Payroll Taxes, Social Insurance and Business Cycles

Michael Burda*
Humboldt Universität zu Berlin
10099 Berlin
Germany

Mark Weder
University of Adelaide
Adelaide SA 5005
Australia

February 15, 2010

Abstract

Payroll taxes represent a major distortionary influence of governments on labor markets. This paper examines the role of payroll taxation and the social safety net for cyclical fluctuations in an nonmonetary 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, as a result, strengthens the model's endogenous propagation mechanism. For conventional calibrations, the model generates a downwardly-sloped Beveridge curve 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 2005, OECD member governments collected about \$3 trillion from employers and employees, representing 9.2 percent of total GDP and, given a wage share of two-thirds, roughly 15 percent of the total wage bill. In some European countries this figure is as high as 40-45 percent.[1] While often described as "contributions to social insurance", they are in fact a highly distortionary form of labor taxation. Payroll taxes distort the hiring decisions of firm and the labor supply decisions of households, and are likely to stimulate the untaxed, informal

Keywords*: Business cycles, labor markets, payroll taxes, unemployment. JEL Classification: **E24, **J64**, **E32**. We are grateful to Chris Edmond, Francisco Gonzalez, Tom Krebs, Nir Jaimovich, Christian Merkl, Dennis Snower, Lutz Weinke and to seminar participants at the Humboldt University, Kiel, Mannheim and Melbourne for useful comments.

[1]Source: OECD Revenue Statistics 2007.

economy. If payroll tax rates vary over time, employers and employees may also react to the intertemporal path of these distortions. Payroll taxes thus not only have important effects on the long-run functioning of labor markets and the macroeconomy, but may affect the magnitude and persistence of business cycle fluctuations.

This paper studies the interaction of payroll taxes, the social welfare system and the business cycle. We begin with an examination of the cyclical behavior of payroll taxation in OECD countries. We find strong evidence that payroll taxation is countercyclical: 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 average labor tax burden, which was already noted by Pigou, Kaldor, and Meade in the 1930s and 1940, 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 of labor is highly nonlinear. It is often zero at low incomes and capped at an upper level, implying a relatively higher effective rate of taxation for low-productivity workers at the extensive margin.

Next, we study the effects of countercyclical payroll taxation in an equilibrium business cycle model with labor market frictions. In this class of models, the elasticity of search activity on both sides of the market is influenced by intertemporal path of the wedge driven between costs paid by firms and income received by households. The endogeneity of the tax burden to cyclical conditions reinforces the intertemporal response of labor market activity and thus increases the endogenous propagation of shocks in the model economy. Following Tripier (2003), Ravn (2008), Ebell (2009) and others, we distinguish between search and leisure. Our model differs from these contributions however, in that unemployment insurance is financed by distortionary (payroll) taxation on a balanced budget basis. In addition, its provision is only imperfectly related to search effort, thus distorting the search-leisure margin. In particular, we explicitly parametrize "Type II" or classification error – paying unemployment benefits to those actually taking leisure. Combined with the endogeneity of labor taxation, these effects significantly increase the internal propagation of the model economy.

Although the use of models with labor market frictions is widespread, Shimer (2005) and Hall (2005) have demonstrated that these models in their simplest form do not generate sufficient volatility in labor market quantities, i.e. vacancies and unemployment. They both show that a modest amount of wage rigidity is sufficient to solve the puzzle. Hagedorn and Manovskii (2008) achieve this end by calibrating the fallback for the worker to be sufficiently high and the bargaining power of the worker to be sufficiently low.[2] More recent work

[2]See also Cole and Rogerson (1999). Costain and Reiter (2008) and Hall and Milgrom (2008) note that high values of fallback induce unrealistically high elasticities of labor supply response. Gertler and Trigari (2007) introduced staggered Nash bargaining. Ravn (2008) has shown that adding a participation margin worsens the model's ability to replicate business

by Shimer (2009) and others show how intratemporal non-separability in utility over consumption and nonwork can generate similar effects.

In this paper, we show that the interaction of payroll taxes with the social welfare system imparts enough rigidity to gross employer labor costs to allow a real equilibrium business cycle to match central stylized facts, inducing persistence to vacancies, increasing the volatility of labor market quantities over the cycle, while preserving the Beveridge curve, the well-established negative correlation of vacancies and unemployment. This represents a considerable improvement over results reported by Tripier (2003), Ravn (2008) and others. Furthermore, this effect can be shown to be increasing in workers' bargaining strength. Time-varying payroll taxes affect the effective cost of labor and the value of vacancies to the firm, as well as the value of time spent by workers in search.

In the next section we document the size and the intertemporal behavior of the payroll tax burden of labor in the major OECD countries. Section 3 lays out a nonmonetary dynamic stochastic general equilibrium economy with a welfare system and endogenous search. The model is calibrated in Section 4, while Section 5 presents the central results and robustness checks. Section 6 concludes.

2 Payroll taxes in the OECD

In this section we present stylized facts on the magnitude and the cyclical pattern of payroll taxes in OECD countries.

2.1 Magnitude of payroll taxes

As Table 1 documents, payroll taxation represents a significant, yet frequently overlooked intervention in labor markets in the developed economies. Our principal data source is the OECD Economic Outlook and Main Economic Indicators. The central variable of interest is total compensation, which represents the gross payment of wages, salaries and other payments made by employers on behalf of their employees, including contributions to social insurance. The latter consists of payments by firms or nominally by workers for pension, health, unemployment and disability insurance, and some other minor elements of social insurance also observed in OECD countries. The first two columns of the table document the level as well as the trend for selected countries.

cycle facts. Pissarides (2008) has invoked one-off costs of hiring as a possible source of real wage rigidity.

Table 1: Payroll taxes in select OECD countries					
Country	Ratio of payroll taxes to wage bill		Correlation of payroll tax with GDP*		
	1970-89	1990-08	1970:1-89:4	1990:1-08:4	1970:1-08:4
US	0.097	0.120	0.226	-0.276	0.147
Germany	0.278	0.337	-0.484	-0.558	-0.514
Netherlands	0.291	0.293	-0.132	-0.026	-0.098
UK	0.229	0.260	0.115	0.041	0.096
Sweden	0.246	0.319	-0.417	0.358	0.087
France	0.366	0.410	-0.039	-0.387	-0.233
Japan	0.167	0.240	-0.389	-0.096	-0.262
Canada	0.055	0.091	-0.267	-0.066	-0.206
Finland	0.143	0.166	-0.532	-0.475	-0.472

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

Payroll taxes range from around 10-15% of the wage bill in Canada, the US and Finland to than a third of total labor costs or more in France, Germany and Spain. Movement of such taxes would appear likely to be of considerable importance, especially in continental Europe.

2.2 Function of payroll taxes

To understand the origin and the nature of social security systems, it is informative to review the history of the German welfare state, which served as a reform model for many industrial countries. Its foundations were laid during the wide-reaching reforms of the 1880s, when Chancellor Bismarck, keen to deflect criticism of rising inequality in a time of rapid growth as well as to counter the burgeoning labor movement, launched a grand program of *Staatssozialismus,* culminating in the Health Insurance Act of 1883 (*Gesetz betreffend die Krankenversicherung der Arbeiter*), the Accident Insurance Bill of 1884 (*Unfallversicherungsgesetz*) and the old age and disability insurance bill 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*).

