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 taxes and the social safety net for cyclical fluctuations in a nonmonetary economy with labor market frictions and unemployment insurance, when the latter is only imperfectly related to search effort. A balanced social insurance budget induces countercyclical payroll taxation, 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.

1 Introduction
Payroll taxes represent a major influence of governments on labor markets. In 2011, OECD member governments collected about $3.8 trillion from employers.

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and employees, representing 9.1 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.\(^2\) 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 several anomalies and shortcomings in matching real data. Tripier (2003),

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\(^1\)Source: OECD Revenue Statistics 2013 and OECD Factbook 2011-2012.

\(^2\)Tripier (2003), Ravn (2008) and Els"ell (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.
Veracierto (2008), and Ravn (2008) show that with endogenous participation, the search model predicts a counterfactually positively-sloped Beveridge relation and procyclical unemployment. Furthermore, 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 Germany, 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 most Western European economies, 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. In Section 4, we calibrate the model and present 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 5. Section 6 examines secular labor market trends through the lens of our model and 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. 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

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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 undesirable properties.
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.

<table>
<thead>
<tr>
<th>Country</th>
<th>Ratio of payroll taxes to total compensation, τ</th>
<th>Correlation of annual payroll tax rate with GDP*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>0.28</td>
<td>0.34</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.24</td>
<td>0.29</td>
</tr>
<tr>
<td>France</td>
<td>0.37</td>
<td>0.41</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.31</td>
<td>0.29</td>
</tr>
<tr>
<td>UK</td>
<td>0.22</td>
<td>0.26</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.09</td>
<td>0.16</td>
</tr>
<tr>
<td>Finland</td>
<td>0.14</td>
<td>0.15</td>
</tr>
<tr>
<td>Japan</td>
<td>0.17</td>
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</tr>
<tr>
<td>Belgium</td>
<td>0.32</td>
<td>0.39</td>
</tr>
<tr>
<td>Italy</td>
<td>0.36</td>
<td>0.38</td>
</tr>
<tr>
<td>Austria</td>
<td>0.30</td>
<td>0.35</td>
</tr>
<tr>
<td>Australia</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Norway</td>
<td>0.23</td>
<td>0.21</td>
</tr>
<tr>
<td>Canada</td>
<td>0.07</td>
<td>0.09</td>
</tr>
<tr>
<td>New Zealand</td>
<td>0.10</td>
<td>0.18</td>
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<tr>
<td>South Korea</td>
<td>0.10</td>
<td>0.18</td>
</tr>
<tr>
<td>Spain</td>
<td>0.25</td>
<td>0.30</td>
</tr>
<tr>
<td>US</td>
<td>0.10</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Source: OECD, authors’ calculations on annual data
Data from Denmark, Italy, New Zealand and South Korea start in 1981, 1980, 1986, and 1975, respectively.
*Tax rates and log real GDP are HP-filtered with smoothing parameter $\lambda = 6.25$.

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 Belgium, France, Germany, Italy and Spain. 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 be important for labor markets, not only in continental Europe, but also in the United States.

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. “Bismarckian” 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 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 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 liabil-

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4In 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).

5In 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).
ity of employers for a given employee. 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 1 and 2 and the first two columns of Table 1 document that the average effective payroll tax rate is subject to long-run trends. To remove low frequency movements in the data, we applied the HP-filter to the payroll tax and real GDP series. The results are displayed in Figures 3 and 4. The overall contemporaneous correlation of payroll tax rate and the business cycle in annual data for the period 1990-2012 was $-0.51$ in Germany (which coincides with results for quarterly data, $\rho = -0.49$). While payroll taxation is acyclical in the United States over the longer sample period, it has become countercyclical since 1990; 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. 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 distortions originating in government regulation and 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.

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 economies 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 wages, given the contributions cap.

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

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6 In the United States, the ceiling on social security contributions, which is adjusted annually for inflation, was $102,000 p.a. This represents the roughly the 85th percentile of the annual gross household income distribution in the US. In Germany, the ceiling was €67,000 p.a. (as of 2012).

7 This finding is not an artifact of the detrending procedure. With first-differenced quarterly data, the correlation in the US over the two respective subperiods declines from 0.01 to -0.20.

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).

