Labor Market Frictions and Monetary Policy Rules: Role of Institutions

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Different labor market institutions have long been seen as a reason for different employment, output and inflation dynamics in different European countries and the US. These differences potentially require different monetary policy settings. In this paper we study implications of different labor market institutions, namely bargaining power and unemployment benefits, for monetary policy rules. We employ a dynamic stochastic general equilibrium model with search frictions on the labor market, sticky prices and monopolistic competition on the goods market. Our finding is that higher bargaining power stimulates monetary policy to move closer to complete price stabilization rule while higher unemployment benefit moves economy further away from an efficient allocation and incentivizes a policy to give up price stability for stabilizing labor market tightness. We found optimized simple monetary rules a’la Taylor for different institutional environments and showed that they exhibit similar features - with higher bargaining power a coefficient before inflation is higher and with higher unemployment benefit labor market tightness becomes more important. Such optimized Taylor rules were also shown to be beneficial in terms of welfare.

Keywords: Search frictions, Optimal monetary policy, Labor market institutions, Taylor rules

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1 Introduction

One of the conclusions in the labor economics literature is that institutions matter. Labor market institutions affect the structure of the labor market and therefore aggregate economic variables and their dynamics. Different institutions can be therefore a potential explanation for differences in unemployment rates, average wages and other labor market characteristics in different countries. For example, Blanchard and Wolfers (2000) showed that interaction of labor market institutions and country specific shocks can be crucial in explaining some stylized facts about cross-country differences in labor market situations in some European countries. Nickell, Nunziata, Ochel and Quintini (2003) provided some empirical evidence that unemployment dynamics in OECD countries in 1960-90 can be well explained by changes in labor market institutions. Alvarez and Veracierto (1999) using Lucas type of model showed that labor market policies determine differences in employment. Many papers argue that European labor market situation is so significantly different from the situation in the US because of a different institutional environment (for example, Nickell 1997, Blanchard, Wolfers, 2000, Layard and Nickell, 1999, A. Campolmi, E. Faia, 2011).

Labor market in Europe is very often argued to be inflexible and rigid. High firing costs, high unemployment benefits and strong unions are perceived to contribute to high unemployment level and slow labor adjustment (Table 1). High union coverage and collective bargaining in Europe (Nickell, Nunziata, Ochel and Quintini, 2003) make a wage negotiation process more rigid. An upward pressure on wages stimulates additional unemployment.

Labor market institutions affect not only a long-run economic equilibrium but also a response of different economic variables to shocks (e.g. Zanetti (2011), Thomas, Zanetti (2009), Krause, Lubik (2007), Merkl, Schmitz (2011)). This means that monetary shocks can create different responses in the economy in case of different labor market institutions. Most of the existing papers dealing with labor market institutions focus on the consequences of monetary shocks in case of different institutional settings. In this paper we address a question of how monetary policy design itself should be adapted to labor market characteristics and labor market institutions. We use a general equilibrium model with search and matching framework (Mortensen-Pissarides, 1994) to allow for
more detailed description of labor market dynamics. For our analysis we restricted our attention to bargaining power of worker and unemployment benefit. These are two types of institutions which have direct effect on wage determination process. We first analyzed the effect of these labor market institutions on optimal policy design and trade-offs of policymaker. Our second question was how simple Taylor rules, which presumably easier to be implemented in reality, should be adopted to different labor market environments (to achieve a best possible welfare level).

Our model is taken from Tang (2010) and is similar to Thomas (2008), Blanchard and Gali (2009), Faia (2008). These papers also addressed a monetary policy design in a model with imperfect labor market and found that Taylor rule with strong inflation stabilization gives a result close to the optimal policy outcome in terms of welfare losses. Faia (2008) found, however, that optimized Taylor rule—the one with a lowest welfare losses among other simple rules—should also positively react to unemployment and Tang (2010) suggest that optimal Taylor rule should put a modest weight on labor market tightness. In this paper we conducted a similar welfare comparison of simple policy rules. We then compare the results in case of different labor market institutions to see how monetary policy design interacts with a labor market situation.

Main finding is that institutions are important for monetary policy design. More specifically, higher bargaining power enables optimal policy to replicate an allocation which is closer to a social optimum. Optimal policy moves closer to a complete inflation stabilization. This result comes from the fact that higher bargaining power brings a wage closer to a marginal product of labor (worker’s value for a firm). So wages (and therefore inflation) become more affected by technology shocks and more volatile. Vacancies and labor market tightness become less volatile, since they do not have to absorb the effect of technology shocks. Optimal policy can therefore focus rather on inflation stabilization. Optimized simple rule a’la Taylor has also a higher weight on inflation in this case. Difference in welfare losses between zero inflation and optimal Taylor rule is rather small in this case, so we concluded that complete prices stabilization is more desirable in economy with such a labor market.

Higher replacement ratio, on contrary, moves economy away from a socially efficient allocation. Wages become closer to a value of non-labor activity and less responsible to
shocks. Firms adjust mainly via vacancy posting decisions. As profit share gets smaller incentives to post vacancies decrease. Labor market variables become more volatile and policy has higher incentive to give up complete price stability in order to stabilize other variables. Similar results can be found in Zanetti (2011), Campori, Faia (2011) who showed that with a higher replacement ratio volatility of inflation and marginal costs falls and volatility of labor market flows increases. We found that optimized Taylor rule puts a higher weight on labor market tightness in this case and this potentially allows policy to achieve higher welfare.

To sum up, we conclude that central bank would benefit from monitoring labor market and reacting to labor market variables. According to our calibration in European type countries with powerful trade unions and high unemployment benefits central bank should react to labor market tightness (or other labor market indicators) stronger then in the US type countries with more flexible labor market institutions.

The rest of the paper is organized as follows. Section 2 presents some empirical evidence. Section 3 describes the model and market equilibrium while Section 4 discusses different possible policy settings - social planner solution, optimal monetary policy design and simple monetary rules. Section 5 presents the analysis of the effect of different labor market institutions on monetary policy outcome as well as welfare analysis. Section 6 concludes.
2 Data analysis

As was pointed out in the previous section unemployment dynamics in Europe is quite different from the one in the US. One can see from Figure 1 that during 1980-2009 there was a significant persistent difference between unemployment rates in the US and Europe with the European being much higher.

![Unemployment rate in US and Europe](image)

**Figure 1**: Unemployment rate in US and Europe. Source: OECD LFS Indicators

Possible explanation in the literature is different labor market structures and institutions. Labor market in Europe features rather high firing costs, high unemployment benefits and strong unions. These all contributes to upward pressure on wages, slow labor marker adjustment and high unemployment level.

Following Blanchard and Wolfers (2000) and Campolmi and Faia (2011) we will analyze unemployment insurance coverage as one of the main institutions which define a labor market structure. Indeed, unemployment benefit is a key determinant of worker outside options hence his decision to keep a job and his position in a bargaining process. Therefore, as Campolmi and Faia (2011) argue, unemployment benefit may be a best proxy of labor market institutions in general. Table 1 presents a data on unemployment insurance as a percentage of previous earnings for some European countries and for the US for 2010 and 2011. Several features are worth pointing out. First, unemployment
Table 1: Labor Market Institutions

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<td>71</td>
<td>69</td>
<td>32.7</td>
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<td>11.4</td>
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Unemployment benefits in percentage of previous earnings is an average of the net unemployment benefit replacement rates for two earnings levels, three family situations and 60 months of unemployment. Union membership in percentage of employees. Source: OECD Employment Outlook.

benefits in Europe apart from Italy and Greece are higher then in the US. Second, in the European countries themselves the level of unemployment benefit varies a lot from 23% in Greece to 71% in Ireland. These differences are rather constant in time. Campolmi and Faia, (2011) also noticed that even though all EMU countries conducted a labor market reforms and increased level and duration of unemployment benefits after a creation of EMU the differences in unemployment insurance between countries remained approximately the same and showed little convergence. This might be a signal of the importance of institutional structure.

Table 1 also displays another measure of labor market institutions - labor union membership coverage. In general, union coverage is fairly high in most of European countries,
for example, 70% in Finland, about 50% in Belgium, 68% in Sweden. Apart from France all countries have much higher union coverage then in the US. Higher union membership is very likely to lead to a higher collective bargaining power of workers and we can think about union membership as about a proxy for worker bargaining power parameter.

We consider unemployment benefits and worker bargaining power as the most important labor market institutions. From theoretical point of view these are highly important labor market parameters in our model since they directly affect wage determination. An empirical evidence of their significance can be found in Nickell (1997) who studied how the unemployment vary with different union coverage and unemployment insurance in European countries. Nickell’s regression indicates that unemployment rate increases by about 0.48 percent with a 1 percent increase in union density and by about 0.62 percent with an increase of unemployment benefit.