An important aspect of the German social insurance system, which became a model for similar systems throughout the world, was a low level of explicit redistribution. Health, pension, and unemployment insurance funds were established to pay entitlements based on past service or accrued eligibility. In theory, Workers and firms were to contribute equally towards the costs of social insurance programs, which ran on a near-balanced budget basis. As a result, the funding of such programs is susceptible to business cycle fluctuations, with frequent adjustments necessary to adjust contributions to maintain budget balance in slumps. Germany's system of unemployment benefits, which in its present form dates back to 1969 (Employment Promotion Act or *Arbeitsförderungsgesetz*), serves as an illustrative example. The law set up the Federal Employment Agency (*Bundesagentur für Arbeit*) to provide income support for the unemployed as well as training and support in job finding and matching. The activities of the agency are funded primarily by payroll tax contributions. Only under certain circumstances may the federal government provide stop-gap assistance in balancing its budget and to provide liquidity in form of interest-free loans, which are generally repaid as soon as income exceeds spending in any given month. As a result, contribution rates have varied considerably over time. For example, the statutory contribution rate moved from 6.5 percent of gross wage eligible income in 2007 to 3.3 percent in 2008 and to 2.8 percent in 2009. With the onset of the Great Recession proposals to increase contribution rates for unemployment insurance are already under consideration. Similar schemes apply for the other pillars of the social security system (health, pension etc).

The Bismarckian system stands in stark contrast to the concept promoted in the United Kingdom by Lord Beveridge in the late 1940s, based on the notion of a sufficient minimum benefit funded if necessary by the general public budget. In many European countries as well as the United States, deficits in social security programs are regularly funded by budgetary transfers. In the United States, the social insurance system is a hybrid of Bismarkian and Beveridgean aspects. Originally, Social Security system of old-age benefits was a reform introduce by President Roosevelt in the 1930s and patterned after the Bismarkian system. It is funded by payroll taxes, with employer withhold 6.2% of an employee's wages and match that amount in social security taxes until the employee's total earnings reach a fixed earnings base (ceiling) for the year. The combined total for the employee and the employer contributions thus equals 12.4% of gross compensation in a given year up to the base, beyond which neither the employee nor the employer owe further social security tax.

2.3 Cyclical behavior of payroll taxes

For at least two reasons, the average payroll tax rate - and thus the tax burden for the average worker moving from unemployment into employment - is likely to be countercyclical. The first reason was described in the previous section. In recessions, budget shortfalls are difficult to close by cutting social expenditures, which have the nature of entitlements. While the model in the next section studies unemployment benefits in particular, this is true of health provision systems, public pensions and welfare. As a result, effective tax rates are actively raised rise in recessions and cut in expansions. A second reason is the highly non-linear and truncated nature of payroll tax systems in most OECD countries, in which a contributions cap limits the total absolute level of payroll tax liable by any employer for a given employee.[3] In expansions when overall wages and productivity is rising, more workers will earn gross pay exceeding the contributions cap, while in recessions, new jobs tend to pay less.

In this section, we investigate the net impact of these potential influences on the temporal behavior of the average effective payroll tax rate, τ_t, levied on wages. Table 1 and in particular Figures 1 and 2 show that the payroll tax is not constant. In fact, it is strongly countercyclical in Germany, France, and the Netherlands, while less so in Sweden and the United States. For example, the total contribution of households and government to social security (payroll taxes) in 2008 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 2009). To remove low frequency movement in the data, we Hodrick-Prescott filtered the series for taxes and output. The overall contemporaneous correlation of the payroll tax rate and the business cycle in Germany is -0.56, while it is acyclical in the United States; as Table 1 reveals, this correlation has become increasingly negative over the sample.

Figures 1, 2, 3, and 4 here

3 An equilibrium business cycle model with payroll taxation

We now embed the payroll tax system in a dynamic stochastic general equilibrium model of the business cycle with labor market frictions with a system of unemployment and social assistence. We impose that payroll taxes are collected by the government to finance the unemployment insurance and social assistance scheme, and are set within the period to guarantee that budget constraint is maintained. Subscripts refer to periods of discrete time $t \geq 0$.

3.1 Labor market search

Workers and jobs are brought together in a decentralized labor market.[4] The matching of workers and jobs is a function of workers' search activities, s_t, and firms' posting of vacancies, v_t. This creation of new jobs is represented as a constant returns and Cobb-Douglas matching function, $M(s_t, v_t) = s_t^{\eta} v_t^{1-\eta}$. At the same time, jobs are terminated at a constant rate, δ^h, with $0 < \delta^h < 1$.[5] Under

[3]In the United States, the ceiling on social security contributions in 2008 was \$102,000, and is adjusted annually for inflation. This represents the roughly the 85th percentile of the annual gross *household* income distribution in the US. In Germany, the cap kicked in 2008 at 5300 Euro per month. At the lower end of the pay spectrum, so-called *Mini-Jobs* (defined as jobs that pay less than 400 Euro per month) face a significantly lower payroll tax, and were for a time exempted entirely. Self-employed persons are generally not required to make contributions.

[4]See also Merz (1995) and Andolfatto (1996).

[5]Shimer (2006) suggests that separations are roughly constant over the cycle.

the constant returns assumption, the vacancy-unemployment ratio $\theta_t \equiv v_t/u_t$ is a sufficient statistic of market tightness. This infers that the vacancy placement rate, q_t, is related to the job-finding rate among the searching unemployed, f_t by the relation $q_t = \frac{M(s_t,v_t)}{v_t} = M(\frac{s_t}{v_t},1) = \frac{M(1,\theta_t^{-1})}{\theta_t} = \frac{f_t}{\theta_t}$.This assumption implies that employment at any given point in time is a state variable to the economy. From the perspective of the individual searcher, f_t is the probability that a match will occur. Then for the aggregate economy, employment obeys

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

Similarly, from the perspective of the individual firm, q_t is the probability that an open vacancy will be matched in a period or the job matching rate per vacancy posted so for the aggregate economy it follows that

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

3.2 Government and the welfare state

The government in this model collects social security contributions from labor income of households, $w_t h_t$, at the nonconstant rate τ_t. Government purchases of goods and services are supressed, so the revenues from these taxes are only used to finance an unemployment benefit, b, paid to unemployed who search, s_t, and εb to those enjoying leisure. The parameter $\varepsilon \in (0,1)$ can be thought of as a measure of "classification error", malfeasance in the unemployment system, or simply the generosity of the welfare state. A positive ε means that agents (or household members) that are not or no longer actively searching are still receiving some social support. To us, this does not seem unlike the several steps in the German social security system, for example. The government is assumed to adjust the payroll tax rate in each period to obey the following budget constraint:

$$bs_t + \varepsilon b(1-s_t-h_t) = \tau_t w_t h_t. \tag{3}$$

As ε approaches 1, search time and leisure are "rewarded" equally in terms of consumption goods. As ε approaches zero, the system replicates the standard model, and leisure is not rewarded at all beyond its utility value to individual households.