9 See Gali and van Rens (2010) for recent evidence on the United States.
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 the setting presented below, we consider the funding constraint as 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 indexed by $t$. 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-household 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.\(^{10}\)

Workers and jobs search for each other in a decentralized labor market.\(^{11}\) 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, $M(s_t, v_t) = s_t^\alpha v_t^{1-\alpha}$. At the same time, filled jobs are broken up each period at an exogenous rate, $\delta^h$, with $0 < \delta^h < 1$.\(^{12}\) 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 $q_t = M(s_t, v_t) = M(s_t^\alpha v_t^{1-\alpha}) = M(1, v_t^{-1}) = \theta_t$. 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

\(^{10}\)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.
a match will occur. For the aggregate economy, employment obeys

\[ h_{t+1} = s_t f_t + (1 - \delta^b) h_t. \]  

(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:

\[ h_{t+1} = v_t q_t + (1 - \delta^b) h_t. \]  

(3)

### 3.2 Government and social insurance

The government collects social security contributions (payroll taxes) 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 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 (social welfare payments), and finance some exogenous part \( g_s \) of total government purchases \( g \), both discussed in more detail below.\(^\text{13}\) 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.\(^\text{14}\) 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

\[ bs_t + \varepsilon b (1 - s_t - h_t) + g_s = \tau_t w_t h_t. \]  

(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 its utility value to households. Writing the payroll tax rate as

\[ \tau_t = \frac{(1 - \varepsilon) bs_t + \varepsilon b (1 - h_t) + g_s}{w_t h_t}, \]  

(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 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 of the social security net, it sufficient to replicate countercyclical patterns of payroll taxation in the data.

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\(^{13}\)Government purchases of goods and services financed by payroll taxes 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.
3.3 Household behavior

A representative household chooses labor and capital market activities to maximize expected utility. Labor services $\eta_t$ are compensated at net rate $(1 - \tau_t)\omega_t$. 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, $\varphi_t$, 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:

$$\delta^k_t = \frac{\Psi}{\omega_t} u_t^\omega$$  \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 $\{\varphi_t\}$ to maximize expected utility given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[ \ln c_t + A \frac{\varphi^{1+\chi}_t}{1 + \chi} \right]$$

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

$$k_{t+1} + c_t = (1 - \tau_t)w_t h_t + (1 + u_tr_t - \delta^k_t)k_t + bs_t + eb(1 - s_t - h_t) - T,$$

the evolution of employment (2) and the dependence of depreciation on utilization (6). It is assumed that $A > 0, 0 < \beta < 1$, and $\chi \leq 0$. $T$ stands for lump-sum taxes imposed by the government so $g - g_s = T$.

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 $t = 0, 1, \ldots$

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

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:

$$\frac{1}{c_t} = \beta E_t \left[ \frac{1 + u_{t+1}r_{t+1} - \delta^k_{t+1}}{c_{t+1}} \right]$$ \hspace{1cm} (8)

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.
Equation (8) is the typical consumption Euler equation while (9) sets the marginal return from renting capital utilization to firms equal to marginal cost. 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 leisure to search activities today. The right-hand side is the net expected discounted marginal utility from search, which consists of the expected utility of earning wages \( w_{t+1}(1 - \tau_{t+1}) \) tomorrow less \( \beta \), the loss of benefit which results 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

\[
y_t = z_t \kappa_t^{\alpha} h_t^{1-\alpha}.
\]

Periodic profits, \( \Pi_t \), are given by

\[
\Pi_t = y_t - w_t h_t - r_t \kappa_t - \alpha v_t.
\]

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 \( w_t \) at cost \( \alpha \) 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:\[ \frac{y_t}{k_t} - r_t = 0. \] (13)

Optimal vacancy decisions are determined by
\[
\frac{a}{q_t} = E_t \rho_{t+1} \left[ (1 - \alpha) \frac{y_{t+1}}{h_{t+1}} - w_{t+1} + (1 - \delta^h) \frac{a}{q_{t+1}} \right]
\] (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 \( V_{h_t} - V_{e_t} \), 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: \( V_{e_t} = 0 \). For firms, the surplus of an additional employed worker is \( W_{h_t} - W_{e_t} \). At the optimum, it must also be the case that \( W_{e_t} = 0 \). 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
\[
V_{h_t} = \frac{w_t (1 - \tau_t) - b}{c_t} + \beta (1 - \delta^h - f_t) E_t V_{t+1}. \] (15)