To sum up, European countries have quite different labor market structure in comparison to the US. As a result it might be the case that quite different monetary policy rules will be more efficient for European countries. In the next section we will present a model framework which we will then use to analyze an effect of unemployment benefits and bargaining power on monetary policy design calibrating these parameters according to the European and the US regimes.
3 Model Description

3.1 Representative household

Economy is populated by infinitively lived representative household with continuum of members of measure unity. Household maximizes a utility function (1) subject to a budget constraint and transition equation for labor. Household can change the consumption path by buying and selling government bonds or by sending additional household members to work. The process of finding a job is, however, subject to search frictions on the labor market. The stock of employment therefore performs like a capital stock and employment is a state variable in the model. We do not have an explicit capital accumulation. All employed and unemployed household members have perfect consumption insurance and ”share the table” withing a family. Total labor force (household size) is normalized to 1.

\[ W_{t_0} = E_{t_0} \sum_{t=t_0}^{\infty} \beta^{t-t_0} [u(c_t) - n_t v(h_t) - Bn_t] \]  

(1)

where \( u(c_t) = \frac{c_t^{1-\tilde{\sigma}}}{1-\tilde{\sigma}} \), \( v(h_t) = \frac{\Gamma h_t^{1+\gamma}}{1+\gamma} \)

\( c_t \) is consumption, \( n_t \) is a number of employed workers in period \( t \), \( h_t \) is a number of hours worked, \( \tilde{v} \) is a disutility from working and \( B \) is fixed costs of working.

s.t.

\[ n_{t+1} = (1-d)(n_t + \lambda_t u_t) \]  

(2)

\[ c_t + \frac{B_{t+1}^n}{P_t R_t} \leq \frac{B_t^n}{P_t} + w_t n_t h_t + u_t b - T_t + D_t \]  

(3)

Equation 2 describes transition of employment. At the beginning of period \( t \) unemployed worker finds a jobs with probability \( \lambda_t \) and makes a match with a firm in the same period. The number of employed people in period \( t \) constitutes of workers remained from the previous period and new matches \( n_t + \lambda_t u_t \). At the end of the period workers are separated with exogenous probability \( d \) and therefore the share of workers \((1-d)\) enters next period \( t+1 \) as employed. \( B_t^n \) is a stock of nominal bonds, \( P_t \) is a price of consumption goods, \( R_t \) is a gross nominal interest rate. Employed household members earn real wage \( w_t \), unemployed members get unemployment benefit \( b \) from government.
Household also pays lump-sum tax $T_t$ and gets profit $D_t$ from firms. Moreover, total household size is normalized to 1 so $u_t = 1 - n_t$. Bellman function is then

$$
\Omega_t(c_t, n_t, u_t, B_{t+1}^n) = \max_{\{c_t, n_t\}} \{u(c_t) - n_t v(h_t) - Bn_t + \beta E_t \Omega_{t+1}\}
$$

Taking the derivatives with respect to $B_{t+1}^n$ and $n_t$ we obtain optimality conditions

$$
\frac{u'(c_t)}{P_t} = \beta R_t E_t \frac{u'(c_{t+1})}{P_{t+1}} \quad \text{(4)}
$$

$$
\Omega^n_t = \left[w_t h_t - \frac{v(h_t) + B}{u'(c_t)} + E_t \beta_{t,t+1} [(1 - d)\Omega^n_{t+1}] - [b + E_t \beta_{t,t+1} (1 - d) \lambda_t \Omega^n_{t+1}] \right] \quad \text{(5)}
$$

The first condition is a standard Euler equation and the second is choice of the number of workers. Namely, when the household sends additional family member to work it receives wage minus disutility of labor and with probability $(1-d)$, if the worker is not separated, discounted value of employment in the next period. At the same time it loses the value of unemployment benefit and loses future discounted value of potential employment - if the person finds a job with probability $\lambda_t$ and is not separated (as in Thomas, 2008). Here

$$
\beta_{t,t+1} = \beta \frac{u'(c_{t+1})}{u'(c_t)}
$$

is a stochastic discount factor and

$$
\Omega^n_t = \frac{d(\Omega_t)/dn}{u'(c_t)}
$$

No-Ponzi condition on wealth is also satisfied.

### 3.2 Producers

Large number of identical intermediate good producers operate on a competitive market. They use labor as the only input and produce intermediate goods according to the production function (6). Firms must post vacancies $v_t$ at fixed costs $\chi$ in order to find workers. The vacancy meets an unemployed person with probability $\mu_t$ and the match becomes operative in the same period. At the end of the period share $d$ of matches dissolves and the rest enters $t+1$ period.

$$
f(n_t h_t) = A_t (n_t h_t)^{1-\phi}, \quad 0 \leq \phi < 1 \quad \text{(6)}
$$
\[
\log(A_{t+1}) = (1 - \rho_A) \log(\xi_A) + \rho_A \log(A_t) + \epsilon_A, \quad |\rho_A| < 1, \epsilon_A \sim N(0, \sigma^2_A)
\]

(7)

\[
n_{t+1} = (1 - d)(n_t + \mu_t v_t)
\]

(8)

Firm’s Bellman equation and FOCs with respect to \( n_t \) and \( v_t \) are

\[
\tilde{J}(n_t, v_t) = \max_{\{n_t, v_t\}} \left\{ p_t^R f(n_t h_t) - w_t n_t h_t - \chi v_t + E_t \beta_{t+1} \tilde{J}_{t+1} \right\}
\]

\[
J_t = p_t^R f'(n_t h_t) h_t - w_t h_t + (1 - d) E_t \beta_{t+1} J_{t+1}
\]

(9)

\[
\chi = (1 - d) \mu_t E_t \beta_{t+1} J_{t+1}
\]

(10)

where \( J_t = \frac{d(J_t)}{dn_t} \). The first condition says that value of additional worker for a firm equals to a marginal product of labor times real wholesale price \( p_t^R \) minus wage plus discounted value of additional worker in the next period if he does not lose the job.

Second arbitrage condition equalizes the cost of posting a vacancy to the potential benefit it creates. Combining both optimality conditions we get a job-creation equation describing an intertemporal choice of the firm

\[
\frac{\chi}{(1 - d) \mu_t} = E_t \beta_{t+1} [p_t^R f'(n_{t+1} h_{t+1}) h_{t+1} - w_{t+1} h_{t+1} + (1 - d) \frac{\chi}{(1 - d) \mu_{t+1}}]
\]

(11)

3.3 Labor market

Unemployed workers and unfilled vacancies randomly meet each other on the labor market and make matches via a matching technology or matching function (12) witch uses \( u_t \) and \( v_t \) as inputs. The function is assumed to have a constant elasticity of substitution \( \epsilon \) and constant return to scale property.

\[
m(u_t, \nu_t) = m[\xi u_t^{(\epsilon-1)/\epsilon} + (1 - \xi) \nu_t^{(\epsilon-1)/(\epsilon-1)}] \quad m > 0, \xi > 0, \quad \epsilon < 1
\]

(12)

Matching friction prevents some workers from finding a job and some vacancies are left unfilled. Matching process reflects the idea that worker needs to spend some time on search in order to find an appropriate vacancy. Thus unemployed workers are looking for a job and at the same time some vacancies are left unfilled. Job-finding rate for a worker is determined as \( \lambda_t = m(u_t, v_t)/u_t = m(1, \theta_t) \) and vacancy-filling rate \( \mu_t = \)
\[ m(u_t, v_t)/v_t = m(1/\theta_t, 1), \] where \( \mu_t = \lambda_t/\theta_t \). \( \theta_t = v_t/u_t \) is called a labor market tightness and is a sufficient statistics to characterize a labor market. Existing matches dissolve at exogenous rate \( d \) which is in accordance with Hall (2004) who showed that workers lose their job with the same frequency in good and bad times.

One important aspect of the labor market is search externalities. \( \lambda(\theta_t) \) is increasing in \( \theta_t \), meaning that more vacancies relative to unemployed people make it easier for a worker to find a job, thick-market effect. And vice versa \( \mu(\theta_t) \) is decreasing in \( \theta \). A vacancy is less likely to meet a worker when there are more vacancies and less unemployed workers, this is a congestion effect. Neither a single firm nor a single worker takes into consideration these effects. This means that additional worker or vacancy that appears on the labor market creates externalities and equilibrium is inefficient as long as these externalities are not internalized.

### 3.4 Wage and hours bargaining

Because labor market is not in equilibrium in a sense that there are both unemployed people and unfilled vacancies at the same time, wage cannot be determined as in the standard Walrasian paradigm. Instead a Nash bargaining approach is used. The firm and the worker in a match are assumed to negotiate a wage and hours worked every period such that they maximize a total surplus created by the match and then share it according to their bargaining powers\(^1\).

\[
\max_{\{w_t, h_t\}} \left\{ \left( \Omega^w_t - \Omega^u_t \right)^\varsigma (J_t - 0)^{1 - \varsigma} \right\}
\]

where \( \varsigma \) is a worker bargaining power and \( 1 - \varsigma \) is a bargaining power of the firm.

