficient outcome of the search process.
to replicate the negatively-sloped Beveridge curve, with unemployment instead fluctuating procyclically; since unemployment is equated with search activity, incentives to search are too procyclical.\textsuperscript{20} Table 4 confirms that our artificial economy - which is driven by a single technology shock - also displays this counterfactual property when the payroll tax rate $\tau$ is set to zero and social insurance is financed via lump-sum taxation. Without payroll taxes, our artificial economy fails to replicate the Beveridge curve relationship, instead generating a $s - \theta$ correlation of 0.87. While this version of the model predicts a positive correlation between productivity and market tightness, it is considerably stronger than in the data (model: 0.99, Germany: 0.29). Furthermore, it cannot generate the observed negative correlations between labor market tightness and labor productivity with unemployment.\textsuperscript{21}

<table>
<thead>
<tr>
<th>$v$</th>
<th>$s$</th>
<th>$\theta$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$v$</td>
<td>1.00</td>
<td>-0.81</td>
<td>0.96</td>
</tr>
<tr>
<td>$s$</td>
<td>1.00</td>
<td>-0.94</td>
<td>-0.24</td>
</tr>
<tr>
<td>$\theta$</td>
<td>1.00</td>
<td>0.29</td>
<td></td>
</tr>
<tr>
<td>$p$</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: $p$ denotes labor productivity.

<table>
<thead>
<tr>
<th>$v$</th>
<th>$s$</th>
<th>$\theta$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$v$</td>
<td>1.00</td>
<td>0.87</td>
<td>0.61</td>
</tr>
<tr>
<td>$s$</td>
<td>1.00</td>
<td>0.15</td>
<td>0.26</td>
</tr>
<tr>
<td>$\theta$</td>
<td>1.00</td>
<td>0.99</td>
<td></td>
</tr>
<tr>
<td>$p$</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A key finding of this paper is that central robust correlations in the data are restored in the presence of payroll taxes and a self-financing social security system. Tables 5 through 9 document these results. In Table 5 we report the same

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\textsuperscript{20}Hagedorn and Manovskii (2008) and Ebell (2009) have shown that some of these problems can be resolved by alternative calibration assumptions.

\textsuperscript{21}Ravn (2008) has called these results the "consumption-tightness puzzle."
labor market correlations for the calibrated economy with a positive and endogenous payroll tax rate and a social safety net of calibrated size ($\tau > 0$) but without government purchases $g_s = 0$. The calibrated model is qualitatively and quantitatively more consistent with correlations from the German economy. First, the Beveridge curve is restored, with a correlation of $-0.74$, essentially the value for the German economy. Second, the model economy produces a significant increase in the volatility of vacancies and unemployment (Table 6). Furthermore, unemployment and tightness are negatively correlated: the correlation reverses sign from 0.15 to $-0.91$, a value which is almost identical to the correlation in the German data. Theory can now also account for a weakly negative correlation between unemployment and productivity. Overall, the model resolves the puzzles put forward by Ravn (2008).

| Table 5: Labor market indicators and labor productivity, artificial economy ($\tau_l > 0$) |
|-----------------|-----------------|-----------------|-----------------|
| $v$  | 1.00  | -0.74  | 0.96  | 0.68  |
| $s$  | 1.00  | -0.91  | -0.03 |
| $\theta$ | 1.00  | -0.03  | 0.44  |
| $p$  | 1.00  | 0.44   | 1.00  |

In Tables 6 and 7 we consider other attributes of the artificial economy and show that the introduction of payroll taxation generates unemployment that not only moves countercyclically, but is also volatile and serially correlated, in line with German data. Likewise, vacancies are strongly cyclical. The "Shimer statistic" measuring the volatility of labor market tightness relative to that of labor productivity ($\sigma_{v}/\sigma_{p}$) increases in the artificial economy by about thirtyfold, also taking on a value similar to that in the data. Employment volatility also rises with procyclical payroll taxes. This is noteworthy since labor supply is relatively inelastic. The model also can track the pattern of other GDP aggregates. The correlation of employment and productivity, $\rho(h,p)$, drops from 0.69 to $-0.02$ after payroll taxes are allowed to vary, so our model better tracks
the orthogonality of productivity and employment. Finally, Table 7 suggests that the intertemporal effects of taxes on search and vacancy choice as well as on wage setting creates labor market persistence commonly observed in data; in our artificial economy, vacancies and unemployment exhibit autocorrelations much more consistent with empirical observation than the model without payroll taxation.\textsuperscript{22}