Note that as the solution to a standard Nash bargaining problem, the gross (before tax) wage is continuously renegotiated and there are no 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:

\[ w_t = \frac{(1 - \mu) b}{1 - \tau_t} + \mu (1 - \alpha) \frac{y_t}{\bar{h}_t} + \mu (1 - \delta^n) \frac{a}{\eta_t} - \mu (1 - \delta^n - E_t) \frac{a E_t (1 - \tau_{t+1})}{1 - \tau_t}. \]

(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

\[ w_t = \frac{(1 - \mu) b}{1 - \tau} + \mu (1 - \alpha) \frac{y_t}{\bar{h}_t} + \mu \theta_t a, \]

(17)

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 \(\omega\). 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 \(\omega\): greater bargaining power of workers implies more shifting of taxes forward onto firms. This also applies to the impact of the expected tax profile on wages; wages of workers with more bargaining power are more likely to reflect intertemporal considerations, i.e. be more rigid. 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 unemployment benefit parameter \(b\) appears in the wage equation, the social insurance parameter \(\epsilon\) does not, given the marginal product of labor \((1 - \alpha) \frac{\bar{w}}{\bar{h}}\), market conditions \((f_t \text{ and } q_t)\), and the expected intertemporal path of taxes \(E_t (1 - \tau_{t+1}) \frac{1}{1 - \tau_t}\). Naturally, \(\epsilon\) plays a central role for the level and intertemporal nature of search intensity by workers \((s_t)\) and firms \((v_t)\), as well as the level and volatility of \(\tau_t\). From (10), as \(\epsilon\) approaches unity, search is not only less attractive, but the gains from intertemporal reallocation of search activity will shift. 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 Properties of the artificial economy

4.1 Equilibrium and benchmark calibration

An equilibrium in this decentralized economy is defined as a set of sequences of prices, quantities and the payroll tax rate \(\{w_t\}, \{r_t\}, \{\nu_t\}, \{s_t\}, \{u_t\}, \{h_t\}, \ldots\)
\( \{ s_t \}, \{ v_t \}, \{ y_t \}, \{ c_t \}, \text{ and } \{ \tau_t \} \) 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 quarterly data in the sample period 1970-2008.\(^{16}\) 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^h )</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 ( a v/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, ( w h/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>0.97</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>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Calculated:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Elasticity of output to capital, ( \alpha )</td>
<td>0.324</td>
</tr>
<tr>
<td>Elasticity of depreciation to utilization, ( \omega )</td>
<td>1.404</td>
</tr>
<tr>
<td>Social transfer (misclassification) rate, ( \epsilon )</td>
<td>0.395</td>
</tr>
<tr>
<td>Bargaining power of workers, ( \mu )</td>
<td>0.569</td>
</tr>
</tbody>
</table>

While most parameter values are standard, our baseline calibration and the implied steady state require more detailed discussion. To focus discussion on the role of payroll taxes, we begin with a calibration in which \( g_s = g = T = 0 \). At the steady state of this economy, 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.\(^{17}\) Our choice of \( \beta \) implies

---


\(^{17}\)In comparison, Hagedorn and Manovskii (2008) estimate the labor costs of posting a
an annual risk free rate of about four percent; physical capital depreciates at 2.5 percent per quarter. By setting $\chi = -5$, we make individual labor supply less elastic than usually assumed in real business cycle models.\footnote{This value is in line with micro studies of labor supply and deflates 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.} 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 steady state unemployment rate is seven percent and $\tau$ is equated to the average rate in Germany (30 percent).\footnote{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.} The government’s steady state financing constraint pins down the "misclassification rate" at

$$\varepsilon = \frac{\tau \frac{h}{w} - s}{1 - s - h} = 0.395$$

The elasticity of the matching function with respect to searching unemployed is set to 0.5. In the steady state, optimal search by households and the wage equation simultaneously determine the periodic utility parameter $A$ and the relative bargaining power $\mu$.\footnote{Note that the last parameter does not coincide with the elasticity of the matching function, hence, the Hosios (1990) condition is not satisfied in this economy. Given severe tax and other distortions already present, it seems inappropriate to assume an efficient outcome of the search process.} The elasticity parameter $\omega$ relating depreciation to capacity utilization is pinned down by the first order conditions for the household (7) and (8): $\omega = \frac{1/\beta - 1 + \delta^k}{\delta^k - 1}$. 