All possible values of wage, defined as a bargaining set, lie between wage that brings a zero surplus for the worker and the wage that creates a zero surplus for the firm. Because of vacancy costs these two wages are not the same and bargaining set exists and is nontrivial (Gali, 2010). Nash bargaining approach provides a way of choosing from this set and this solution is personally efficient, meaning that neither the worker nor the firm has an incentive to deviate (Hall, 2005). Note that wages are flexible and

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\(^1\) An alternative approach to the choice of hours is "right to manage" when a firm decides on a particular number of hours for every worker. See Pissarides, 2000
can be negotiated every period. Although many papers argue that sticky wages is an important mechanism which translates labor market outcome into monetary policy goals (e.g. Christoffel and Linzert, 2006), in the model considered here even in the absence of wage stickiness labor market frictions still introduce an additional trade-off for a policymaker. Moreover, when considering a matching process we mean new hirings. It is quite natural to assume that for them wages can be negotiated freely. While it is quite well-known that wages on average are sticky, wage stickiness for new hirings is a rather ambiguous point (Haefke et al., 2007). Flexible wage assumption is also not subject to a so-called Barro critique (Barro, 1997, see also Shimer, 2004).

Differentiating with respect to wage brings a surplus sharing rule $\varsigma J_t = (1 - \varsigma)\Omega^n_t$. Rearranging the term we can show that the worker gets $\varsigma$ share and the firm receives $1 - \varsigma$ of the total surplus $\Omega^n_t + J_t$.

Using this rule and differentiation with respect to $h_t$ we get

$$\varsigma(\Omega^n_t)^{-1}(J_t - 0)^{1-\varsigma}[w_t - v'(h_t)] + (1 - \varsigma)(\Omega^n_t)^{\varsigma}(J_t - 0)^{-\varsigma}p_t^s f'(n_th_t) - w_t = 0$$

$$\varsigma(\Omega^n_t)^{-1}J_t[w_t - v'(h_t)] = (1 - \varsigma)[w_t - p_t^s f'(n_th_t)]$$

$$p_t^s f'(n_th_t) = \frac{v'(h_t)}{u'(c_t)}$$ (13)

The hours worked are chosen such that a marginal rate of substitution between consumption and leisure is equal to the marginal product of labor as in the frictionless framework. This means that under a Nash-bargaining intensive margin is efficient regardless of the distortions for extensive margin.

Now from the definition of $\Omega^n_t$, $J_t$ and surplus sharing rule we can define a total wage bill payed by a firm

$$w_t h_t = \varsigma[p_t^s f'(n_th_t)h_t + \chi\theta] + (1 - \varsigma) \left[\frac{v(h_t) + B}{u'(c_t)} + b\right]$$ (14)

This is a pretty standard result that wage splits the total created surplus according to the bargaining power of the sides. Specifically, the higher is a firm bargaining power $(1 - \varsigma)$ the closer is a wage bill to the alternative costs of working for a household member - unemployment benefit plus saved disutility of working. When a worker has a strong bargaining position a wage bill is close to the firm’s benefit from additional worker -
marginal product of labor and saved vacancy posting costs. Note that bargaining power
determines the elasticity of wages with respect to productivity shocks. Both bargaining
power and unemployment benefit also affect the size of the wage in a steady state. This
creates a channel through which these institutions affect the dynamics of the economy.

3.5 Retailers

There are two types of retailers in the model. Intermediate retailers indexed by
\( j \in [0, 1] \) buy intermediate goods from producers for price \( p^*_t \) and convert them into
differentiated intermediate goods. Since intermediate retailers operate under a monop-
opolistic competition they are able to set different prices \( P_j \). Prices are set optimally but
every period can be adjusted with probability \( 1 - \alpha \) only as in Calvo (1983). Intermediate
retailers then sell their differentiated products to a final goods retailer. He, in turn,
collects a continuum of intermediate goods according to the Dixit-Stiglitz aggregator
(1977) and creates a final output (consumption basket) \( y_t \) which is then sold to the
household for a final price \( P_t \). Such a complicated structure of goods production allows
us to separate a matching process on the labor market faced by producers from imperfect
competition and price setting process of intermediate retailers (see for example Tang,
2010 and Trigari, 2009).

Final retailer decides what amount of intermediate goods \( j \) to buy by solving a profit
maximization problem

\[
\max_{y_{jt}} P_t y_t - \int_0^1 P_j y_{jt} dj
\]

s.t. \( y_t = \left[ \int_0^1 y_{jt}^{(\epsilon_p-1)/\epsilon_p} dj \right]^{\epsilon_p/(\epsilon_p-1)} \) \hspace{1cm} (15)

then demand \( y_{jt} \) is

\[
P_t \frac{\epsilon_p}{\epsilon_p - 1} \left[ \int_0^1 y_{jt}^{(\epsilon_p-1)/\epsilon_p} dj \right]^{1/(\epsilon_p-1)} \frac{\epsilon_p - 1}{\epsilon_p} y_{jt}^{-1/\epsilon_p} - P_{jt} = 0
\]

\[
y_t^{1/\epsilon_p} y_{jt}^{-1/\epsilon_p} = \frac{P_{jt}}{P_t}
\]

\[
y_{jt} = \left[ \frac{P_{jt}}{P_t} \right]^{-\epsilon_p} y_t \hspace{1cm} (16)
\]

From the intermediate goods demand function and a definition of final output (15) we
can derive a Dixit-Stiglitz aggregator for a final price $P_t$.

$$P_t = \left[ \int_0^1 P_{tj}^{1-\epsilon_p} \, dj \right]^{1/(1-\epsilon_p)} \quad (17)$$

An intermediate retailer knowing the demand for its goods $y_{jt}$ purchases exactly this amount from producer and decides on the price $P_{jt}$ in order to maximize an expected future profit stream which comes until it will be able to readjust the price again. Every period with probability $1 - \alpha$ an intermediate retailer receives a signal to optimize the price and sets it to $P_{jt}^*$. A period profit in case when the price is still $P_{jt}^*$, which happens with probability $\alpha$, is then $(1 - \tau) \frac{P_{jt}}{P_T} - \frac{P_s}{P_T}$ where $\tau$ is a sales-tax.

$$\max_{P_{jt}} \mathbb{E}_t \sum_{t=T}^\infty \beta_t (1 - \tau) \frac{P_{jt}}{P_T} - \frac{P_{jt}^*}{P_T} y_{Tj}$$

s.t. $y_{jt} = \left[ \frac{P_{jt}}{P_T} \right]^{\epsilon_p} y_t$

$$E_t \sum_{t=T}^\infty \beta_t (1 - \tau) \left( \frac{P_{jt}}{P_T} \right)^{1-\epsilon_p} - \frac{P_{jt}^*}{P_T} \left( \frac{P_{jt}}{P_T} \right)^{-\epsilon_p} \right] y_T = 0$$

$$E_t \sum_{t=T}^\infty \beta_t (1 - \tau)(1 - \epsilon_p) \frac{P_{jt}^{1-\epsilon_p}}{P_T^{1-\epsilon_p}} - \frac{P_{jt}^*}{P_T} \left( \frac{P_{jt}^{1-\epsilon_p}}{P_T^{1-\epsilon_p}} \right)^{-\epsilon_p} \right] Y_T = 0$$

$$P_{jt}^* = \frac{E_t \sum_{T=t}^\infty (\alpha \beta)^{T-t} u'(c_T) y_T P_T^s (P_T/P_{jt})^{\epsilon_p}}{E_t \sum_{T=t}^\infty (\alpha \beta)^{T-t} (1 - \Phi_y) u'(c_T) y_T (P_T/P_{jt})^{\epsilon_p-1}} \quad (18)$$

where we used a definition of stochastic discount factor, the fact that price remains the same $P_{jt} = P_{jt}^*$ in all the periods and $p_T^s = P_T^*/P_T$. We dropped $j$ index since the optimality condition is the same for all firms and they all will choose the same price $P_{jt}^*$. $\Phi_t$ is defined as $1 - \Phi_y = (1 - \tau)(\epsilon_p - 1)/\epsilon_p$ and can be seen as a monopolistic distortion measure. This is a mark-up received by an intermediate retailer taking into consideration a sales tax. When prices are flexible they are all equal to the average price level. From the equation above it follows that $1 - \Phi_y = P_t^* = \frac{v(h_t)}{u'(c_t)} f'(n_t h_t)$. Intermediate retailers do not have any profit in this case since either $\epsilon_p = 1$, meaning that intermediate goods are perfect substitutes and firms have no monopolistic power, or $\tau = 1$ and all the profit are extracted by the government. This important result shows that government is able to eliminate monopolistic distortions when it is able to impose an appropriate sales tax.
From Calvo pricing it follows that \((1 - \alpha)\) share of firms will change prices in period \(t\) and set them to \(P^*_t\), while the share \(\alpha\) will leave the price unadjusted and therefore the same as in the previous period. Price index is therefore

\[
P_t = [(1 - \alpha)P_t^{1-\epsilon_p} + \alpha P_{t-1}^{1-\epsilon_p}]^{1/(1-\epsilon_p)}
\]

(19)