3.3 Households

The economy is populated by a large number of infinitely-lived, identical consumer-worker households each of unit one. Each household consists of a large number of individuals who derive utility from consumption and leisure. Unlike to most other studies, here workers (or family members) can spend their nonworking time either being actively unemployed (i.e. searching) or they simply consume leisure.[6] If we normalize non-sleeping time to unity, we have a representative agent with the following time allocation:

$$h_t + s_t + \ell_t = 1 \tag{4}$$

where h_t, s_t, and ℓ_t are working time, search time, and leisure (which could include home production). Households endogenously decide upon their participation in labor market activities. They own the capital stock, k_t and rent capital services deriving from it, κ_t, to firms in a competitive market. These capital services are defined as the product of the stock and capital utilization rate, u_t, i.e. $\kappa_t = u_t k_t$. The owners of capital choose κ_t and u_t subject to the dependence of depreciation on capital utilization

$$\delta_t^k = \frac{1}{\omega} u_t^\omega \tag{5}$$

where $\omega > 1$. Modeling depreciation as a convex function of capacity utilization is common and follows Greenwood, Hercowitz and Huffman (1988) among others.

Given a sequence of market real wages, w_t, and rental rates for capital services, r_t, the problem faced by a representative household at $t = 0$ is to choose a sequence of consumption, c_t, search time, labor, capital and capital utilization to maximize expected utility

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

given initial stock of capital, k_0 and level of employment h_0, and subject to the periodic budget constraint of the household

$$k_{t+1} + c_t = (1-\tau_t) w_t h_t + (1 + u_t r_t - \delta_t^k) k_t + b s_t + \epsilon b (1 - s_t - h_t) \tag{6}$$

the evolution of employment (1) and the dependence of depreciation on utilization (5). The parameters are restricted such that $A > 0$, $0 < \beta < 1$, $\chi \leq 0$.

Let z_t stand for an exogenous stationary stochastic process which summarizes the productivity of the economy, to be made more precise below. The household's maximization problem can be expressed in value function form so that for all $t = 0$, 1, ... the following Bellman equation holds:

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

subject to (1), (6) and (5), while taking h_t, k_t and z_t as given. Optimality is characterized as follows:

$$\frac{1}{c_t} = \beta E_t \left[\frac{1 + \alpha \frac{y_{t+1}}{k_{t+1}} - \delta_{t+1}^k}{c_{t+1}} \right] \tag{7}$$

[6] See, however, Burda and Weder (2002), Ebell (2008), or Ravn (2008).

$$r_t - u_t^{\omega-1} = 0 \tag{8}$$

and

$$A\,(1 - s_t - h_t)^{\chi} - \frac{b}{c_t}(1-\epsilon) = \beta E_t \frac{f_t}{f_{t+1}}[\left(1-\delta^h - f_{t+1}\right) A\,(1 - s_{t+1} - h_{t+1})^{\chi}$$
$$-\frac{b\left(1-\delta^h\right)(1-\epsilon)}{c_{t+1}} + \frac{f_{t+1}}{c_{t+1}}(w_{t+1}(1-\tau_{t+1}) - \epsilon b)] \tag{9}$$

or

$$\left[A\,(1 - s_t - h_t)^{\chi} - \frac{b}{c_t}(1-\epsilon)\right] = \beta f_t E_t \left[\frac{1}{c_{t+1}}(w_{t+1}(1-\tau_{t+1}) - \epsilon b)\right] \tag{10}$$
$$+\beta f_t E_t \left[f_{t+1}^{-1}[\left(1-\delta^h - f_{t+1}\right) A\,(1 - s_{t+1} - h_{t+1})^{\chi} - \frac{b\left(1-\delta^h\right)(1-\epsilon)}{c_{t+1}}]\right]$$

Condition (7) is the typical Euler equation for capital, while (8) sets the optimal utilization rate: at the optimum, the marginal return from increasing capital utilization must equal its marginal (depreciation) costs. Equation (10) determines the optimal intertemporal search-labor supply sequence. The left-hand side of denotes the marginal utility of leisure time lost from shifting from non-search leisure to search activities. This must equal the discounted marginal benefit of employment, which consists of the expected utility of earning $w_{t+1}(1-\tau_{t+1})$ in wages tomorrow less ϵb, the loss of the government payment for leisure (note if $\epsilon = 0$, leisure is not subsidized). Note that today's search is also influenced by the expected 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. Profits are discounted using the stochastic subjective discount factor $\rho_{t+1} = \beta\lambda_{t+1}/\lambda_t$. Firms produce output y_t using a constant returns production function

$$y_t = z_t \kappa_t^{\alpha} h_t^{1-\alpha}. \tag{11}$$

Profits, Π_t, are given each period by

$$\Pi_t = y_t - w_t h_t - r_t \kappa_t - a v_t. \tag{12}$$

The term z_t denotes TFP and summarizes the state of the economy. In what follows, we will assume that it obeys a first-order autoregressive process. Firms maximize the expected discounted value of profits by hiring capital services from households ($\kappa_t = u_t k_t$), posting vacancies v_t and, given the transition equation for employment by choosing the volume of employment in the next period h_{t+1}. The Bellman equation of the firm implies

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

subject to (12) and the transition equation for employment from the firm's perspective (2).

First order conditions for the firm can be expressed as follows. Equations (13) reflects the firm's optimal capital service, equalizing marginal product of capital services and their cost:

$$\alpha \frac{y_t}{\kappa_t} - r_t = 0. \tag{13}$$

Optimal vacancy decisions are characterized by the condition

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

which equates expected marginal costs of posting a vacancy to the expected discounted value of profits of filling it (the marginal surplus plus saved hiring costs next period for nonseparated jobs).

3.5 Wage bargaining

The two surpluses derived above constitute the joint surplus between a worker and a firm from a match. The surplus to a matched worker is $V_{h_t}(h_t, k_t) - V_{s_t}(h_t, k_t)$, since the fallback position of a matched worker is to resume search or spend time in leisure. At the optimum, these two alternatives should yield equal utility. By optimality, the marginal contribution to the value of the utility maximization programm of an additional unit of time spent in search unemployment equals zero $V_{s_t}(h_t, k_t) = 0$. For firms the surplus is $W_{h_t}(h_t) - W_{v_t}(h_t)$. Free entry is assumed to occur until $W_{v_t}(h_t) = 0$. The joint surplus in the symmetric equilibria we will study in this model is therefore equal to $W_{h_t}(h_t) + V_{h_t}(h_t, k_t)$.

The wage has the function of dividing the match surplus between worker and firm and is assumed to take place at the individual level (we abstract completely from collective bargain). Individual workers are assumed to be 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 household is given as

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

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 λ_t as given. In the Appendix, we show that the wage which solves this problem can be expressed as

$$w_t = \frac{(1-\mu)\,b}{1-\tau_t} + \mu\,(1-\alpha)\,\frac{y_t}{h_t} + \mu(1-\delta^n)\frac{a}{q_t} - \mu(1-\delta^n - f_t)\frac{a}{q_t}\frac{E_t\,(1-\tau_{t+1})}{1-\tau_t}. \tag{15}$$

Note that while the wage is influenced by the "unemployment benefit" paid to searching unemployed, it is independent of the social safety net parameter ϵ, given the marginal product of labor, $(1-\alpha)\,\frac{y_t}{h_t}$, labor market tightness, θ_t, and the path of taxes, τ_t, τ_{t+1}.