### 4.2 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. 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 vacancy at 11% of labor productivity. In our more realistic benchmark calibration with $g_a > 0$, $a = 0.304$ and $p = y/h = 2.904$ in the steady state, implying a comparable statistic of 10.4%.
between vacancies and unemployment. Second, the table features the inverse relationship of unemployment and labor market tightness, which is measured by $\theta \equiv v/s$, the ratio of vacancies to unemployment. This measure of tightness rises in booms and declines in recessions. Third, unemployment and labor productivity, $p \equiv y/h$, are slightly negatively correlated; booms tend to be periods of higher labor productivity.

| Table 3: Correlation of labor market indicators and labor productivity, Germany, 1970:1 - 2008:4 |
|---|---|---|---|
| $v$ | $s$ | $\theta$ | $p$ |
| $v$ | 1.00 | -0.81 | 0.96 | 0.30 |
| $s$ | 1.00 | -0.94 | -0.24 |
| $\theta$ | 1.00 | 0.99 |
| $p$ | 1.00 |

Note: $p$ denotes labor productivity $(y/h)$; $\theta$ denotes labor market tightness $(v/s)$

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 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.\(^{21}\) Table 4 confirms that our artificial economy - which is driven by a single technology shock - also displays this counterfactual property in the absence of a social-security system payroll tax ("without payroll tax"). Without the payroll taxes, our artificial economy fails to replicate the Beveridge curve relationship, instead generating a $s - v$ correlation of 0.85. 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.\(^{22}\)

\(^{21}\)Hagedorn and Manovskii (2008) and Ebell (2009) have shown that some of these problems can be resolved by alternative calibration assumptions.

\(^{22}\)Ravn (2008) has called these results the "consumption-tightness puzzle."
A key finding of this paper is that central robust correlations in the data are generated by the model 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 labor market correlations for the calibrated economy with a positive and endogenous payroll tax rate and a social safety net of calibrated size. 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 $-0.79$, 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 $0.17$ to $-0.92$, a value which is almost identical to the correlation in the German data. Theory can now also account for a weak correlation between unemployment and productivity. Overall, the model resolves the puzzles put forward by Ravn (2008).

### Table 5: Correlation of labor market indicators and labor productivity, artificial economy, (with payroll tax)

<table>
<thead>
<tr>
<th></th>
<th>$v$</th>
<th>$s$</th>
<th>$\theta$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$v$</td>
<td>1.00</td>
<td>-0.79</td>
<td>0.97</td>
<td>0.58</td>
</tr>
<tr>
<td>$s$</td>
<td></td>
<td>1.00</td>
<td>-0.92</td>
<td>0.04</td>
</tr>
<tr>
<td>$\theta$</td>
<td></td>
<td></td>
<td>1.00</td>
<td>0.36</td>
</tr>
<tr>
<td>$p$</td>
<td></td>
<td></td>
<td></td>
<td>1.00</td>
</tr>
</tbody>
</table>

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," which measures the volatility of labor market tightness relative to that of labor productivity, $\sigma_\theta/\sigma_p$, 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. 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.

Table 6: Macro moment comparisons, data and model

<table>
<thead>
<tr>
<th>Germany</th>
<th>Model w/o payroll tax</th>
<th>Model with payroll tax</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_v/\sigma_y$</td>
<td>13.24</td>
<td>1.66</td>
</tr>
<tr>
<td>$\sigma_h/\sigma_y$</td>
<td>11.41</td>
<td>1.27</td>
</tr>
<tr>
<td>$\rho(v, y)$</td>
<td>0.64</td>
<td>0.15</td>
</tr>
<tr>
<td>$\rho(s, y)$</td>
<td>-0.74</td>
<td>0.16</td>
</tr>
<tr>
<td>$\rho(h, y)$</td>
<td>0.55</td>
<td>0.75</td>
</tr>
<tr>
<td>$\sigma_{c}/\sigma_y$</td>
<td>0.83</td>
<td>0.27</td>
</tr>
<tr>
<td>$\rho(c, y)$</td>
<td>0.64</td>
<td>0.97</td>
</tr>
<tr>
<td>$\sigma_i/\sigma_y$</td>
<td>2.64</td>
<td>2.27</td>
</tr>
<tr>
<td>$\rho(i, y)$</td>
<td>0.82</td>
<td>0.99</td>
</tr>
<tr>
<td>$\rho(c, \theta)$</td>
<td>0.66</td>
<td>0.98</td>
</tr>
<tr>
<td>$\rho(h, p)$</td>
<td>0.04</td>
<td>0.66</td>
</tr>
</tbody>
</table>