Defining \(\Pi_t = P_t/P_{t-1}\) we can rearrange

\[
1 = [(1 - \alpha)\left(\frac{P^*_t}{P_t}\right)^{1-\epsilon_p} + \alpha \left(\frac{P_{t-1}}{P_t}\right)^{1-\epsilon_p}]^{1/(1-\epsilon_p)}
\]

\[
\frac{P^*_t}{P_t} = \left(\frac{1 - \alpha\Pi_{t-1}^{\epsilon_p-1}}{1 - \alpha}\right)^{1/(1-\epsilon_p)}
\]

Equation (18) can be then expressed recursively as

\[
\frac{P^*_t}{P_t} = \left(\frac{1 - \alpha\Pi_{t-1}^{\epsilon_p-1}}{1 - \alpha}\right)^{1/(1-\epsilon_p)} = K_t/F_t
\]

with

\[
K_t = u'(c_t)y_tP^*_t + (\alpha\beta)E_t\Pi_{t+1}^{\epsilon_p-1}K_{t+1}
\]

(20)

\[
F_t = (1 - \Phi_y)u'(c_t)y_t + (\alpha\beta)E_t\Pi_{t+1}^{\epsilon_p-1}F_{t+1}
\]

(21)

Equations (17), (18) and (19) can be combined to obtain a supply Phillips curve (22)

\[
\pi_t = \beta E_t\pi_{t+1} + \frac{(1 - \alpha)(1 - \alpha\beta)}{\alpha}\hat{p}^*_t
\]

(22)

where \(\pi_t = \hat{p}_t - \hat{p}_{t-1}\) and every hat variable denotes a log-deviation from a steady state level \(\hat{x}_t = \log x_t - \log x\). According to the Phillips curve behavior of current inflation is determined by expectations about future inflation and by a real part - marginal costs of production which are equal to \(p^*_t\). Note that since producers deal with frictions during the hiring process, labor market distortions affect their marginal costs and therefore price \(p^*_t\) and thus enter an aggregate supply dynamics.

3.6 Complete the model

Government budget is assumed to be balanced \(P_tw_t = P_tT_t + \tau \int_0^1 P_{ij}y_{ij}dj = P_tT_t + \tau P_t y_t\). Unemployment benefits paid by the government are financed through a lump-sum
tax and sales tax. Government bonds are in zero net supply in equilibrium. These two conditions together with a household budget constraint and a definition of the profit give market clearing condition for final goods (23). Defining a price dispersion measure $\Delta_t$ the market clearing conditions for intermediate goods market is (24).

$$c_t = w_t n_t h_t + u_t b - T_t + D_t$$

$$y_t = c_t + \chi v_t = c_t + \chi \theta_t (1 - n_t)$$

$$f(n_t h_t) = \int_0^1 y_t d\bar{y} = y_t \int_0^1 \left( \frac{P_t}{P_t} \right)^{-\epsilon} d\bar{y} = y_t \Delta_t$$

Behavior of a central bank which is of particular interest for us will be discussed in the next chapter.

4 Social Optimum, Optimal Policy and Simple Monetary Rules

Our model is yet incomplete since we need to specify a monetary policy behavior. We are interesting in several questions. First, how an optimal policy and policy trade-offs will change with different labor market institutions. Second, how simple monetary rules should be adjusted according to a particular institutional environment. Lastly, what is the welfare losses from labor market frictions and how these losses are affected by labor market institutions.

In order to have a benchmark for monetary policy analysis we will first look at the social optimum - an allocation which would be chosen by a social planner and can be treated as an efficient allocation. We will then compare different policy regimes - zero inflation policy, optimal policy and simple monetary rules a’la Taylor with social optimum.

Socially efficient allocation can be characterized as social planner solution who can neglect prices (and therefore all the distortions which arise from incomplete price adjustment) but still faces labor market frictions. Social planner directly chooses a path of $\{y_t, n_t, h_t, v_t\}_{t=0}^\infty$ and maximizes the same utility function as a household subject to transition equation for labor, feasibility constraint on the intermediate goods market.
and production technology combined with resource constraint.

\[
\max_{\{c_t, h_t, y_{jt}, v_t, n_t\}} \sum_{t=0}^{\infty} \beta^{t-t_0} \left[ \frac{c_t^{1-\sigma^{-1}}}{1-\sigma^{-1}} - \frac{\Gamma h_t^{1+\gamma}}{1+\gamma} - B n_t \right]
\]

s.t. \( n_{t+1} = (1-d)(n_t + m(u_t, v_t)) \) \((\tilde{S}_t)\)

\[
\int_0^1 y_{jt} dj \leq f(n_t h_t) \quad (\tilde{\lambda}_t)
\]

\[y_t = c_t + \chi v_t = \left[ \int_0^1 y_{jt}^{(\epsilon_p-1)/\epsilon_p} dj \right]^{\epsilon_p/(\epsilon_p-1)} \quad (\check{\lambda}_t)\]

taking derivatives with respect to \(c_t, h_t\) and \(y_{jt}\) and noting that Lagrange multipliers associated with the last two constraints are equal \(\tilde{\lambda} = \check{\lambda}\) we have

\[
\int_0^1 y_{jt} dj = f(n_t h_t) = y_t = y_{jt} \quad (25)
\]

\[f(n_t h_t) = \frac{v'(h_t)}{w'(c_t)} \quad (26)\]

Differentiating with respect to \(v_t\) and \(n_t\) with obtain a centralized version of the job creation condition

\[S_t = f'(n_t h_t) h_t - \frac{\bar{v}(h_t)}{w'(c_t)} + (1-d)(1-\eta_t \lambda_t) E_t \beta_{t,t+1} S_{t+1} \quad (27)\]

where \(S_t = \tilde{S}_t / w'(c_t)\), \(m'_v\) and \(m'_u\) denote derivatives of the matching function with respect to vacancies and unemployment accordingly and \(\eta_t\) is an elasticity of the matching function with respect to unemployment.

We can now compare social optimum and decentralized equilibrium to identify under what conditions they might coincide. Comparing (24) and (25) one can see that price dispersion measure \(\Delta_t\) needs to be 1 in all the periods meaning that the prices are flexible and all the same. From (13) and (25) we see that \(p^*_t\) must be 1 in all the periods or in other words \(P^*_t = P_t\). This implies that price of production is equal to the final price. In this case \(\Phi_y = 0\), intermediate retailers do not make any profit and there are no distortions due to monopolistic power. Conditions (10) and (27) are equivalent if \(J_{t+1} = (1-\eta_t) S_{t+1}\) as if firms have taken into account an elasticity of matching. Using
this equality and substituting the values from (9), (27) and wage equation (14) we have

\[ p_t f'(n_t h_t)h_t - w_t h_t + (1 - d)E_t \beta_{t,t+1} J_{t+1} = \\
= (1 - \varsigma) \left[ f'(n_t h_t) - \frac{\nu(h_t) + B}{u'(e_t)} \right] - (1 - \varsigma) b - (1 - d)E_t \beta_{t,t+1} S_{t+1} [(1 - \eta_t)(1 - \varsigma \lambda_t)] \]

(28)

Now we see that necessary conditions for equilibrium to be socially efficient is unemployment benefit must be zero and, more importantly, worker bargaining power must be equal to the elasticity of the matching function with respect to unemployment \( \eta_t = \varsigma \) in all periods. It means that a worker is fully compensated through the wage for his participation in search and for positive externalities he creates for firms on the labor market. In other words, positive congestion effect is fully internalized. This condition is called Hosios condition (Hosios, 1990) and is rather controversial. First of all \( \varsigma \) is constant in our setting and elasticity of matching \( \eta_t \) is not. Even if matching function is of a Cobb-Douglas form and \( \eta_t \) is a constant there is no empirical evidence that these two variables must be equal. However, it is possible to achieve an optimal allocation in a steady state by choosing an appropriate unemployment benefit. From (28) in a steady state

\[ \Phi_\theta \equiv b - \frac{\eta - \varsigma}{1 - \varsigma} \left[ f'(nh)h + \chi \theta - \frac{\nu(h) + B}{u'(e)} \right] \]

(29)

where all the variables without indexes \( t \) are steady state values. If government chooses a value of \( b \) such that \( \Phi_\theta = 0 \), then the inefficiency due to search externalities can be corrected. If worker is undercompensated in a bargaining process he gets a positive unemployment benefit and vice versa. Economy-wide value of additional employed worker is the same as a value of unemployed person.

To conclude, not surprisingly, market equilibrium coincides with a socially optimal allocation when all the distortions arising from monopolistic competition, staggered pricing and search frictions are eliminated.

In our model it is possible for a government to decentralize a first best allocation in a steady state if 1) prices are held constant 2) sales-tax (or subsidy) is chosen such that \( \Phi_y \) is zero 3) unemployment benefit is chosen according to (29). This means that after an appropriate choice of \( \tau \) and \( b \) any monetary policy that is able to completely
stabilize prices can achieve an efficient equilibrium as in the "case for price stability" in New-Keynesian literature (Woodford, 2003, Thomas, 2008). In order to be able to compare different allocations we assume that in the steady state of decentralized version of the model it is indeed the case. Steady state is therefore efficient and coincide with social optimum. However, during economic fluctuations the condition (29) might not hold which creates tread-offs for monetary policy.  