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|}
\hline
 & Germany & Model: $\tau = 0$ & Model: $\tau > 0$ \\
\hline\hline
$\sigma_y/\sigma_y$ & 13.24 & 1.82 & 12.37 \\
$\sigma_z/\sigma_y$ & 11.41 & 1.46 & 8.57 \\
$\sigma_h/\sigma_y$ & 0.64 & 0.16 & 0.80 \\
$\rho(v, y)$ & 0.67 & 0.61 & 0.99 \\
$\rho(s, y)$ & -0.74 & 0.16 & -0.81 \\
$\rho(b, y)$ & 0.55 & 0.76 & 0.78 \\
\hline
$\sigma_c/\sigma_y$ & 0.83 & 0.30 & 0.71 \\
$\rho(c, y)$ & 0.64 & 0.97 & 0.85 \\
$\sigma_i/\sigma_y$ & 2.64 & 3.63 & 2.66 \\
$\rho(i, y)$ & 0.82 & 0.99 & 0.84 \\
$\rho(b, p)$ & 0.04 & 0.69 & -0.02 \\
$\rho(c, \theta)$ & 0.66 & 0.98 & 0.77 \\
\hline
\end{tabular}
\caption{Macro moment comparisons, data and model}
\end{table}

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|}
\hline
 & Germany & Model: $\tau = 0$ & Model: $\tau > 0$ \\
\hline\hline
$\sigma_y/\sigma_p$ & 34.52 & 0.99 & 31.47 \\
$\rho(\theta, p)$ & 0.29 & 0.79 & 0.51 \\
$\rho(v, v_{-1})$ & 0.95 & 0.31 & 0.82 \\
$\rho(s, s_{-1})$ & 0.95 & 0.25 & 0.91 \\
\hline
\end{tabular}
\caption{Labor market tightness and persistence}
\end{table}

Note: $\tau$ stands for gross fixed domestic capital formation (investment expenditures).

\textsuperscript{22}When capital depreciation is held constant, $\rho(s, v) = -0.68$, $\rho(s, y) = -0.76$, and $\sigma_y/\sigma_p = 27.93$, hence while helpful, our results regarding the puzzles do not appear to depend on this feature of the model.

The model’s superior ability to replicate business cycle facts originates in the countercyclical behavior of payroll taxation, which follows directly from the balanced budget restriction and its effect on the wage bargain. Table 8 studies the cyclical behavior of real product wages in the artificial economy and
Germany, 1970-2008. Real wages are computed as the ratio of total labor compensation to total employees divided by the GDP deflator, with West German data chained with unified German data in 1991:1. The table shows that the introduction of taxes reduces (before tax) wage volatility significantly, with the relative standard deviation of wages declining by almost 50 percent. The wage rises less during booms, and the correlation with output is also cut by half. The effect of the tax system is to induce rigidity in gross wages paid by employers, even though gross and net wages are perfectly flexible. In Table 8, we show this directly by comparing wage behavior in the two models.

<table>
<thead>
<tr>
<th>Table 8: Wages (total compensation per employee)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \frac{\sigma_w}{\sigma_y} )</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>( \sigma_y )</td>
</tr>
<tr>
<td>( \rho(w, y) )</td>
</tr>
</tbody>
</table>

In Figures 5 to 8 we plot impulse responses of the model economy to a single productivity shock with and without a social security system financed by payroll taxes. In the presence of taxes, the model’s response becomes substantially more persistent. In particular, Figure 7 demonstrates the countercyclical pattern of taxes that arises endogenously in response to a positive technology shock. Figure 8 displays the relatively rigid response of the gross-of-tax wage, which is less volatile than output and dies out rapidly.

**Figures 5, 6, 7, and 8 about here**

### 6 Dissecting and interpreting the mechanism

Our central finding is that a calibrated RBC model with labor market frictions combined with an endogenous payroll tax and a distortion of the search-leisure decision can significantly increase endogenous propagation, restore the Beveridge curve, and significantly increase the volatility of labor market quantities. Our model achieves this without *ad hoc* assumptions regarding sticky wages,
extreme fallback positions or low worker bargaining power. In this section we examine the nature of these mechanisms in more detail.