Note: $i$ denotes gross fixed domestic capital formation (investment expenditures).

Table 7: Labor market tightness and persistence

<table>
<thead>
<tr>
<th>Germany</th>
<th>Model (w/o payroll tax)</th>
<th>Model (with payroll tax)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_v/\sigma_p$</td>
<td>34.52</td>
<td>1.00</td>
</tr>
<tr>
<td>$\rho(\theta, p)$</td>
<td>0.29</td>
<td>0.99</td>
</tr>
<tr>
<td>$\rho(v, v-1)$</td>
<td>0.95</td>
<td>0.30</td>
</tr>
<tr>
<td>$\rho(s, s-1)$</td>
<td>0.95</td>
<td>0.25</td>
</tr>
</tbody>
</table>

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 pre-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 8: Wages (total compensation per employee)

<table>
<thead>
<tr>
<th></th>
<th>Germany</th>
<th>Model (w/o payroll tax)</th>
<th>Model (with payroll tax)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_w/\sigma_y$</td>
<td>0.83</td>
<td>0.87</td>
<td>0.66</td>
</tr>
<tr>
<td>$\rho(w, y)$</td>
<td>0.38</td>
<td>0.99</td>
<td>0.54</td>
</tr>
</tbody>
</table>

5 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, the roles of countercyclical payroll taxes and the participation margin. We also present some cross-country comparisons and implications regarding the US cycle and labor market.

5.1 The role of countercyclical payroll taxation

We first show that the dynamic behavior of payroll taxes is central for generating 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.

\[ \frac{d\ln \theta}{d\ln p} = \left[ \frac{(1-\mu)(1-\alpha)p}{\eta(1-\mu)\left((1-\alpha)p - \frac{1}{\eta} \right) + (1-\eta)\mu \theta} \right] - \left[ \frac{(1-\mu)b}{\eta(1-\mu)\left((1-\alpha)p - \frac{1}{\eta} \right) + (1-\eta)\mu \theta} \right] \frac{\tau}{(1-\tau)^2} \frac{d\ln \tau}{d\ln p} \]

so if $\frac{d\ln \tau}{d\ln p} < 0$, the elasticity of $\theta$ to labor productivity will be greater than in the standard case ($\frac{d\ln \tau}{d\ln p} = 0$).
Table 9: Behavior of payroll tax rate

<table>
<thead>
<tr>
<th></th>
<th>Germany</th>
<th>Model (with payroll tax)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \sigma_t / \sigma_y )</td>
<td>1.57</td>
<td>2.23</td>
</tr>
<tr>
<td>( \rho(\tau, y) )</td>
<td>-0.51</td>
<td>-0.89</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

\[
bs_t + \varepsilon b(1 - s_t - h_t) = \tau w_t h_t + T_t. \tag{18}
\]

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. While the model performs better than the version without distortionary taxation, the slope of the Beveridge curve remains counterfactually positive at \( \rho(v, s) = 0.99 \), and unemployment is procyclical at \( \rho(s, y) = 0.33 \). Under the alternative financing arrangement, the correlation of the wage with output rises to close to one and its relative volatility nearly doubles. We have thus established that the variability of payroll taxes, rather than its level, is driving the results reported in Tables 5-8.

### 5.2 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. Merz (1995) and Andolfatto (1996). Lifetime expected utility is now

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

which is maximized subject to the time constraint

\[ 1 = h_t + s_t. \]

and the periodic budget constraint of the household

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

The social insurance budget constraint becomes

\[ \tau_t w_t h_t = g_s + bs_t, \]
where social security expenditures on output \( g_s \) (in excess of unemployment benefits) are set to target the same steady state payroll tax rate in the original calibration, i.e. \( \tau = 0.3 \). The firm’s side of the model is unaffected by these changes.