One novel feature of the wage equation (15) is the central role of payroll taxation, and in particular, its intertemporal path. Ceteris paribus, a rising profile of payroll taxation will raise the gross-of-tax wage bargain today, while the expectation of falling payroll taxes will cause the bargained wage to decline *today.* If taxes are constant at value τ 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 $\tau_t = \tau_{t+1} = 0$ the expression collapses to the wage equation derived by, for example, Pissarides (1999), Ebell (2008) or Ravn (2008). A second noteworthy aspect of (15) is the interaction of effect of payroll taxation with the extent of worker bargaining power in the economy parametrized by μ. The degree of intertemporal effects of payroll taxation on the wage depend crucially on workers' ability to pass on tax increases onto the firm, and this extends to the effect of the tax profile on wages.

4 Equilibrium and calibration

We define an equilibrium in this decentralized economy as a set of sequences of prices, quantities and payroll tax rates which satisfy optimality conditions of households and firms, all resource and budget constraints as well as a transversality condition for the capital stock. For most plausible calibrations which we consider here, the model will possess a unique steady state equilibrium path. This steady state path is derived in the Appendix.

We begin by specifying the stationary state of this economy and its calibration, which is summarized in Table 2. We calibrate our economy to averages of the German economy over our sample period.[7] The fundamental period is a quarter.

[7]See Cooley (1997) for an authoritative description of calibration.

Table 2 Calibration	
Labor share, wh/y	0.64
Discount factor, β	0.99
supply elasticity of nonleisure time, $-1/\chi$	0.2
Vacancy posting costs, av/y	0.01
Capital depreciation rate, δ^k	0.025
Job separation rate, δ^h	0.06
Replacement rate, b/w	0.6
Unemployment rate	0.07
Time working and searching, $h+s$	0.5
Matching elasticity, ψ	0.5
AR coefficient of TFP, ρ	0.95

While most parameter values are standard, calibration and the implied steady state solution merit discussion. We set the labor share at 64 percent, which in a bargaining model is not necessaily equal to the labor elasticity of the production function. Steady state output in this closed economy can be expressed as shares of income:

$$1 = \frac{wh}{y} + \alpha + \frac{av}{y}$$

from which the target of the labor share and the expenditure share of vacancies on output jointly determine $\alpha = 0.35$. Our choice of β implies an annual risk free rate of four percent; physical capital depreciates at 2.5 percent per quarter. By setting $\chi = -5$, we make labor supply less elastic than usually assumed in real business cycle models ($\chi = -1$ is associated with the log utility case). This is in line with micro studies of labor supply and deflects the usual criticism of the labor market in real business cycle models. In fact, we do not need to resort to high supply elasticities: our simulations will show that the movements of taxes will invoke high employment volatility. The model is calibrated to match the replacement rate, b/w, to 60 percent. Note that this value is significantly lower than the value chosen by Hagedorn and Manovskii (2008); furthermore it corresponds to values found in Germany and other Western European countries. The steady state nonsleeping leisure time $1-h-s$ is set to 1/2 (Burda, Hamermesh Weil, 2008); τ is equated to the average of observed rate for Germany (30 percent). The government's steady state financing constraint is then

$$\tau \frac{wh}{b} = s + \varepsilon(1-s-h)$$

which determines $\varepsilon = 0.395$. The firm's vacancies equation and the wage equation determine A and the relative bargaining power $\mu = 0.4250$.[8] The elasticity

[8] Note that the last parameter does not coincide with the elasticity of the matching function, hence, the Hosios condition is not satisfied in our model.Given the severe distortions present in this model, there are no compelling arguments for assuming such an efficient outcome of the search process in the first place.

parameter ω relating depreciation to capacity utilization is pinned down by the first order condition for the household (8) and the parameters already fixed as

$$\omega = \frac{1/\beta - 1 + \delta^k}{\delta^k} = 1.4040.$$

5 Cyclical properties of the theory

In this section we examine the central predictions of our theory with respect to macroeconomic and labor market variables. To do this, we simulate the artificial economy and compare the outcome to German data. 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. Because we are focusing on business cycle movements, all data are quarterly, Hodrick-Prescott detrended and cover the period 1970:I to 2008:IV.

We focus attention on three important regularities often cited in the data. Firstly, the most salient in Table 3 is the Beveridge curve, the empirical negative correlation betweeen vacancies and unemployment. Secondly, the table identifies an 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 productivity.

We begin the analysis by characterizing the dynamics of a benchmark model without payroll taxes. This model is close in spirit to Tripier (2003), Ravn (2008), and Veracierto (2008) who also model distinct activities in unemployment, i.e. search versus leisure. Theis work suggests a number of counterfactual predictions. For example, they cannot replicate the negatively-sloped Beveridge curve; in these models unemployment has the awkward property of fluctuating *procyclically*. Since unemployment is equivalent to search activity in this model, incentives to search harder in booms are so procyclical that they generate this counterfactual property. Table 4 shows the same correlations as in Table 3, but now for our artificial model economy without payroll taxes: the payroll tax rate τ is set to zero (thus, any social insurance is financed via lump-sum taxation). The only disturbances to this economy are shocks to technology. The version of our own artificial economy without payroll taxes, presented in Table 4, shares above mentioned problem: it fails to replicate the Beveridge curve relationship, instead generating a $u - v$ correlation of 0.83. While this version of the model predicts a positive correlation between productivity and market tightness, it is too strong (0.78 versus 0.29 in the data), and furthermore it cannot generate the observed negative correlation between labor market tightness and unemployment.

Table 3 Labor market indicators and labor productivity, Germany, 1970:I - 2008:IV				
	v	u	θ	p
v	1.00	-0.81	0.96	0.30
u		1.00	-0.94	-0.24
θ			1.00	0.29
p				1.00

Table 4 Labor market indicators and labor productivity, artificial economy ($\tau = 0$)				
	v	u	θ	p
v	1.00	0.83	0.99	0.72
u		1.00	0.78	0.23
θ			1.00	0.78
p				1.00

A key finding of this paper is that the above-mentioned counterfactual predictions of the model can be overturned when payroll taxes and social security system are introduced. It is important to stress the difference in this paper to that of Hagedorn and Manovskii (2008), who consider distortionary, constant taxation.

Tables 5 through 9 document our findings. In Table 5 we report the same labor market correlations as before and they are now very much in line with German data. It becomes now possible to generate substantial movement along a downwardly-sloped Beveridge curve: Table 5 displays a correlation of -0.80 for the artifitial economy which is essentially the number we report for the German economy; and Table 6 shows the significant rise in voltility of vacancies and unemployment. Furthermore, unemployment and tightness are negatively correlated: the correlation moves from 0.72 to -82 which is almost identical to our findings for the German economy. Theory can now also account for a weakly negative correlation between unemployment and productivity.

Table 5 Labor market indicators and labor productivity, artificial economy ($\tau > 0$)				
	v	u	θ	p
v	1.00	-0.80	0.99	0.59
u		1.00	-0.82	-0.05
θ			1.00	0.56
p				1.00

Before presenting an economic interpretation of the payroll-related mechanism, it is informative to consider other attributes of the artificial economy. The upper panel of Table 6 shows that the introduction of payroll taxation generates unemployment that not only moves countercyclically, but is also highly volatile. The correlation that is produced by the model is again very much in line with German data. Likewise, vacancies vary considerably over the cycle as well. The inability of the standard model to replicate the volatility of vacancies and unemployment is known as the Hall-Shimer puzzle (Hall, 2005, Shimer 2005). Lastly, Table 7 suggests that the intertemporal effects of taxes (on search and vacancy choice as well as on wage setting) can help create labor market persistence commonly observed in data: in our artificial economy, vacancies and unemployment exhibit autocorrelations consistent with empircal observation.