6.1 The role of countercyclical payroll taxation

In this section, we show that the dynamic behavior of payroll taxes is central for generating for our results. Table 9 verifies that the payroll tax in the artificial economy with a fully-funded social insurance scheme exhibits relative volatility and countercyclical behavior consistent with the overall intertemporal pattern of average payroll tax rates in the data noted in Section 2. While \( \tau_t \) is more strongly correlated with output than in the data, it is important to keep in mind that our model is driven by a single shock. Overall, the general mechanism of tax fluctuations that we have uncovered in this paper is both qualitatively and quantitatively relevant.

<table>
<thead>
<tr>
<th>Table 9: Behavior of payroll tax rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
</tr>
<tr>
<td>( \sigma_{\tau}/\sigma_y ) = 1.57</td>
</tr>
<tr>
<td>( \rho(\tau, y) ) = -0.51</td>
</tr>
</tbody>
</table>

To demonstrate the importance of the countercyclical aspect of the distortionary payroll tax channel, we examine the behavior of our model economy under an alternative financing regime consisting of a constant payroll tax rate \( \tau \) and variable lump sum taxes, \( T_t \), adjusted each period to obey the government funding constraint

\[
g_s + bs_t + \varepsilon b(1 - s_t - h_t) = \tau w_t h_t + T_t. \tag{17}
\]

To maintain the comparability of both models and to isolate the level effect, we impose \( T = 0 \) in the steady state, so \( \tau \) assumes the same long-run value as in our baseline calibration and the steady state payroll tax distortion is unchanged. For comparability we continue to impose \( g_s = 0 \). While the model performs better than the version without distortionary taxation, the slope of the Beveridge curve
remains counterfactually positive, and unemployment is procyclical and \( \sigma_o/\sigma_p \) is only 3.48. Under the alternative financing arrangement, the correlation of the wage with output rises to 0.99 and its relative volatility nearly doubles. We have thus established that the variability of the payroll taxes, rather than its level, is the central factor driving the results reported in Tables 5-8.

The level of unemployment insurance payments is also important for our results, however. Reducing the steady state level of payroll taxation (and/or the replacement rate or the exogenous component of payroll tax-financed government purchases) attenuates the Beveridge curve correlation and can renders it positive (see Tables 4 versus 5). In addition, persistence and volatility of labor market quantities decline sharply. The generosity of the social welfare system, parametrized by \( \varepsilon \), plays a similar role; reducing \( \varepsilon \) lowers the volatility of vacancies and unemployment, yet the Beveridge relation survives. Lower values of \( \varepsilon \) reduce the payroll tax burden at any level of employment and gross wage, thereby reducing the amplitude of \( \tau_t \) necessary to maintain budget balance. The margin between leisure and search is crucial for generating volatility of labor market quantities; while the effect of lower \( \varepsilon \) is ambiguous in theory, the size of the welfare state, as given by in our calibrations is important for generating our findings.23

6.2 The role of the participation margin

The natural issue arises: how much of the above results is dependent on the labor market participation channel and how much comes from payroll taxation? To investigate this aspect, we contrast our model with those in which participation is constant, i.e. the agents either work or are searching while unemployed, e.g. 

\[ \tau_t = \frac{2s_t + b_t + \varepsilon(1-s_t-h_t)}{\sigma_b h_t}, \]

so for fixed \( b, s, h, \) and \( w_t \), \( \frac{\partial \tau_t}{\partial \varepsilon} = \frac{b(1-s_t-h_t)}{w_t h_t} > 0 \). However, lower values of \( \varepsilon \) will affect \( s_t, h_t \) and \( w_t \), so the general equilibrium effect is theoretically ambiguous.

23 Note \( \tau_t = \frac{2s_t + b_t + \varepsilon(1-s_t-h_t)}{\sigma_b h_t} \), so for fixed \( b, s, h, \) and \( w_t \).

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[ \ln c_t + A \frac{(1-h_t)^{1+\chi}}{1+\chi} \right]$$

which is maximized subject to the time constant

$$1 = h_t + s_t,$$

and a period budget of the household

$$k_{t+1} + c_t = (1 - \tau_t)u_t h_t + (1 + u_t r_t - \delta^k_t) k_t + b(1 - h_t).$$

The social insurance budget constraint becomes

$$\tau_t u_t h_t = g_s + bs_t.$$

In this exercise, social security expenditures $g_s$ are set to target the same steady state payroll tax rate in the original calibration ($\tau = 0.3$). The firm’s side of the model is unaffected by these changes. Payroll taxes in the simulated economy are countercyclical again, $\rho(\tau, y) = -0.98$. The model predicts $\sigma_0/\sigma_{y/h}$ at 12.24, closing a large part of the Shimer puzzle; in the absence of the tax channel, $\sigma_0/\sigma_{y/h}$ falls to 2.57.