Payroll taxes in the simulated economy are countercyclical, with \( \rho(\tau, y) = -0.98 \). The model predicts \( \rho(s, y) = -0.81 \), and a negatively sloped Beveridge curve. \( \sigma_\theta/\sigma_p \) at 12.07, closing a large part of the Shimer puzzle; in the absence of the tax channel, \( \sigma_\theta/\sigma_p \) declines to roughly 2.5.

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 continue to shut down the labor participation margin and examine the implied volatility as a function of the steady state payroll tax rate. This is done by varying social insurance expenditures \( g_s \). The results, displayed in Figure 5, show that a higher steady-state tax rate is associated with higher volatility, as in the original model.

Figure 5 about here

5.3 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 (quarterly) data for five countries in the panels of Figure 6.

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, \( \sigma_\theta/\sigma_p \), 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 6 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 6 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, labor market quantities become more volatile, supporting our theory’s claim of a significant role of payroll taxation

\[^{24}\text{Unfortunately, quarterly data availability and consistency for the longer period (1970-2008) limited the sample to five OECD countries.}\]
on the dynamics of labor markets. Finally, Figure 6c) shows a tight positive relationship between the volatility of labor market tightness and the level of payroll taxes (as in Figure 5).

Figure 6 about here

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

In Figure 6, the United States appears to be an outlier, especially in panel 6c). This status could be explained by differences with Western Europe with respect to institutions or ultimately preferences. To explore this possibility, we recalibrated the original artificial economy to key characteristics of the US economy. Hence, we set $\varepsilon$ to match $\tau = 0.12$ and assume that the steady state unemployment equals five percent. Other parameters were not changed. The model economy’s Beveridge correlation is $\rho(u,v) = -0.36$. Unemployment is countercyclical at $\rho(s,y) = -0.59$. Hence, the model and the payroll tax mechanism can help account for US labor facts. Moreover, $\sigma_0/\sigma_p$ is 8.22 — over one third of the US’s observed value. 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 overall, this is not true of the second half of our sample, nor is it true of Barro and Redlick’s (2011) constructed marginal payroll tax rates. When looking across countries — say, when comparing Germany and the US —, the model preserves the relative sizes of $\sigma_0/\sigma_p$. However, the artificial variances are more pronounced than in the data. In other word, other institutional differences appear to play important roles, and they are not captured by our model.

5.5 Interpretation

Our model with variable labor taxation generates more realistic labor market behavior 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. 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

\begin{itemize}
  \item 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.
  \item 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.
\end{itemize}
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 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 via (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 significantly higher vacancy creation 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.27

6 Secular trends

Our model not only matches key business cycle facts; it also offer a plausible account of secular changes in payroll taxation, unemployment and employment over time. In particular, an increase of $\tau$ in Germany from an average of 0.28 in the period 1970-1990 to 0.37 in the late 1990s is generally attributed to a sharp rise in Eastern German unemployment, which triggered an extension of unemployment assistance to large groups of the employable population as well as an increase in active labor market policies funded by social contributions. While cyclical variation in $\tau$ is well-explained by cyclical variation in employment and unemployment, secular increases in $\tau$ are only possible in the model as a result of

27Veracierto (2008) conjectures that the Beveridge curve anomaly could be solved if unemployment insurance is paid only to those actually seaching, making non-participation less attractive. We considered a calibration in which $b/w = 0$, $\varepsilon = 1$ (via setting $\eta, y = 0.1934$) while maintaining the average payroll tax rate at 30 percent while allowing $\tau$ to vary with the budget situation. We find support for Veracierto’s (2008) hypothesis: $\rho(s, y) = 0.25$ and $\rho(s, v) = 0.92$. 
expansions of the social welfare state – payroll-tax-financed public expenditures \( g_s \), unemployment compensation \( b \), or the generosity of social welfare \( \varepsilon \). Indeed our estimate of \( g_s \) rose from 1990 from 5% of GDP to 6.5% in 2005 before falling back to 6% in 2012. During this same period \( \tau \) rose from roughly 0.30 in 1990 to 0.35 in 2005, decreasing to 0.32 in 2012.