Table 6 Unemployment and vacancies

	Germany	Model: $\tau = 0$	Model: $\tau > 0$
σ_v/σ_y	13.24	1.57	11.69
σ_u/σ_y	11.41	1.20	7.99
$\rho(v, y)$	0.67	0.64	0.99
$\rho(u, y)$	-0.74	0.08	-0.81

Table 7 Labor market tightness and persistence

	Germany	Model: $\tau = 0$	Model: $\tau > 0$
σ_θ/σ_p	34.52	1.76	20.45
$\rho(\theta, p)$	0.29	0.79	0.54
$\rho(v, v_{-1})$	0.95	0.32	0.83
$\rho(u, u_{-1})$	0.95	0.27	0.94

Why does our artificial economy perform so much better with payroll taxes? The answer lies in the countercyclical nature of payroll taxation, which is the result of the balanced budget mechanism and its effect on wages. Table 8 shows that the introduction of taxes reduces (before tax) wage volatility significantly, with the relative standard deviation of wages falling by almost 50 percent. Moreover, the wage rises less during booms: the correlation with output is also cut by half. The tax system induces apparent stickiness in the gross wage paid by employers, even though gross and net wages are perfectly flexible.

In Table 8 we compare the two different models. We support our argument by reporting the following simple accounting exercise from the model with payroll taxes: we make use for this accounting of the wage equation (13). We gather that part of the (general equilibrium) wage fluctuations for which taxes are responsible for. The decline can be attributed to the countercyclical effect of taxes as part of the wage determination process: without the payroll tax system, wage volatility would increase by factor three and the correlation with output would rise from 0.32 to 0.79.

Table 8 Wage, w		
	$\tau = 0$	$\tau > 0$
σ_w/σ_y	0.88	0.54
$\rho(w, y)$	0.99	0.32

Figures 5 through 8 plot the impulse responses of the model to technology shocks when there is no payroll tax and when payroll taxes are present. In the presence of taxes, the model becomes substantially more persistent. In particular, Figure 7 demonstrates the countercyclical pattern of tax that is endogenously created.

Figures 5, 6, 7, and 8 here

5.1 Interpretation

The main findings thus far can be summarized as follows: a calibrated RBC-M model combined with an endogenous payroll tax and a distortion of the search-leisure decision can 1) increase endogenous propagation significantly 2) restore the Beveridge curve and 3) contribute significantly towards accounting for the Hall-Shimer puzzle.

We now present some interpretation of our findings. Sticky real gross wages (employers' costs) are the key variable that drive the results. This is consistent with Hall's (2005) claim that fixed wages are the answer to solve the puzzle (and potentially other labor market features as well). In this paper, wages are sticky only in appearance and for endogenous reasons; they appear rigid because the movement in gross wages is generated by the volatile payroll tax rate. With relatively sticky wages, higher employment does not translate into higher costs for firms. Assume firms observe higher realization of productivity. The posting of vacancies is a dynamic problem and future wage labor costs also determine the optimal vacancy posting policy (14). If the gross wage paid by to the firm remain relatively flat, the expected surplus of creating jobs will be higher. Hence, firms will post more vacancies, which raises their volatility as well. At the same time, countercyclical payroll taxes make it possible for net, after-tax wages to be procyclical. Hence, even with sticky wages, workers will see their expected benefits from searching go up in a boom (see equation (10)). Hence in a parallel argument as layed out for vacancies, search (i.e. unemployment) will react less strongly to to disturbances to the economy. For example in a boom, while the labor market improves, the net wage increases much less; furthermore, the strong increase in labor market tightness increases the efficacy of given search activity, so that workers search less in recessions, not more. Furthermore, the generosity of the social welfare system, parametrized by ε, also plays a central role. We can show that a significant reduction of ε reduces the volatility of vacancies and unemployment (while preserving the Beveridge relation). That is, since we would like for agents to react by a lot in the artificial economy, the margins between leisure and search matter as Hagedorn and Manovskii (2008). However, simulations with lower values of ε reduce the volatility of payroll taxation as well.

This being said, it is intriguing to check if our artificial economy in fact generates a reasonable payroll tax sequence. Table 9 documents that our calibrated model can generate fluctuations of the payroll tax that are similar to those observed in the data. The artificial payroll tax's relative volatility and its countercyclical path are consistent with the overall intertemporal pattern of the tax rate in the data. The model's endogenous tax is about as volatile as in German data and moves strongly against the cycle. We take this as favorable evidence that the general mechanism that we have uncovered in this paper is qualitatively and quantitatively relevant.

Table 10 Behavior of the payroll tax

	Germany	model w/tax
σ_τ/σ_y	1.57	1.34
$\rho(\tau, y)$	-0.55	-0.92

Finally, we would like to emphasize that while the mechanism we have identified can contribute to resolving the Hall-Shimer puzzle, it need not be the only one. The aspects of the model that are new mimic a particular facet of the German and many other European labor market, and for the US in the last half of our sample. Without taxes, our model would still exhibit the same anomaly reported by Ravn (2008). The payroll tax mechanism thus represents a simple way to account better for central relative variances in the data while incorporating an important feature of modern labor markets.

It was not the purpose of this paper to come up with a general account of the high volatility of labor market indicators in modern economies, but rather to illustrate one possible strategy for improving our understanding of the labor market. While payroll taxes do not vary over the cycle in the United States to the same extent as they do in France or Germany, the countercyclicality of these taxes appears to be a stylized fact. Furthermore, it is easy to identify similar tax and transfer mechanisms that might work in a similar fashion in other countries. The evidence presented in Table 1 suggests that many of a large number of mechanisms may be at work to create the observed outcome. Our results for artificial economies imply that the presence of endogenously payroll taxes combined with an inadvertent subsidy of leisure can significantly affect the qualitative properties of an important class of equilibrium business cycle models.

6 Conclusions

Payroll taxes represent a major distortionary influence of governments on labor markets. This paper examined the role of payroll taxation and the social safety net - articulated as an overly generous system of unemployment insurance - for cyclical fluctuations in an nonmonetary 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, as a result, strengthens the model's endogenous propagation mechanism. The existence of social insurance serves to aggravate this effect, as does worker bargaining power. For conventional calibrations, the model can generate a Beveridge curve and can match the high volatility of vacancies and unemployment relative to labor productivity. In future work, we plan to turn to micro data to uncover the quantitative sources of countercyclical payroll taxation and its potentially changing behavior over time.

References

[1] Burda, Michael C. and Mark Weder (2002): "Complementarity of Labor Market Institutions, Equilibrium Unemployment and the Persistence of Business Cycles", *German Economic Review* 3, 1-24.

[2] Burda, Michael C., Dan Hamermesh and Philippe Weil "The Distribution of Total Work in the EU and the US," in Boeri, et al. eds., *Working Hour and Job Sharing in the EU and the USA: Are Europeans Lazy or Americans Crazy?* Oxford: Oxford University Press, 2008.