### 6.3 Cross-country implications: Dynamics

The mechanism described in this paper can help understand a wider range of countries’ labor market dynamics besides those in Germany. This subsection compares patterns of payroll taxes and labor market dynamics across countries with some of the implications of our theory, keeping in mind that our model abstracts from a number of alternative influences such as fiscal and monetary policy, the banking system, and nominal price and wage rigidities. We have summarized some of the regularities of the data for five countries in the panels of Figure 9.24

\[24\] Unfortunately, data availability and data consistency for the longer period (1970-2008) limited the sample to only five OECD countries.
The first implication is that countries in which the correlation between payroll taxation and the business cycle is the most negative should have the largest value of the Shimer statistic \( \sigma_\theta/\sigma_\mu \) of relative volatility of labor market tightness. Intuitively, the greater the countercyclical variation of the tax rate, the more damped are gross labor costs to firms and the greater the quantity response. Panel a) of Figure 9 confirms this regularity for the period 1970-2008.

A second implication is that changes in the correlation over time should be negatively correlated with changes in the Shimer statistic. The second panel of Figure 9 shows this also to be the case for the five countries considered, with the most prominent changes originating in the United States (where the correlation between \( \tau \) and GDP became markedly more negative over the sample) and in Sweden (where an earlier negative correlation became positive). When payroll taxation becomes more countercyclical, on average labor market quantities become more volatile, supporting our theory’s claim of a significant role of payroll taxation on the dynamics of labor markets. Finally, Figure 9c) shows a tight positive relationship between the volatility of labor market tightness and the level of payroll taxes.

**Figure 9 here**

What is the quantitative prediction of the model of the link between the volatility of labor market tightness and the level of payroll taxes? To study this, we shut down the labor participation margin and vary \( T_i \) in government’s budget to rule out any feedback from varying marginal taxes rates. The wage equation becomes

\[
  w_t = \frac{1 - \mu}{1 - \tau} b + \mu (1 - \alpha) \frac{y_t}{h_t} + \mu \theta_i a.
\]

While a higher tax rate implies higher volatility, as in the original model, the effect is too weak to explain fully the level differences fully.
6.4 Cross-country implications: Steady States

Our model not only matches key business cycle facts, but it can offer a plausible account of changing levels of payroll taxation over time. In particular, increases in $\tau$ in Germany immediately following unification from 0.30 (the sample average) to almost 0.37 in the late 1990s can be attributed to a sharp increase in Eastern German unemployment, which triggered an extension of unemployment assistance to large groups of unemployable population as well as an increase in active labor market policies funded by the employment offices. While cyclical increases in $\tau$ are explained by cyclical variation in unemployment, secular increase in $\tau$ are only possibly in the model as a result of expansions of the social welfare state – unemployment compensation $b$, welfare generosity $\epsilon$, or the level payroll-tax-financed public expenditures $g_s$.

To illustrate this point, we examine a calibration of our model that matches the (West) German economy in the first half of our sample (1970-1990) when the average value of $\tau$ was 0.28. We assume a value of $g_s/y$ of 0.06, which effectively attributes the entire difference in $g_s$ between the two subperiods to increases in the cost of health care.25 The unemployment rate is pegged at 5% of the labor force. The implied bargaining power of labor, the scaling parameter for leisure’s contribution to period utility and vacancy costs are somewhat different ($\mu = 0.5255$, $\lambda = 0.0427$, and $a = 0.2123$). Besides values of $g_s$, $\epsilon$ and $b$, all other parameters are constant, as are calibration values for the labor share, vacancy costs in GDP, and UI replacement ratio. We then calculate increases in individual parameters of the social insurance system necessary to induce a steady state value of $\tau$ which matches its average value over the entire sample ($\tau = 0.30$) as well as over the sec-

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25According to the OECD, health costs in Germany were roughly 10% in the post 1990 period and roughly 8% in the 1970-1990 period. A lion’s share of increases in German health costs can be associated with the reunification episode.
The results are reproduced in Table 10.