Social optimum described above is an ideal or first-best case. Optimal policy can only achieve a second best allocation due to the presence of price rigidities. Optimal policy solution is again a choice of policymaker who faces all the imperfections in the economy but can directly decide on inflation, output, market tightness and employment. Optimal policy as before maximizes an infinite sum of the stream of representative household utilities and follows a commitment. Optimal policy problem is taken from Tang (2010) and has a form of linear-quadratic loss function as in Woodfrod (2003).

\[
\max_{\pi_t, \theta_t, \hat{n}_t} E_{t_0} \sum_{t=t_0}^{\infty} \beta^{t-t_0} L_t, \text{ where } L_t \approx q_\pi \pi_t^2 + q_\theta (\hat{y}_t^c - \hat{y}_t^c)^2 + q_\theta (\hat{\theta}_t - \hat{\theta}_t^*)^2
\]

where \(\hat{y}_t^c - \hat{y}_t^c\) and \(\hat{\theta}_t - \hat{\theta}_t^*\) are some measures of output and labor market tightness gaps. Tang (2010) showed that monetary policy faces additional trade-off. When a technology shock occurs it affects both firms’ demand for workers and household decision about how many family members to send to search for a job. However, new desired level of employment is not achievable due to matching frictions. Firms must endure costs of posting vacancies which affects marginal costs and therefore inflation. If a central bank wants to fight inflation by increasing an interest rate it have to allow the output and labor market tightness to deviate from its target value.

As we saw in our comparison of social optimum and market outcome a first-best policy should try to deal with three main market imperfections in our economy. Since we assume that under (or over) compensation of workers can be corrected by appropriate unemployment benefit and distortions arising from monopolistic competition are corrected by sales tax monetary policy can try to neutralize a sticky prices effect and just

\footnote{Note that when Hosios conditions are satisfied the zero inflation policy replicates a first best not only in the steady state but also under real shocks}
keep inflation being zero. In the next section we will examine this proposition. We will calibrate the model and discuss different policy settings - optimal policy, zero inflation policy and also simple monetary rules.

5 Role of Labor Market Institutions

To discuss the model behavior under different labor market institutions we will calibrate and solve the model using first-order local approximation around deterministic efficient steady state (see S. Schmitt-Grohe and M. Uribe, 2007). In order to pursue a simulation of the decentralized version of the economy we calibrated the structural parameters. All parameters are summarized in Table 2.

Household discount factor is set 0.997 so the annual risk-free interest rate is about 4%. The coefficient of relative risk aversion is $\tilde{\sigma}^{-1}$ is 0.6 implying a higher value for an intertemporal elasticity $\tilde{\sigma} \approx 6$. As described in Rotemberg, Woodford (1997) when consumer purchases contain both consumer goods and investment goods they are likely to be more sensitive to interest rate. Since we do not have an explicit capital accumulation in our model we prefer to use this high value of intertemporal elasticity.

Total hours worked are normalized to 1 as total labor force. The value for scaling factor in disutility from labor $\Gamma$ is then 0.74. A steady state level of unemployment is 6% which corresponds to empirical value for US. Exogenous job-separation rate is $d=0.028$ as in Shimer (2005). This brings a value for a job-finding rate in equilibrium 0.45 and implies the average duration of working contract to be 2.9 years which is close to empirical evidence that jobs last for two and a half years (Thomas, 2008). Inverse Frish elasticity is a little bit controversial parameter because macroeconomic literature usually uses a value higher than microeconomic evidence suggests. However, even in the business cycles analysis this value varies significantly. While Trigari (2009) and Gali (2010) set it to be equal to 5, for example, Rotemberg and Woodford (1997) found the value 9.5 in their empirical studies and Tang (2010) obtained 11.9 from a moment matching procedure. We choose a value of 11.96 for comparability reasons. Implied labor

\footnote{Note that since we have only two labor margins, this level implies that all non-participating workers are counted as employed in our model}
supply elasticity $1/\gamma$ is then 0.08 which is on the lower bound of the interval proposed by microlevel evidence (Card, 1994, or Altonji, 1986). At the same time, lower elasticity of labor (higher Frish elasticity) will lessen the reaction of labor to exogenous shocks which may become excessively large in a model without capital (Tang, 2010).

Labor output share $(1 - \phi)$ is 0.7 which is pretty standard. Unemployment benefit $b$ and sales tax $\tau$ are chosen such that in equilibrium both $\Phi_y$ and $\Phi_\theta$ are equal to zero so that monopolistic and labor market distortions are eliminated in a deterministic steady state. Producer price in steady state is $p^s = 1$ accordingly. Elasticity of substitution on production technology $\epsilon_p$ is equal to 11 and the steady state mark-up is approximately 10% which is close to empirical findings. Calvo parameter $\alpha = 0.88$ meaning that the probability of price adjustment is 12% and average price duration is 8 month as in Nakamura and Steinsson (2008) and Basu and Gottschalk (2009).

According to Hagedorn, Manovskii (2008) low worker bargaining power is needed to account for only moderate procyclical movements of wages. Small reaction of wages and low vacancy posting costs will create a strong response of firms to productivity shocks and make labor market tightness more volatile than output. As in their studies and Shimer (2009) we set worker bargaining power $\varsigma = 0.0532$ and vacancy posting costs to 0.0045 of the quarterly wage. GDP share of vacancy posting costs is therefore $s_v = 0.0014$. We also set steady state value for $\theta$ equal to 0.634 as in these studies. What follows from these calibrated values is a relatively high return to non-market activity and replacement ratio $b/w$. Hagedorn, Manovskii argue that workers include not only unemployment benefits in the value of non-market activities. For example, in frictionless case working and non-working activities are equally valuable and the worker in indifferent in equilibrium (Hagedorn, Manovskii, 2008). In order to increase replacement ratio up to the relevant value we adjusted fixed costs of working $B$ as in Tang (2010).

Finally, for the matching function we set $\xi = \frac{1}{2}$ which is consistent with an efficient steady state and is often assumed in the literature (see Gali, 2010). $\bar{m} = (1/2)^{\epsilon/(1-\epsilon)}$ as in Den Haan et al (2000) and $\epsilon = 0.435$ (which follows from our $\lambda = 0.45$) is also close to the value in this paper.

Table 3 present the comparison of the empirical and simulated moments after a one standard deviation positive technology shock.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>Discount factor</td>
<td>0.997</td>
</tr>
<tr>
<td>$\tilde{\sigma}^{-1}$</td>
<td>Relative risk aversion</td>
<td>0.6</td>
</tr>
<tr>
<td>$\Gamma$</td>
<td>Scaling factor in disutility of labor</td>
<td>0.74</td>
</tr>
<tr>
<td>$d$</td>
<td>Job destruction</td>
<td>0.028</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Frish elasticity of labor supply</td>
<td>11.96</td>
</tr>
<tr>
<td>$\tau$</td>
<td>Sales tax</td>
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</tr>
<tr>
<td>$b$</td>
<td>Unemployment benefit</td>
<td>0.12</td>
</tr>
<tr>
<td>$\varsigma$</td>
<td>Worker bargaining power</td>
<td>0.052</td>
</tr>
<tr>
<td>$\epsilon$</td>
<td>Elasticity of substitution in matching</td>
<td>0.435</td>
</tr>
<tr>
<td>$\pi$</td>
<td>Elasticity of a worker-finding rate</td>
<td>0.356</td>
</tr>
<tr>
<td>$s_v$</td>
<td>GDP share of vacancy costs</td>
<td>1.4%</td>
</tr>
<tr>
<td>$b/w_h$</td>
<td>Replacement ratio</td>
<td>0.17</td>
</tr>
<tr>
<td>$\epsilon_p$</td>
<td>Elasticity of substitution in production</td>
<td>11</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Calvo parameter</td>
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<tr>
<td>$B$</td>
<td>Fixed costs of working</td>
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</tr>
<tr>
<td>$\chi$</td>
<td>Vacancy posting costs</td>
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</tr>
<tr>
<td>$\bar{h}$</td>
<td>Steady state value of hours</td>
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</tr>
<tr>
<td>$u$</td>
<td>Steady state level of unemployment</td>
<td>6%</td>
</tr>
<tr>
<td>$\theta$</td>
<td>Steady state market tightness</td>
<td>0.634</td>
</tr>
<tr>
<td>$A$</td>
<td>Steady state technology level</td>
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</tr>
<tr>
<td>$y$</td>
<td>Steady state level of GDP</td>
<td>0.96</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>Job-finding rate</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>Data</td>
<td>Model</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td><strong>Standard deviation (in %)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>y</td>
<td>1.53</td>
<td>0.91</td>
</tr>
<tr>
<td>v</td>
<td>12.90</td>
<td>6.48</td>
</tr>
<tr>
<td>u</td>
<td>11.25</td>
<td>3.88</td>
</tr>
<tr>
<td>( \theta )</td>
<td>23.73</td>
<td>8.02</td>
</tr>
<tr>
<td>n</td>
<td>0.77</td>
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</tr>
<tr>
<td>h</td>
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<td>0.03</td>
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<tr>
<td>w</td>
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<tr>
<td><strong>Correlation with output</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>v</td>
<td>0.90</td>
<td>0.78</td>
</tr>
<tr>
<td>u</td>
<td>-0.88</td>
<td>-0.73</td>
</tr>
<tr>
<td>( \theta )</td>
<td>0.91</td>
<td>0.98</td>
</tr>
<tr>
<td>n</td>
<td>0.89</td>
<td>0.96</td>
</tr>
<tr>
<td>h</td>
<td>0.68</td>
<td>0.73</td>
</tr>
<tr>
<td>w</td>
<td>0.25</td>
<td>0.99</td>
</tr>
<tr>
<td><strong>Correlation between u and v</strong></td>
<td>-0.93</td>
<td>-0.14</td>
</tr>
</tbody>
</table>