[3] Cole, Harold L and Richard Rogerson (1999): "Can the Mortensen-Pissarides Matching Model Match the Business-Cycle Facts?," *International Economic Review* 40, 933-59.

[4] Cooley, Thomas F. (1997): "Calibrated Models ", *Oxford Review of Economic Policy* **13**, 55-69.

[5] Daveri, Francesco and Guido Tabellini (2000): "Unemployment, growth and taxation in industrial countries," *Economic Policy* 15, 47-104.

[6] Ebell, Monique (2008): "Resurrecting the Participation Margin", CEP Discussion Paper 0873.

[7] Gertler, Mark and Antonella Trigari (2009): "Unemployment Fluctuations with Staggered Nash Wage Bargaining", *Journal of Political Economy* 117.

[8] Greenwood, Jeremy, Zvi Hercowitz and Gregory Huffman (1988): "Investment, Capacity Utilization, and the Real Business Cycle", *American Economic Review* **78**, 402-417.

[9] Hall, Robert (2005): "Employment Fluctuations with Equilibrium Wage Stickiness", *American Economic Review*, 95, 50-65.

[10] Hall, Robert and Paul R. Milgrom (2005): "The Limited Influence of Unemployment on the Wage Bargain", *American Economic Review* 98, 1653-1674.

[11] Merz, Monika (1995): "Search in the labor market and the real business cycle," *Journal of Monetary Economics* 36, 269-300.

[12] Ravn, Morten (2008): "The Consumption-Tightness Puzzle", in: Reichlin, Lucrecia and West, Kenneth (eds.) *NBER International Seminars in Macroeconomics*, Chicago: University of Chicago Press.

[13] Reiter, Michael and Jim Costain (2007) "On the relevance of saving for labor market fluctuations", mimeo.

[14] Shimer, Robert (2005): "The Cyclical Behavior of Equilibrium Unemployment and Vacancies," *American Economic Review* 95, 25–49.

[15] Shimer, Robert (2009) *Labor Markets and Business Cycles,* manuscript, University of Chicago, February.

[16] Tripier, Fabien (2003): "Can the Labor Market Search Model Explain Fluctuations of Allocations of Time?", *Economic Modeling* 21, 131-46.

[17] Veracierto, Marcelo (2008): "On the Cyclical Behavior of Employment, Unemployment and Labor Force Participation", *Journal of Monetary Economics* 55, 1143-57.

7 Appendix. The DSGE model in detail

7.1 Derivation of search equation

The first order condition for search and the Benveniste-Scheinkman equation for the value function of employment are:

$$-A\left(1-s_t-h_t\right)^{\chi}+\beta f_t E_t V_{h_{t+1}}+\lambda_t b(1-\epsilon)=0 \tag{16}$$

$$V_{h_t}=-A\left(1-s_t-h_t\right)^{\chi}+\beta(1-\delta^h)E_t V_{h_{t+1}}+\lambda_t(w_t(1-\tau_t)-\epsilon b) \tag{17}$$

subtracting (1) from (2) yields

$$V_{h_t}=\beta(1-\delta^h-f_t)E_t V_{h_{t+1}}+\lambda_t(w_t(1-\tau_t)-b) \tag{18}$$

multiply both sides of (3) by $(1-\delta^h)$

$$(1-\delta^h)V_{h_t}=\beta(1-\delta^h-f_t)(1-\delta^h)E_t V_{h_{t+1}}+(1-\delta^h)\lambda_t(w_t(1-\tau_t)-b) \tag{19}$$

multiply both sides of (2) by $(1-\delta^h-f_t)$

$$\begin{gathered}(1-\delta^h-f_t)V_{h_t}=-(1-\delta^h-f_t)A\left(1-s_t-h_t\right)^{\chi}\\ +(1-\delta^h-f_t)\beta(1-\delta^h)E_t V_{h_{t+1}}+(1-\delta^h-f_t)\lambda_t(w_t(1-\tau_t)-\epsilon b)\end{gathered} \tag{20}$$

now subtract (5) from (4) to obtain

$$\begin{aligned} f_t V_{h_t} &= (1-\delta^h)\lambda_t(w_t(1-\tau_t)-b)+(1-\delta^h-f_t)A\left(1-s_t-h_t\right)^{\chi} \\ &\quad -(1-\delta^h-f_t)\lambda_t(w_t(1-\tau_t)-\epsilon b) \end{aligned} \tag{21}$$

$$f_t V_{h_t} = (1-\delta^h - f_t) A (1-s_t-h_t)^\chi \tag{22}$$
$$-(1-\epsilon)(1-\delta^h)\lambda_t b + f_t \lambda_t (w_t(1-\tau_t) - \epsilon b) \tag{23}$$

$$V_{h_t} = f_t^{-1}\left[(1-\delta^h - f_t) A (1-s_t-h_t)^\chi - (1-\epsilon)(1-\delta^h)\lambda_t b\right] \tag{24}$$
$$+\lambda_t (w_t(1-\tau_t) - \epsilon b) \tag{25}$$

now lead this by one period and rearrange

$$V_{h_{t+1}} = f_{t+1}^{-1}\left[(1-\delta^h - f_{t+1}) A (1-s_{t+1}-h_{t+1})^\chi - (1-\epsilon)(1-\delta^h)\lambda_{t+1} b\right] \tag{26}$$
$$+\lambda_{t+1}(w_{t+1}(1-\tau_{t+1}) - \epsilon b) \tag{27}$$

and insert into (1) rewritten as

$$A(1-s_t-h_t)^\chi - \lambda_t b(1-\epsilon) = \beta f_t E_t V_{h_{t+1}} \tag{28}$$

to yield

$$\begin{aligned} & A(1-s_t-h_t)^\chi - \lambda_t b(1-\epsilon) \\ = & \left[\begin{array}{c} \beta f_t E_t \left[f_{t+1}^{-1}(1-\delta^h - f_{t+1}) A (1-s_{t+1}-h_{t+1})^\chi\right] \\ -\beta f_t E_t \left[f_{t+1}^{-1}(1-\epsilon)(1-\delta^h)\lambda_{t+1} b\right] \\ +\beta f_t E_t \left[\lambda_{t+1}(w_{t+1}(1-\tau_{t+1}) - \epsilon b)\right] \end{array}\right] \end{aligned} \tag{29}$$

or

$$\frac{A(1-s_t-h_t)^\chi - \lambda_t b(1-\epsilon) - \beta f_t E_t\left[\lambda_{t+1}(w_{t+1}(1-\tau_{t+1}) - \epsilon b)\right]}{f_t} \tag{30}$$
$$= \beta E_t\left[\frac{(1-\delta^h - f_{t+1}) A (1-s_{t+1}-h_{t+1})^\chi - (1-\epsilon)(1-\delta^h)\lambda_{t+1} b}{f_{t+1}}\right] \tag{31}$$

7.2 Wage equation

The first order condition from the Nash bargaining problem is

$$\frac{\mu(1-\tau_t)}{c_t V_{h_t}} = \frac{(1-\mu)}{W_{h_t}} \tag{32}$$

or, given that the value of an additional employed worker to the firm is given by (**??**),

$$c_t V_{h_t} = \frac{\mu(1-\tau_t)}{1-\mu}\left[(1-\alpha)\frac{y_t}{h_t} - w_t + (1-\delta^n)\frac{a}{q_t}\right] \tag{33}$$