<table>
<thead>
<tr>
<th>Calibration 1970-89</th>
<th>SI parameters needed to yield steady-state:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tau = 0.28$</td>
<td>$\tau = 0.30$</td>
</tr>
<tr>
<td>$\frac{g_s}{y}$</td>
<td>0.08278</td>
</tr>
<tr>
<td>$\epsilon$</td>
<td>0.09692 (+17.1%)</td>
</tr>
<tr>
<td>$b$</td>
<td>0.2515</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>0.2731 (+10.9%)</td>
</tr>
<tr>
<td>$\beta$</td>
<td>1.168</td>
</tr>
<tr>
<td>$\nu$</td>
<td>1.217 (+17.2%)</td>
</tr>
<tr>
<td>$\sigma_o/\sigma_p$</td>
<td>n.c.</td>
</tr>
<tr>
<td>$\psi$</td>
<td>0.08278</td>
</tr>
<tr>
<td>$\psi$</td>
<td>0.09692 (+17.1%)</td>
</tr>
<tr>
<td>$\psi$</td>
<td>0.1190 (+43.8%)</td>
</tr>
<tr>
<td>$\psi$</td>
<td>0.2515</td>
</tr>
<tr>
<td>$\psi$</td>
<td>0.2731 (+10.9%)</td>
</tr>
<tr>
<td>$\psi$</td>
<td>1.168</td>
</tr>
<tr>
<td>$\psi$</td>
<td>1.217 (+17.2%)</td>
</tr>
<tr>
<td>$\psi$</td>
<td>n.c.</td>
</tr>
</tbody>
</table>

6.5 Is the US an outlier? An alternative calibration and the role of the replacement rate

The United States is clearly an outlier in Figure 9. This status can be explained by a number of institutional aspects, or might reflect deep differences between it and Western Europe. To address this, we recalibrated our artificial economy to key characteristics of the US economy. We set $\epsilon$ to match $\tau$ to average US average payroll taxation and assume that the steady state unemployment equals five percent. Other parameters were not changed. The model economy’s Beveridge correlation is $\rho(u, v) = -0.45$; without the variable payroll tax, this correlation would have been strongly positive at 0.83. Moreover, unemployment is countercyclical at $\rho(s, y) = -0.81$. Hence, the model and the payroll tax mechanism can help account for US labor facts. Moreover, $\sigma_o/\sigma_p$ is 9.29 which is considerably higher than 0.99, the value for the artificial economy without variable payroll taxes. While the model is not designed to explain all aspects of the US labor market, it nevertheless offers a partial solution to key puzzles discussed in the literature. While payroll taxes are less countercyclical in the US, this is no longer true in the second half of our sample, nor is it true of Barro and Redlick’s (2011) constructed marginal payroll taxes.\(^{26}\)

\(^{26}\)Barro and Redlick (2011) construct annual series for average marginal federal, state and local income taxes as well as the federal payroll tax. We correlated all series with annual deviations from HP trended real GDP and find that while most tax series exhibited positive correlation with the business cycle, the correlation of payroll taxes with GDP was -0.347 in the period 1980-2006 and rose to -0.649 in the period 1990-2006.
To further compare our artificial economy with the results of others, we next vary the replacement rate. Hagedorn and Manovskii (2008) have shown that by setting $b/w$ sufficiently high, the Shimer puzzle disappears. Yet Mortensen and Nagypal (2007) criticize Hagedorn and Manovski’s small surplus calibration as unrealistic. Table 11 shows the effect of the surplus size for the payroll tax model (to conserve space we consider a model where we have assumed away the participation margin): by setting $b/w$ higher, yet not as high as Hagedorn and Manovskii (2008), payroll taxes can address both the Shimer as well as the Raviv puzzles.

<table>
<thead>
<tr>
<th>Table 11</th>
<th>Impact of replacement rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_y/\sigma_{y/h}$</td>
<td>$b/w = 0.4$</td>
</tr>
<tr>
<td>2.31</td>
<td>18.16</td>
</tr>
<tr>
<td>$\rho(s, y)$</td>
<td>-0.72</td>
</tr>
</tbody>
</table>

### 6.6 Interpretation

Our model with variable labor taxation better captures of labor market quantities because it induces a relative rigidity of gross wages, i.e. employers’ costs, and supports Hall’s (2005) claim that sticky wages can help align search models and data.\textsuperscript{27} Wages in our artificial economy accomplish this end even though they are endogenous. Although net wages and the return to work rise in upturns when labor markets are tightening, the negative effects on labor demand and vacancies are dampened by declining payroll taxation. Because gross wages react less strongly, higher employment does not translate as rapidly into higher costs for firms.