We investigated the power of our model to replicate these longer-run developments with a calibration of the German economy similar to the baseline calibration. Details of this calibration are provided in the Appendix. We set \( g_s \), government purchases of output financed by payroll taxes, to 0.063, its average value in the period 1990-2012.\(^{28}\) This pins down total government purchases \( g \) at \( g/y = 0.19 \), which is close to the value given by the OECD (0.20). The government adjusts the payroll tax rate \( \tau \) in each period to respect the budget constraint

\[
g_s + b s_t + \varepsilon b(1 - s_t - h_t) = \tau_t w_t h_t.
\]

As before, the calibration matches an unemployment rate of 7%; the shares of labor and vacancy costs in output, and unemployment to UI replacement ratio match those of the benchmark calibration. As a result, the implied model parameters are slightly different for labor bargaining power (\( \mu = 0.5255 \)). We then calculate changes in social insurance system parameters (\( g_s, \varepsilon \) and \( b \)) needed individually to match steady state \( \tau \) to its average value in the first and second halves of the sample (\( \tau = 0.28 \) and \( \tau = 0.34 \), respectively). The results as well as the implied steady state values of employment, unemployment and nonparticipation are displayed in Table 10.\(^{29}\)

\(^{28}\)Source: Federal Statistical Office. According to the OECD, health costs in Germany were roughly 10% of GDP in the post 1990 period and roughly 8% in the 1970-1990 period. A large share of increases in German health costs can be associated with the reunification episode.

\(^{29}\)While the new calibration alters the model’s steady state, its dynamic properties are robust, as evidenced by the Beveridge curve \( \rho(s, s) = -0.80 \); labor market tightness and labor productivity: \( \rho(b, p) = 0.44 \), countercyclical unemployment: \( \rho(s, y) = -0.84 \); and the Shimer statistic: \( \sigma(\theta)/\sigma(p) = 30.08 \).
Table 10: Values of government spending $g_s$, welfare generosity $\epsilon$, and unemployment benefit $b$ needed to match steady state values of $\tau$

<table>
<thead>
<tr>
<th>Benchmark</th>
<th>Steady state values necessary for:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\tau = 0.30$</td>
<td>$\tau = 0.28$</td>
<td>$\tau = 0.34$</td>
</tr>
<tr>
<td>$g_s$</td>
<td>0.0851</td>
<td>0.104 (+22.2%)</td>
<td>0.0726 (-14.7%)</td>
</tr>
<tr>
<td>implied $h$</td>
<td>0.4660</td>
<td>0.4696 (+1.0%)</td>
<td>0.4640 (-3.4%)</td>
</tr>
<tr>
<td>$s$</td>
<td>0.0350</td>
<td>0.0327 (-7.0%)</td>
<td>0.0428 (+22.3%)</td>
</tr>
<tr>
<td>$\ell$</td>
<td>0.5000</td>
<td>0.4977 (-0.5%)</td>
<td>0.5032 (+0.6%)</td>
</tr>
<tr>
<td>$\epsilon$</td>
<td>0.2493</td>
<td>0.2298 (-7.8%)</td>
<td>0.2775 (+11.3%)</td>
</tr>
<tr>
<td>implied $h$</td>
<td>0.4650</td>
<td>0.4711 (+1.3%)</td>
<td>0.4509 (-3.0%)</td>
</tr>
<tr>
<td>$s$</td>
<td>0.0350</td>
<td>0.0328 (-6.3%)</td>
<td>0.0426 (+21.7%)</td>
</tr>
<tr>
<td>$\ell$</td>
<td>0.5000</td>
<td>0.4961 (-0.8%)</td>
<td>0.5065 (+1.3%)</td>
</tr>
<tr>
<td>$b$</td>
<td>1.1676</td>
<td>1.118 (-4.2%)</td>
<td>1.203435 (+3.1%)</td>
</tr>
<tr>
<td>implied $h$</td>
<td>0.4650</td>
<td>0.4726 (+1.6%)</td>
<td>0.4480 (+3.7%)</td>
</tr>
<tr>
<td>$s$</td>
<td>0.0350</td>
<td>0.0298 (-14.9%)</td>
<td>0.0495 (+41.4%)</td>
</tr>
<tr>
<td>$\ell$</td>
<td>0.5000</td>
<td>0.4976 (-0.5%)</td>
<td>0.5025 (+0.5%)</td>
</tr>
</tbody>
</table>