Summary statistics calculated with US data for 1964-2006 (source: J-H Tang, 2010). All series were logged and HP-filtered with \( \lambda = 1600 \). We used a \( \ln R_t - \ln R_{ss} = 0.9(\ln R_{t-1} - \ln R_{ss}) + 1.7\pi_t + 0.5/4(\ln y_t - \ln y_{ss}) \) Taylor rules for simulation.
One can see from the table that the model reproduces main important features found in the data. Namely, vacancies and labor market tightness are more volatile than output, while employment, hours and wages are less volatile. Employment and vacancies are positively correlated with output while unemployment has a negative correlation. Wages have a higher correlation with an output in the model in comparison to the data because of flexible wage assumption. Although search and matching frictions allow to reduce this correlation by breaking a link between wage and marginal costs which are in turn highly correlated with output (as in Krause and Lubik, 2007 for example), intensive margin preserves this link. Labor market tightness is highly procyclical as in the data. Finally, the model is able to capture a negative correlation between unemployment and vacancies or Beveridge curve, which is known to be difficult to reproduce.

We will now compare the optimal policy outcome for the case of baseline calibration which can be seen as a US type economy, with an alternative calibrations in which we will alter worker bargaining power and unemployment benefit. For our computation we used Dynare Ramsey Policy optimization routine which computes a first order approximation to a Ramsey policy with a specified objective function (in our case a utility function of a household) subject to equilibrium constraints.

Figure 2 presents results for model dynamics after a one standard deviation positive technology shock. Social planner solution is depicted by black dotted line and optimal monetary policy by black solid line. Social planner would keep all the variables almost constant and let an output to absorb all the positive consequences of an increase in productivity. In contrast, when a policymaker faces price stickiness he must decide whether to let inflation or real variables to absorb the effect of the shock. Increased marginal productivity of labor and lower marginal costs create an increase in profits which induces firms to post more vacancies. As a result, more matches occur on the

\[\text{4}\text{Alternatively one can solve a policy problem by hands using LQ approximation as it was done in}\]

Thomas (2006) or Tang (2010) for example. One can also follow Faia (2006) and take a second order approximation of a policy functions which were computed for a stationary allocation of the first order approximation. We compared the results from first order approximation that we got from a Dynare function with those in Tang (2010) for a baseline calibration. Our conclusion is that the difference between the two is negligible. Note also, that for a welfare analysis later on we will use a second order approximation.
Figure 2: Equilibrium Dynamics with Different Institutions. Impulse responses to a positive one standard deviation technology shock. Social planner solution (dotted line) and optimal policy (solid line): black lines depict a benchmark calibration with bargaining power=0.052, blue lines - alternative calibration with bargaining power=0.5.

Labor market, unemployment falls. The response of hours (not shown) is also positive but relatively weak (in accordance with Thomas, 2008). However, due to a low bargaining power of workers they are undercompensated for participation in the labor market. The level of vacancies relative to unemployed people is inefficiently too high. This results in higher volatility of market tightness, employment and output in comparison to social optimum. In such a situation optimal policy allows inflation to deviate from a zero level (upper graph on the left) in order to be able to stabilize employment, market tightness and output and bring them closer to efficient levels.

Blue lines on the same pictures present the reaction of optimal policy with a higher level of bargaining power. More specifically, we increase the parameter from 0.052 to 0.5.
(which is more in accordance with a European data)\(^5\). Note that elasticity of marching function is 0.4 in equilibrium meaning that by the change in bargaining power we do not eliminate inefficiency arising from violation of Hosios condition. Worker still receives inappropriate compensation but is overcompensated now\(^6\).

When a worker bargaining power increases wage gets closer to an implicit value of a worker for a firm (product of labor). It means that wage elasticity with respect to productivity shocks increases. As a result wage to a larger extent absorbs effect of the shock and gets more volatile. This in turn through marginal costs affects inflation which gets more volatile as well. On the other hand, higher worker bargaining power also reduces a profit share in total surplus and decreases firms incentives to post new vacancies. As cyclical deviations of the profit become larger in relative terms so does a vacancy posting process and therefore labor market tightness become more volatile. Change in bargaining power affects both volatility of inflation and labor market tightness. In our calibration the first effect dominates and labor market tightness is less volatile in the new regime (standard deviation decreases from 7.8 to 0.8 percent). It allows an optimal policy to focus on inflation stabilization. As can be seen from the graph optimal policy almost completely stabilizes inflation (blue line on the left upper graph is close to zero) and is able to bring output and labor market variables closer to a social optimum level. Deviation of the wage becomes higher however.

In other words, when worker bargaining power is too low and worker is undercompensated (as in the baseline case), unemployment is inefficiently low relative to vacancies on the labor market. After a positive technology shock marginal costs of firms decrease but the prices are sticky which results in increasing mark-ups. Optimal policy has an incentive to decrease a number of vacancies by reducing inflation and therefore mark-ups and profits. In case of higher bargaining power, however, worker is overcompensated for his participation in labor market. It means that policy should stimulate additional vacancies by letting mark-ups to increase.

Figure 3 depicts additionally the outcome of a complete inflation stabilization policy for both values of bargaining power (dashed lines). First thing which is worth noticing

\(^5\)Fixed disutility of working was also changed according to 29 so that the steady state is still efficient

\(^6\)We must note however, that 0.5 is closer to an optimal level then 0.052. We tried therefor as a robustness check 0.8 value and obtained qualitatively the same results
Figure 3: Equilibrium Dynamics with Different Institutions. Impulse responses to a positive one standard deviation technology shock. Social planner solution (dotted line), zero-inflation equilibrium (dashed line) and optimal policy (solid line): black lines depict a benchmark calibration with bargaining power=0.052, blue lines - alternative calibration with bargaining power=0.5.

is that optimal policy is able to bring all the variables closer to a social optimum levels in comparison to a zero inflation policy at costs of giving up inflation stabilization. Second, in case of higher bargaining power both optimal policy and zero inflation policy move closer to a complete inflation stabilization and can achieve almost optimal levels of output and labor market parameters.

Next Figure 4 presents model dynamics for different values of unemployment benefit: 0.12 percent of steady state total wage bill in a baseline calibration and 0.36 percent in an alternative one. This number is close to an average level for European countries as indicated in Table 1. Higher unemployment benefit means a better outside option for a

\[^{7}\text{Note that fifed disutility of working was also changed according to 29 so that the steady state is still}\]
Figure 4: Equilibrium Dynamics with Different Institutions. Impulse responses to a positive one standard deviation technology shock. Social planner solution (dotted line) and optimal policy (solid line): black lines depict a benchmark calibration with unemployment benefit=0.12 and blue lines - for the alternative calibration with b=0.36

worker. This puts an upward pressure on wages and decreases a profit share. As a result changes in profit will be larger in relative terms. It will affect vacancy posting decisions in a way that vacancies will become more volatile and as a result a labor market tightness will be more volatile as well (increase in labor market tightness volatility changes from 7.8% to 12%). Optimal policy therefore tries to stabilize labor market variables at cost of inflation. Complete inflation stabilization becomes less desirable as we can also see from the Figure 5 which shows additionally zero inflation policy outcome in dashed lines for both calibrations. We see as before that optimal policy is closer to social optimum than a complete price stabilization policy. Blue lines are always farther away
Figure 5: Equilibrium Dynamics with Different Institutions. Impulse responses to a positive one standard deviation technology shock. Social planner solution (dotted line), zero-inflation equilibrium (dashed line) and optimal policy (solid line): black line depicts a benchmark calibration with unemployment benefit=0.12 and blue line for the alternative calibration with b=0.36 from socially efficient levels then black lines meaning that higher unemployment benefit pushes economy away from an efficient allocation. As a consequence optimal policy is not able to bring all the variables as close to social optimum levels as before and lets inflation to be absorb some effect of the shock. This finding is in accordance with Tang (2010), Zanetti (2011), Campori, Faia (2011) who showed that with a higher replacement ratio volatility of inflation and marginal costs falls and volatility of labor market flows increases.