Lead this expression by one period and premultiply by the pricing kernel ρ_{t+1}:

$$\rho_{t+1}c_{t+1}V_{h_{t+1}} = \frac{\mu\left(1-\tau_{t+1}\right)}{1-\mu}\rho_{t+1}\left[\left(1-\alpha\right)\frac{y_{t+1}}{h_{t+1}} - w_{t+1} + (1-\delta^n)\frac{a}{q_{t+1}}\right]. \tag{34}$$

Take expectation of both sides conditional on t, and use (14) and the fact that $\rho_{t+1}c_{t+1} = \beta c_t$ to rewrite the last expression as

$$E_t\rho_{t+1}c_{t+1}V_{h_{t+1}} = \beta c_t E_t V_{h_{t+1}} = \frac{\mu E_t\left(1-\tau_{t+1}\right)}{1-\mu}\frac{a}{q_t} \tag{35}$$

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

$$c_t V_{h_t} = (1-\tau_t)w_t - b + \rho_{t+1}(1-\delta^n - f_t)c_{t+1}E_t V_{h_{t+1}} \tag{36}$$

and

$$c_t V_{h_t} = (1-\tau_t)w_t - b + (1-\delta^n - f_t)\frac{\mu E_t\left(1-\tau_{t+1}\right)}{1-\mu}\frac{a c_t}{q_t} \tag{37}$$

Now insert this and (**??**) into (32):

$$\begin{aligned} & \mu(1-\tau_t)\left[\left(1-\alpha\right)\frac{y_t}{h_t} - w_t + (1-\delta^n)\frac{a}{q_t}\right] \\ = \; & (1-\mu)\left[(1-\tau_t)w_t - b + (1-\delta^n - f_t)\frac{\mu E_t\left(1-\tau_{t+1}\right)}{1-\mu}\frac{a}{q_t}\right] \end{aligned} \tag{38}$$

which can be solved to obtain

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

or

$$w_t = \frac{\left(1-\mu\right)b}{1-\tau_t} + \mu\left(1-\alpha\right)\frac{y_t}{h_t} + \mu(1-\delta^n)\frac{a}{q_t}\frac{E_t\left(\tau_{t+1}-\tau_t\right)}{1-\tau_t} + \mu\theta_t a\frac{E_t\left(1-\tau_{t+1}\right)}{1-\tau_t} \tag{39}$$

7.3 Model reduction

By substitution, we can reduce the description of equilibrium to the following equations:

1. Optimal capital utilization follows from (**??**)

$$u_t^\theta = \alpha\frac{y_t}{k_t}$$

2. Optimal capital services follows from (13)

$$r_t = \alpha \frac{y_t}{u_t k_t} \tag{40}$$

3. Euler equation is the outcome of combining (**??**) with **??** to eliminate W_{h_t} and $W_{h_{t+1}}$:

$$\frac{1}{c_t} = \beta E_t \left[\frac{1 + \alpha \frac{y_{t+1}}{k_{t+1}} - \delta^k_{t+1}}{c_{t+1}} \right] \tag{41}$$

4. Labor supply / optimal search is derived by by combining (8) and (**??**) to eliminate V_{h_t} and $V_{h_{t+1}}$.

$$\begin{aligned} & A\left(1 - s_t - h_t\right)^{\chi} f_t^{-1} - \frac{b}{c_t}(1-\epsilon) f_t^{-1} \\ = \quad & \beta \frac{1 - \delta^h - f_{t+1}}{f_{t+1}} A\left(1 - s_{t+1} - h_{t+1}\right)^{\chi} - \beta \frac{b\left(1-\delta^h\right)(1-\epsilon)}{f_{t+1} c_{t+1}} \\ & + \beta \frac{1}{c_{t+1}} (w_{t+1}(1 - \tau_{t+1}) - \epsilon b) \end{aligned}$$

5. Resource constraint (6) using the NIPA identity:

$$k_{t+1} - (1 - \delta^k_t) k_t + c_t + a v_t = y_t \tag{42}$$

6. Technology: (11):

$$y_t = z_t \kappa_t^{\alpha} h_t^{1-\alpha} \tag{43}$$

7. Wage equation is (15):

$$w_t = \frac{(1-\mu) b}{1 - \tau_t} + \mu (1 - \alpha) \frac{y_t}{h_t} + \mu (1 - \delta^n) \frac{a}{q_t} \frac{E_t (\tau_{t+1} - \tau_t)}{1 - \tau_t} + \mu \theta_t a \frac{E_t (1 - \tau_{t+1})}{1 - \tau_t} \tag{44}$$

8. Firm's vacancies are given by (14).

$$\frac{a}{q_t} = E_t \rho_{t+1} \left[(1 - \alpha) \frac{y_{t+1}}{h_{t+1}} - w_{t+1} + (1 - \delta^h) \frac{a}{q_{t+1}} \right]. \tag{45}$$