Our model can readily account for the long-term shifts in mean values of unemployment, employment and other macroeconomic indicators observed in Germany since 1970. A 22% increase of social security financed government spending is sufficient to raise the steady state payroll tax rate from 30 to 34%. The unemployment rate rises from its baseline value of 7% to 8.4%, while the employment rate declines from 46.5% to 45.4%. The same payroll tax hike in the steady state could be generated by an increase in the "misclassification rate" $\epsilon$ from 0.249 to 0.278, with a concomitant rise in the unemployment rate to 8.6% and decline in the employment ratio to 45.1%. An increase of the unemployment benefit (measured in terms of output) of 3.1% would have the same fiscal impact, but raise unemployment to 9.9%, depress the employment rate to 44.6%, and push the system to the limits of fiscal sustainability.

7 Conclusion

It is well-known that payroll taxes represent a significant long-run distortionary influence of governments in labor markets. In this paper, we argue that they can also affect business cycle dynamics. For most 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 (2011) description of a countercyclical labor wedge. Our analysis considers the role of the social safety net – modeled as a generous system of unemployment insurance and subsidy of
leisure – in creating such cyclical movements of payroll taxation in an 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 Ravn-Tripier-Veracierto anomaly. 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


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8 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 by

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

(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:

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

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

which can be solved to obtain

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

or

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


## 9 Appendix: Alternative Calibration

<table>
<thead>
<tr>
<th>Table A1: Parameter values, alternative calibration $g_s &gt; 0$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Postulated/assumed:</strong></td>
</tr>
<tr>
<td>Discount factor, $\beta$</td>
</tr>
<tr>
<td>Steady state capital depreciation rate, $\delta^k$</td>
</tr>
<tr>
<td>Job separation rate, $\delta^b$</td>
</tr>
<tr>
<td>Frisch supply elasticity of nonleisure time, $-1/\chi$</td>
</tr>
<tr>
<td>Matching function elasticity, $\eta$</td>
</tr>
<tr>
<td>AR coefficient of log TFP process $\rho$</td>
</tr>
<tr>
<td>Vacancy cost share $\alpha_v/\gamma$</td>
</tr>
</tbody>
</table>

| **Calibrated/matched to data:**                             |
| Labor share, $wh/y$                                         | 0.67 |
| Replacement rate, $b/w$                                     | 0.60 |
| Unemployment rate $s/(s + h)$                               | 0.07 |
| Time working and searching, $h + s$                         | 0.50 |
| Labor taxation rate $\tau$                                  | 0.30 |
| Consumption share $c/y$                                     | 0.58 |
| Government purchases paid by soc.sec., $g_s/y$              | 0.063 |

| **Calculated:**                                             |
| Elasticity of output wrt capital $\alpha$                   | 0.3242 |
| Vacancy cost $\alpha$                                       | 0.3036 |
| Social transfer (misclassification) rate $\epsilon$         | 0.2493 |
| Bargaining power of workers $\mu$                          | 0.5698 |
| GDP share of government purchases $g/y$                     | 0.1841 |
Figure 1: Payroll taxes as fraction of total compensation ($\tau$), United States, 1970:1-2010:4
Figure 2: Payroll taxes as a fraction of total compensation ($\tau$), Germany, 1970:1-2010:4
Figure 3: HP-detrended payroll taxes and log GDP, United States, 1970:1-2010:4
Figure 4: HP-detrended payroll taxes and log GDP, Germany, 1970:1-2010:4
Figure 5: Steady-state payroll taxation ($\tau$) and Shimer statistic ($\sigma_\theta/\sigma_p$) in the model without a participation margin.
Figure 6: Payroll taxation, GDP and labor market tightness, five countries, 1970-2008

a) Payroll tax-GDP correlation $\rho(\tau, y)$ versus Shimer statistic ($\sigma_\theta/\sigma_p$)
b) Change in payroll tax-GDP correlation ($\rho(\tau, y)$) versus change in Shimer statistic ($\sigma_\theta/\sigma_p$), 1970-1989 to 1990-2008
c) Payroll tax level ($\tau$) versus Shimer statistic ($\sigma_0/\sigma_p$)