To conclude we can say that high worker bargaining power enables optimal policy to achieve better outcome which is closer to the social optimum while higher unemployment benefit moves economy away from efficient allocation and worsens an optimal policy
outcome.

We must also point out that the effect of an increase of bargaining power might differ under different calibrations. An increase in profits volatility may be more pronounced so labor market tightness will become more volatile. Moreover, an assumption about sticky or flexible wage might be crucial for our results. For example in Faia (2006) paper in contrast to our results, increase in bargaining power creates more incentives for an optimal policy to deviate from complete inflation stabilization. In the case of higher bargaining power in Faia (2006) paper the difference between bargaining power and elasticity of matching function with respect to unemployment is larger than in case of too low bargaining power. In other words violation of Hosis conditions is more pronounce in high bargaining power regime than in a low one. According to Faia, monopolistic competition and searching frictions induce a policy to deviate from price stability while price stickiness stimulates a zero inflation policy. The decision about this trade-off might be different in different settings. As a robustness check we also used a bargaining power 0.8. Features of an optimal policy plan remain the same. So the result about zero inflation desirability depends rather on how far away is the bargaining power from its efficient level and not on its level itself. Nevertheless, we treat our calibration as a realistic approximation of the the US and European labor markets and therefore appropriate for drawing some conclusions.

We so far analyzed the differences between outcomes of optimal and zero inflation policy in case of different institutions. We are also interested in a question how the policy goals should be perhaps adjusted to the institutional environment itself. Tang (2010), Faia (2009) and Thomas (2008) among others showed that optimal policy behavior can be described by a policymaker’s objective or loss function which can be rewritten in terms of quadratic deviations of output, inflation and labor market tightness from its target levels and takes a form of $L_t \approx q_t \pi^2 + q_y (\hat{y}_t - \hat{y}_t^*)^2 + q_\theta (\hat{\theta}_t - \hat{\theta}_t^*)^2$. What is of particular interest for us is how the weights in a loss function are affected by labor market institutions. In other words, to which variables should a central bank pay more attention in different institutional environment. We can derive the coefficients analytically using a second order approximation approach of M. Woodford (Benigno and Woodford, 2003) following Tang (2010) or Thomas (2006). However, weights in a loss function are highly non-
linear functions of structural parameters of the model. Moreover, these weights depend also on steady state values of economic variables which in turn affected by structural labor market parameters as well. As a result the relationships between labor market parameters and loss function weights is not straightforward.

We will instead focus on simple monetary rules or rules a’la Taylor (Taylor, 1993) which are presumably used by central banks in reality. We will use a Taylor type rule in the model and then obtain optimal coefficients or weights in this rule such that it gives the highest value of a household utility function, given that with this Taylor rule a rational expectations equilibrium exists. We use a second order accurate approximation of the utility function (30) following Lucas (1987) approach (see also Lucas, 2008, Tang 2010, Evers 2012 among others). To calculate first and second order moments of the variables we use Nonlinear Movering Average (nlma) Software (Lan and Meyer-Gohde, 2013) which enables us to use theoretical second order accurate moments and is also faster than standard Dynare calculations\(^8\). We then compare the welfare levels for Taylor rules with different parameters and use a simple grid search to find an optimal rule. Welfare second order approximation looks like

\[
W \approx \frac{c_{ss}^{1-\sigma}}{1-\sigma} - \Gamma \frac{h_{ss}^{1-\gamma}}{1-\gamma} n_{ss} - B n_{ss} + c_{ss}^{\sigma} E_t \hat{c}_t - n_{ss} \Gamma h_{ss}^{\gamma} E_t \hat{h}_t - B E_t \hat{n}_t - \Gamma \frac{h_{ss}^{1+\gamma}}{1+\gamma} E_t \hat{n}_t - 0.5 \sigma c_{ss}^{\sigma-1} E_t \hat{c}_t^2 - 0.5 n_{ss} \Gamma \gamma h_{ss}^{\gamma-1} E_t \hat{h}_t^2 - 0.5 \Gamma h_{ss}^{\gamma} E_t \hat{h}_t^2 - 0.5 \Gamma h_{ss}^{\gamma} E_t \hat{n}_t^2.
\]

(30)

Similar exercise was done in Faia (2009) who compared different simple rules a’la Taylor based on a theoretical measure of welfare losses. She found that a rule which includes inflation and unemployment gap \(\hat{R}_t = 2.1838 \pi_t + 0.15 \hat{u}_t\) is the best simple rule. Tang (2010) also investigated simple rules augmented with a labor market tightness and employment. He found that a simple rule with market tightness and optimized coefficients \(\hat{R}_t = 2.1838 \pi_t + 0.00097 \hat{\theta}_t\) generates larger volatility of inflation than strong

\(^8\)One must notice that for second and higher order approximation nlma software calculates the moments of deviations from stochastic steady state while for our welfare measure we need deviations from a deterministic steady state. To recalculate moments we used a simple procedure, detailed description is available on request.
inflation targeting but lower volatility of labor market tightness, employment and output. It therefore outperforms the complete inflation stabilization rule.

Our results are presented in Table 4. First observation for the baseline case is that proposed optimized rule is quite similar to the standard Taylor rule except that it also reacts to labor market tightness. In the baseline case an optimal Taylor rule responds strongly to inflation deviations with a coefficient 2.0 and slightly to output. The coefficient before $\theta$ is small but positive. Imperfect labor market creates additional trade-off for monetary policy meaning that a central bank can benefit from monitoring a labor market and reacting to labor market variables. Second and third rows of the Table present the coefficients of the optimized monetary rule in case of higher bargaining power or higher replacement ratio respectively. With an increase in bargaining power the importance of inflation stabilization becomes higher and output and labor market tightness have almost the same weights as they did before. As we discussed already higher bargaining power reduces volatility of labor market variables and enables policy to get better outcome by paying closer attention to inflation. When unemployment benefit increases (third raw), and so does the wage, higher wage will reduce firms profit and number of posting vacancies. It means that economic shocks will stronger affect labor market tightness and monetary policy has more incentives to respond to it. Coefficient before labor market tightness is higher than in a baseline case while coefficient for inflation is the same$^9$.

Last raw shows the result for both hight unemployment benefit and bargaining power of the worker. We see that in this situation output and labor market tightness become even more important for monetary policy. The results suggest that countries with pretty inflexible labor market (like European type countries) should pay more attention to labor market fundamentals.

One can argue that a central bank does not know utility function and rather has a target function with observable variables. We can assume, for example, that a central bank simply tries to minimize variance of observable variables: output, inflation, employment

$^9$As a robustness check we also run the same experiment making bargaining power lower then in the baseline case. Resulting coefficient before labor market tightness decreases while those for output and inflation remains approximately the same.
Table 4: Optimized Taylor Rules

<table>
<thead>
<tr>
<th>Value</th>
<th>$\rho_\pi$</th>
<th>$\rho_y$</th>
<th>$\rho_\theta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline case</td>
<td>2.0</td>
<td>0.3</td>
<td>0.009</td>
</tr>
<tr>
<td>High bargaining power</td>
<td>2.5</td>
<td>0.3</td>
<td>0.010</td>
</tr>
<tr>
<td>High unemployment benefit</td>
<td>2.0</td>
<td>0.1</td>
<td>0.014</td>
</tr>
<tr>
<td>High $b$, high $\varsigma$</td>
<td>1.5</td>
<td>0.1</td>
<td>0.020</td>
</tr>
</tbody>
</table>

Comparison of optimized Taylor rules using a nlma software (Lan and Meyer-Gohde, 2013). Baseline calibration corresponds to bargaining power $\varsigma=0.052$, unemployment benefit $b=0.12$. High bargaining power corresponds to $\varsigma=0.5$ and high unemployment benefit to $b=0.36$. Objective function used is second order log approximation of a utility function.

Table 5: Alternative Optimized Taylor Rules

<table>
<thead>
<tr>
<th>Value</th>
<th>$\rho_\pi$</th>
<th>$\rho_r$</th>
<th>$\rho_y$</th>
<th>$\rho_\theta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline case</td>
<td>1.991</td>
<td>0.0033</td>
<td>0.445</td>
<td>0.029</td>
</tr>
<tr>
<td>High bargaining power</td>
<td>1.993</td>
<td>0.0052</td>
<td>0.571</td>
<td>0.085</td>
</tr>
<tr>
<td>High unemployment benefit</td>
<td>1.986</td>
<td>0.0045</td>
<td>0.628</td>
<td>0.080</td>
</tr>
<tr>
<td>High $b$, high $\varsigma$</td>
<td>1.992</td>
<td>0.0079</td>
<td>0.73</td>
<td>0.099</td>
</tr>
</tbody>
</table>

Comparison of optimized Taylor rules using a Dynare osr routine. Baseline calibration corresponds to bargaining power $\varsigma=0.052$, unemployment benefit $b=0.12$. High bargaining power corresponds to $\varsigma=0.5$ and high unemployment benefit to $b=0.36$. Objective function used is var($y$)+var($\pi$)+var($\eta$)+var($\theta$).

and labor market tightness. For this exercise we alternatively used Dynare OSR routine which uses a Sims optimization procedure. Results can be seen in the Table 5.