9. Government budget constraint (3):

$$b s_t + \varepsilon b (1 - s_t - h_t) = \tau_t w_t h_t \tag{46}$$

10. The state equation for employment:

$$h_{t+1} = M(s_t, v_t) + (1 - \delta^h) h_t. \tag{47}$$

11. Depreciation:

$$\delta^k_t = \frac{1}{\theta} u_t^{\theta}.$$

Figure 1: Payroll taxes as a fraction of total wages bill, US 1970-2008

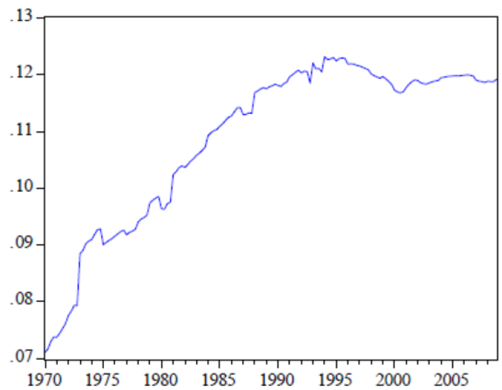

Figure 2: Payroll taxes as a fraction of total compensation, Germany 1970-2008

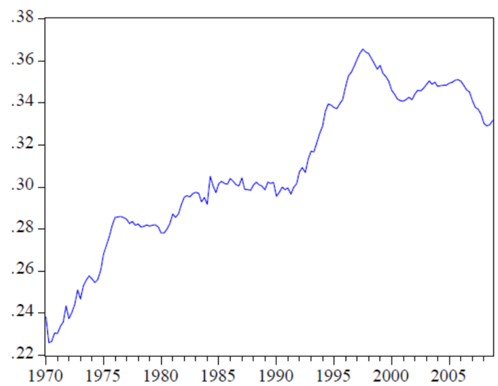

Figure 3: HP-detrended payroll taxes and GDP per capita, US, 1970-2008

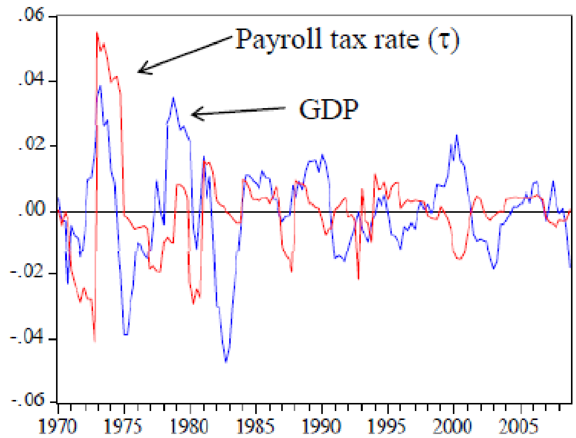

Figure 4: HP-detrended payroll taxes and GDP per capita, Germany 1970-2008

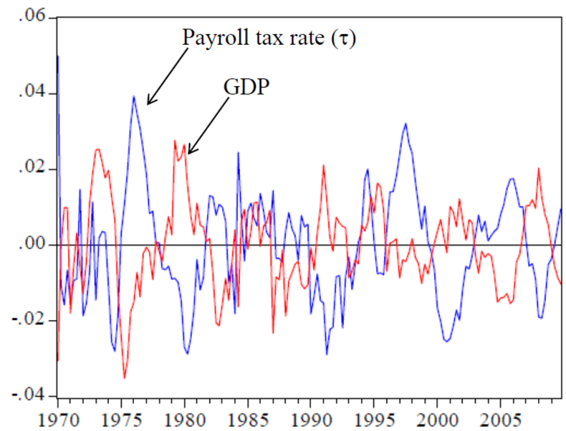

Figure 5: Impulse responses of the artificial economy without payroll taxes and social system to a positive 1% technology shock: Output, unemployment, labor share

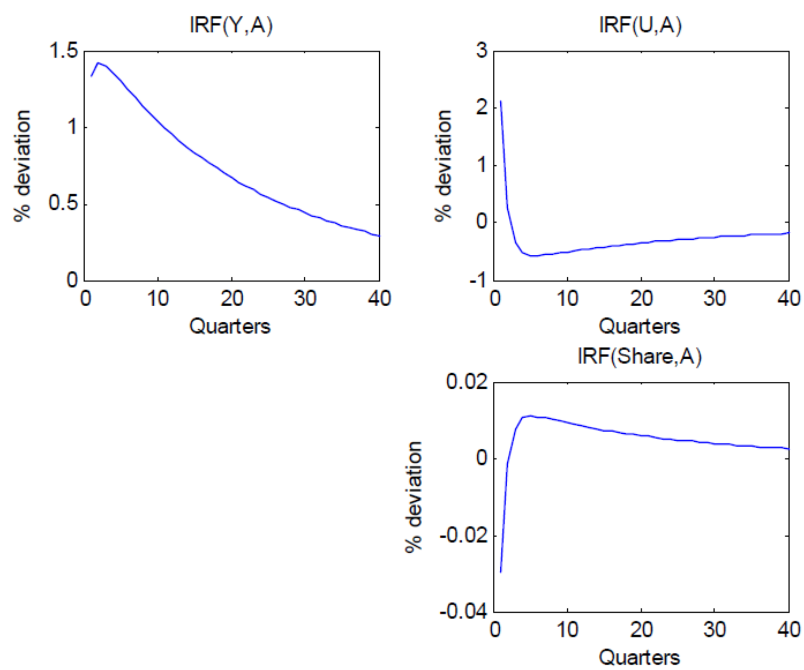

Figure 6: Impulse responses of the artificial economy without payroll taxes and social system to a postive 1% technology shock: Vacancies, employment, wages, labor market tightness (v/u)

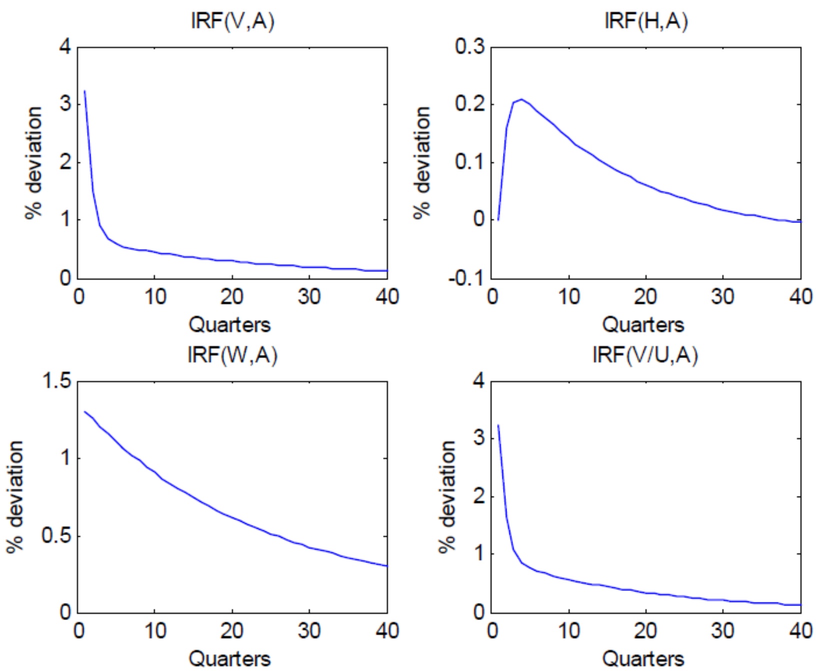

Figure 7: Impulse responses of the artificial economy payroll taxes and social system to a positive 1% technology shock: Output, unemployment, tax rate, labor share

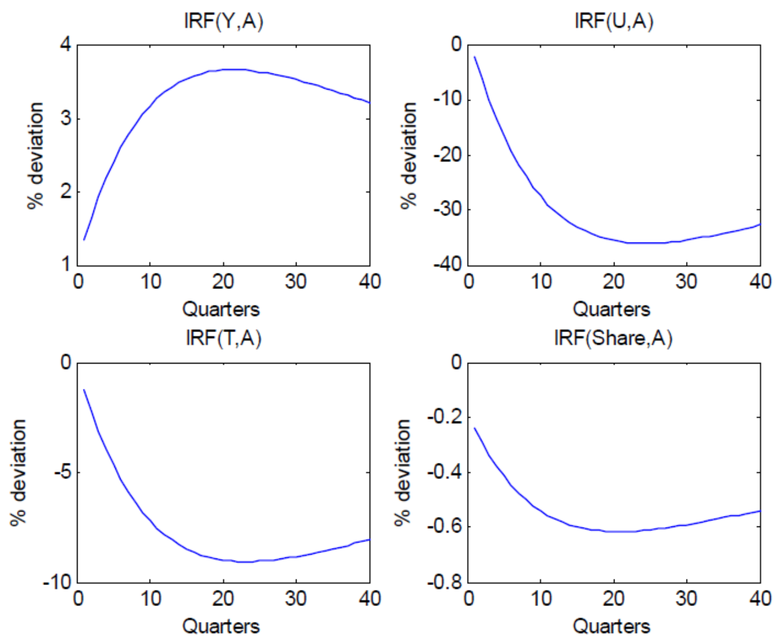

Figure 8: Impulse responses of the artificial economy with payroll taxes and social system to a positive 1% technology shock: Vacancies, employment, wages, labor market tightness (v/u)