Consider a firm facing a higher realization of total factor productivity, $z_t$. Because posting of vacancies is a dynamic problem, present and future wage labor costs determine the optimal policy via (14). If labor costs faced by firms

\textsuperscript{27}In the extreme case of a zero workers’ bargaining power, i.e. $\mu \rightarrow 0$, the wage (15) does not respond to changes to productivity and it is fixed, given a constant tax rate. Thus, variation of bargaining power across countries can also account for different values of the Shimer statistic.
are expected to remain relatively flat over time, the expected surplus of creating jobs will be higher, and firms post more vacancies, which raises their volatility as well. At the same time, countercyclical payroll taxes renders net after-tax wages much less procyclical. Hence, even with sticky gross wages, workers will expect greater benefits from search in booms (see Equation 10), but because vacancies respond so strongly, search is more effective and the optimal strategy involves less search in recessions, not more.

The dampened volatility of gross wages induced by payroll tax movements is essential for bringing our model correlations in line with the data. As Table 6 shows, the standard model without payroll taxes cannot generate countercyclical unemployment. Households respond to a positive productivity shock by moving out of leisure and into search activities, which raises the level of unemployment sharply. In our model, a flatter labor cost profile induces the creation of many more vacancies than in the standard formulation, so while a positive technological shock makes search more attractive, searching workers are moved more rapidly out of leisure and into employment. The result is that at any stage of an expansion, fewer workers are unemployed, which is also consistent with empirical evidence that unemployment durations are strongly countercyclical. This is linked to the fact that vacancies become relatively more volatile than search (Table 6) so under the payroll tax regime search unemployment will be countercyclical – the combined effect is a negatively-sloped Beveridge curve.

7 Conclusion

It is well known that payroll taxes represent a significant long-run distortionary influence of governments on labor markets. In this paper, we argue that they can also affect business cycle dynamics. For a number of Western European economies as well as the United States for last two decades, the average payroll
tax burden has been countercyclical. Although we examine a specific type of labor tax, its behavior is consistent with Rogerson and Shimer’s (2010) description of a countercyclical labor wedge. Our analysis considers the role of the social safety net – modeled as a generous system of unemployment insurance – in creating such cyclical movements of payroll taxation in a nonmonetary economy with labor market frictions. A balanced social insurance budget renders gross wages more rigid over the cycle and, as a result, strengthens the model’s endogenous propagation mechanism. The existence of social insurance magnifies this effect, as does worker bargaining power. For conventional calibrations, the model generates a negatively-sloped Beveridge curve and matches the high volatility of vacancies and unemployment relative to labor productivity.

It is not the intention of this paper to produce a general account of high volatility of labor market quantities observed in modern economies, but we have identified a new mechanism which can contribute towards understanding the labor market and its interaction with the business cycle. Countercyclical taxation of labor can help resolve the Hall-Shimer puzzle and realign theory with many labor market regularities such as the Beveridge curve and countercyclical unemployment. Our results for a calibrated artificial economy imply that payroll taxes combined with a high subsidy of leisure can significantly affect the qualitative properties of an important class of equilibrium business cycle models. Other tax and transfer mechanisms in which a balanced budget constraint is operative each period may work in a similar fashion. The novel aspects of our model allow it to mimic a particular aspect of many OECD labor markets, and for the US in the latter half of our sample. In the absence of payroll taxes, our model exhibits the anomaly identified by Ravn (2008). A payroll tax used aggressively to balance a large social insurance budget is a straightforward mechanism for generating key second moments in the data while incorporating an important feature of modern labor markets.
References


Appendix: Wage equation

The first order condition from the Nash bargaining problem is

\[
\frac{\mu (1 - \tau_t)}{c_t V_{ht}} = \frac{(1 - \mu)}{W_{ht}}
\]

or, given that the value of an additional employed worker to the firm is given

\[
c_t V_{ht} = \frac{\mu (1 - \tau_t)}{1 - \mu} \left[ (1 - \alpha) \frac{y_t}{h_t} - w_t + (1 - \delta^n) \frac{a}{q_t} \right]
\]