With an alternative objective function the coefficient before labor market tightness becomes larger because now volatility of labor market tightness creates the same welfare losses as volatility of output or inflation. Main conclusions are however rather similar. Increase in worker bargaining power slightly increases an importance of inflation while higher unemployment benefit decreases the coefficient before inflation. In both cases labor market tightness become much more important under alternative institutional settings. Last row again indicates that inflexible labor market with high unions power
and high social benefits implies that a central bank should pay rather close attention to labor market tightness.

Our last question of interest is the welfare costs associated with different policy set-ups. For example, what is the difference between welfare losses under zero inflation policy and under an optimal policy solution or whether the costs of monitoring labor market in order to respond to a labor market tightness would be compensated by significant gain in welfare. To see this we will calculated a welfare compensation $\Omega$ in terms of permanent steady state consumption that a representative household should receive in order to be indifferent between a policy under consideration and staying in a deterministic steady state.

$$U = \sum_{t=0}^{\infty} \beta^t E_t W(c_t, h_t, n_t) = \sum_{t=0}^{\infty} \beta^t E_t W((1 + \Omega)\bar{c}, \bar{\pi}, \bar{h})$$ (31)

In our case a consumption compensation can be calculated using 30

$$\Omega \approx \frac{1}{c_{ss}^\sigma} [\hat{c}_t - n_{ss} \Gamma h_{ss}^\gamma \hat{h}_t - BE_t \hat{n}_t - \frac{h_{ss}^{1+\gamma}}{1 + \gamma} E_t \hat{n}_t - 0.5\sigma c_{ss}^{-\sigma} E_t \hat{c}_t^2 - 0.5 n_{ss} \Gamma \gamma h_{ss}^{\gamma-1} E_t \hat{h}_t^2 - 0.5 \Gamma h_{ss}^\gamma E_t \hat{n}_t^2 - 0.5 \Gamma h_{ss}^\gamma E_t \hat{h}_t^2]$$ (32)

In other words a household receiving a steady state level of consumption all the periods will be indifferent between losing $\Omega$ percent of this constant consumption value (values for $\Omega$ are negative) and being put under a particular policy regime. The result for consumption compensation $\Omega$ are presented in Table 6\textsuperscript{10}. We compared zero inflation policy (meaning that inflation is zero all periods), optimized simple rules that we found before and standard Taylor rule which reacts to inflation and output log

$R_t - \log R_{ss} = 0.9(\log R_{t-1} - \log R_{ss}) + 1.7\pi_t + 0.5/4(\log y_t - \log y_{ss})$.

Welfare losses under a social optimum solution is very small so we can treat them as zero. In a baseline case optimized Taylor rule brings the best welfare result and is much better then zero inflation policy or standard Taylor rule which does not take labor market into account. However, when a bargaining power increases the result for optimal Taylor rule becomes much closer to a zero inflation policy. The difference between using zero inflation policy and optimized Taylor rule is approximately 0.003% of steady state

\textsuperscript{10}Optimal policy result cannot be compared in terms of welfare compensation because in Dynare optimization routine we used only first order approximation is currently available
Table 6: Welfare Analysis

<table>
<thead>
<tr>
<th></th>
<th>Baseline case</th>
<th>High $\zeta$</th>
<th>High $b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Optimum</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Zero Inflation Rule</td>
<td>-0.0480</td>
<td>-0.0198</td>
<td>-0.0599</td>
</tr>
<tr>
<td>Optimized Simple Rule</td>
<td>-0.0001</td>
<td>-0.0165</td>
<td>-0.0012</td>
</tr>
<tr>
<td>Standard Taylor Rule</td>
<td>-0.0523</td>
<td>-0.0219</td>
<td>-0.0439</td>
</tr>
</tbody>
</table>

Value for social optimum is a numerical zero. Optimized Taylor rules are taken from 4. Standard Taylor rule is $\log R_t - \log R_{ss} = 0.9(\log R_{t-1} - \log R_{ss}) + 1.7\pi_t + 0.5/4(\log y_t - \log y_{ss})$. Values for bargaining power and unemployment benefit in baseline case and alternative calibration are as before.

consumption which is rather small. So as before we can conclude that zero inflation policy is more favorable in this case. Increase in welfare that can be achieved by using optimized Taylor rule instead of standard one is 0.005% of steady state consumption.

When unemployment benefit is increased form 12 to 36% of steady state wage bill optimized Taylor rule, which stronger responds to labor market tightness, is better in terms of welfare compensation. Standard Taylor rule and zero inflation policy have close values of welfare losses which are approximately 0.04% higher then an optimized Taylor rule. So in case of high unemployment benefit switching from standard Taylor rules to an optimized one can increase social welfare by 0.04% of steady state consumption. Again as we described before zero inflation is less desirable in this case and labor market tightness is more important for policy design.

To conclude we showed that optimal policy outcome is affected by labor market institutions, in particular thouse which strongly affect wage determination. Higher bargaining power enables optimal policy to get an allocation closer to a social optimum solution. Optimal policy is closer to a zero inflation policy in this case. Optimized simple rule a’la Taylor also features a higher weight on inflation. Difference in welfare losses between zero inflation and optimal Taylor rule become smaller so we conclude that complete prices stabilization is more desirable in economy with such a labor market. Higher replacement ratio on contrary moves economy away from socially efficient allocation. Labor market variables become more volatile and policy has higher incentive to give up complete price
stabilization. Optimized Taylor rule puts a higher weight on labor market tightness in this case and this potentially brings a welfare gain of 0.04% of steady state consumption.

6 Conclusion

The goal of this research is to better understand effect of labor market institutions on monetary policy design from a theoretical prospective. Many previous papers showed that different labor market institutions create different inflation volatility and economy response to shocks in general. These findings naturally lead to a hypothesis that countries with different institutional environments on labor market need different monetary policy rules. In this paper we study how imperfect labor market affect a monetary policy design and how different labor market institutions may alter this effect. We constructed a New-Keynesian DSGE model with search frictions on the labor market and monopolistic competition and sticky prices on goods market. We then compared the model dynamics under a social planner solution, optimal monetary policy, zero inflation policy as well as different simple monetary rules. Additionally to standard simple rule a’la Taylor we found optimized Taylor rules, i.e simple rules which react to deviations of output, inflation and labor market tightness and bring the highest possible welfare. For our analysis we focus on two main institutions - worker bargaining power and unemployment benefit. We showed that these labor market variables have an important implications for monetary policy design.

We showed that in a presence of labor market frictions optimal policy has an incentive to give up a complete price stabilization. Optimal policy deviates from zero inflation rule in order to mitigate the response of other variables to productivity shocks and move economy closer to a social optimum.

Motivated by different labor market structures in European countries and the US we tried to calibrate labor market parameters according to a European type country and a US type country.

Higher bargaining power enables optimal policy to get an allocation closer to a social optimum and incentivizes a policy to keep inflation closer to zero. Optimized simple rule also features a higher weight on inflation in this case and achieves a welfare 0.005%
of steady state consumption higher than a standard Taylor rule. Optimized simple rule
is also closer to a zero inflation in terms of welfare so we conclude that complete price
stabilization is more desirable in economy with such a labor market. Higher replacement
ratio, on contrary, moves economy away from socially efficient allocation. Labor market
variables become more volatile and policy has a higher incentive to give up complete
price stabilization. Optimized Taylor rule puts a higher weight on labor market tightness
in this case and this potentially allows for a 0.04% of steady state consumption welfare
gain in comparison to a standard Taylor rule.

Our findings can be seen as a contribution to the discussion about optimal monetary
policy and optimal simple rules. However, the model used here leaves a room for a richer
economic environment. As we already mentioned a flexible wage assumption might be
important for our results. Therefore we find it interesting to verify our results with
a sticky-wages setting. Another important extensions of the model could be a capital
accumulation and endogenous separation. We also assumed a fiscal policy being able to
eliminate all the distortions in equilibrium apart from labor market frictions. Studying
an extended version of the model with capital accumulation as well interaction between
monetary and fiscal policy in a New-Keynesian model with imperfect labor market is an
interesting task for future research.

One of the main conclusion of our analysis is that monetary authority should monitor
a labor market and take labor market variables into account. We strongly believe that in
reality central banks do monitor situation on a labor market. A central bank might have
several departments with hundreds of economists who calculate and monitor hundreds
or even thousands of indicators. We suppose that labor market indicators are very im-
portant ones among them. Therefore an empirical investigation of whether labor market
indicators are significant variables in monetary rules will be an important contribution.

7 References

Journal of Monetary Economics, 3(3), 305-316.