(A1)

Lead this expression by one period and premultiply by the pricing kernel \(\rho_{t+1}\):

\[
\rho_{t+1} c_{t+1} V_{ht+1} = \frac{\mu (1 - \tau_{t+1})}{1 - \mu} \rho_{t+1} \left[ (1 - \alpha) \frac{y_{t+1}}{h_{t+1}} - w_{t+1} + (1 - \delta^n) \frac{a}{q_{t+1}} \right].
\]

Take expectation of both sides conditional on \(t\), and the fact that \(\rho_{t+1} c_{t+1} = \beta c_t\) to rewrite the last expression as

\[
E_t \rho_{t+1} c_{t+1} V_{ht+1} = \beta c_t E_t V_{ht+1} = \frac{\mu E_t (1 - \tau_{t+1}) a}{1 - \mu} \frac{1}{q_t}
\]

Premultiply both sides of the household surplus from employment by \(c_t\), substitute the last expression and use \(\rho_{t+1} = \beta c_t / c_{t+1}\) to obtain

\[
c_t V_{ht} = (1 - \tau_t) w_t - b + \rho_{t+1} (1 - \delta^n - f_t) c_{t+1} E_t V_{ht+1},
\]

and

\[
c_t V_{ht} = (1 - \tau_t) w_t - b + (1 - \delta^n - f_t) \frac{\mu E_t (1 - \tau_{t+1}) a c_t}{1 - \mu} \frac{1}{q_t}
\]

Now insert this and (A1) into the Nash bargaining first-order condition:

\[
\frac{\mu (1 - \tau_t)}{c_t V_{ht}} = \frac{(1 - \mu)}{W_{ht}}
\]

\[
= (1 - \mu) \left[ (1 - \tau_t) w_t - b + (1 - \delta^n - f_t) \frac{\mu E_t (1 - \tau_{t+1}) a}{1 - \mu} \frac{1}{q_t} \right]
\]
which can be solved to obtain

\[ w_t = \frac{(1 - \mu) b}{1 - \tau_t} + \mu (1 - \alpha) \frac{y_t}{h_t} + \mu (1 - \delta^n) \frac{a}{q_t} \frac{E_t (\tau_{t+1} - \tau_t)}{1 - \tau_t} + \mu \beta_t \frac{E_t (1 - \tau_{t+1})}{1 - \tau_t} \]

or

\[ w_t = \frac{(1 - \mu) b}{1 - \tau_t} + \mu (1 - \alpha) \frac{y_t}{h_t} + \mu (1 - \delta^n) \frac{a}{q_t} - \mu (1 - \delta^n - f_t) \frac{a}{q_t} \frac{E_t (1 - \tau_{t+1})}{1 - \tau_t}. \]
Figure 1: Payroll taxes as a fraction of total compensation, United States, 1970:1-2008:4

Figure 2: Payroll taxes as a fraction of total compensation, Germany 1970:1-2008:4
Figure 3: HP-detrended payroll taxes and GDP per capita, United States, 1970:1-2008:4

Figure 4: HP-detrended payroll taxes and GDP per capita, Germany 1970:1-2008:4
Figure 5: Impulse response functions (IRF) of the model economy without payroll taxes and social insurance system to a positive 1% technology shock (z): Output, unemployment, labor share
Figure 6: Impulse response functions (IRF) of the model economy without payroll taxes and social insurance system to a positive 1% technology shock ($z$): Vacancies, employment, wages, labor market tightness ($v/s$)
Figure 7: Impulse response functions (IRF) of the model economy with payroll taxes and social insurance system to a positive 1% technology shock: Output, unemployment, tax rate, labor share.
Figure 8: Impulse response functions (IRF) of the model economy with payroll taxes and social insurance system to a positive 1% technology shock: Vacancies, employment, wages, labor market tightness (v/s)
Figure 9: Payroll taxation, GDP and labor market tightness, five countries, 1970-2008

a) Payroll tax-GDP correlation $\rho(t, y)$ versus Shimer statistic ($\alpha_t/\alpha_y$)

b) Change in payroll tax-GDP correlation $\rho(t, y)$ versus change in Shimer statistic ($\alpha_t/\alpha_y$), 1970-1989 to 1990-2008

c) Payroll tax level versus Shimer statistic ($\alpha_t/\alpha_y$)