Macroeconomic implications of Downward Wage Rigidities

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Abstract

In this paper we introduce downward real wage rigidities in a monetary DSGE model with search and matching frictions in the labor market to study the implications of asymmetric wage adjustment for labour market dynamics, inflation and monetary policy. We find that the presence of downward wage rigidities introduces an important asymmetry in the business cycle: during booms real wages increase in line with the desired level, limiting vacancy posting and employment creation; in recessions, shocks are mainly absorbed through a strong decline in vacancy posting and employment, while the reaction of inflation is smaller. We then investigate whether the presence of downward wage rigidities can help to explain the asymmetric business cycle of many OECD countries where long and smooth expansions are followed by sharp but short recessions. Finally, we analyse how the prescriptions for monetary policy change when real wages are downwardly rigid.

JEL classification: E31; E52;C61.

Key words: Labour market, unemployment, Downward wage rigidity, asymmetric adjustment costs, non–linear dynamics.

1 Introduction

Labour market conditions are at the core of business cycle dynamics. The adjustment of labor through hours or employment is a crucial element in shaping the business cycle of different countries. In recent years, with the surge of matching models pioneered by Diamond, Mortensen and Pissarides, the adjustment of wages for existing employment relationships and new hires has become the focus for understanding the labor market. Shimer (2005) and Hall (2005) call for wage rigidity as an important factor in explaining vacancy volatility, while Blanchard and Galì (2008) and Christoffel and al. (2008) identify wage rigidity as an important transmission mechanism from labor markets to inflation. Finally, the labor market is strongly characterized by asymmetries, both for the process of hiring and firing, but also for the adjustment of wages. Indeed, wages are often found to be downward rigid either in nominal or in real terms in European

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countries and the US. The aim of this paper is to show that the inherent asymmetry of the labor market for quantities and prices is at the heart of business cycle asymmetries and helps to unify the debate that tries to determine whether labor market adjustments are mainly due to variability in hiring or firing.

The recent empirical research on wage dynamics has highlighted the presence of downward wage rigidities in a large number of countries. Dickens et al. (2007) summarize the findings of the International Wage Flexibility Project, which uses micro-economic wage data to investigate the extent to which nominal and real wages are downwardly rigid across countries. Within the context of the Eurosystem Wage Dynamics Network Du Caju et al. (2008) confirms and updates some of these findings, quantifying the extent of downward wage rigidity across a number of European countries[1]. Holden and Wulfsberg (2008a, 2008b) analyze wage changes at the industry level for 19 OECD countries over the period 1973–1999 and confirm the existence of both nominal and real downward wage rigidities of different extent across different countries even at the more aggregate level.

In this paper we analyze, in a simple but rigorous framework, the macroeconomic implications of downward wage rigidities for labor market dynamics, inflation and monetary policy. Fahr and Smets (2008) indicate a strong difference in the adjustment following positive and negative shocks in the presence of downward nominal and real wage rigidities. After a positive technology shock nominal and real wages tend to adjust strongly while hours worked are affected only by a small amount. Instead, after a negative productivity shock, due to the asymmetry in wage adjustments, hours worked declines strongly. Our aim here is to exploit this asymmetry of adjustment within a frictional labor market and to highlight how this asymmetry transmits into inflation, unemployment and other labor market variables.

We set up a monetary DSGE model with frictional labor markets of the matching type, best summarized by Christoffel et al. (2008). Downward wage rigidities are introduced by employing a version of Hall's notion of the wage norm, where the real wage is a linear combination of last period's wage and the newly bargained, or desired, one. The way we model the wage norm introduces a fundamental asymmetry between wage increases and wage cuts: while wages increase rapidly following positive productivity shocks, negative productivity shocks are only partially - and slowly - transmitted into wage cuts[2]. Our modelling device captures, in intuitive and simple terms, the downward wage rigidity documented by many empirical papers.

The contribution of this paper is threefold. First, we introduce asymmetry in the adjustment of real wages in a matching framework which is at the same time easily tractable and effective. The model provides a rigorous framework to study the implications of asymmetric wage adjustment for labor market dynamics, inflation and monetary policy. We find that the presence of downward wage rigidities introduces an important asymmetry in the business cycle: during

[1] Within the EMU, one interesting case characterised by prevalent downward real wage rigidity is Belgium, which still has a system of widespread indexation of wages to changes in consumer prices.

[2] Specifically, the asymmetry regards the weight given, in the wage norm, to the last period's wage and the bargained one. If the newly bargained wage is above the former one a large weight is attributed to the bargained wage, while in the prospect of wage cuts, the relative weight shifts in favour of last period's wage. The advantage of this way of modelling lies in the fact that it is easy to see how real wage changes evolve as a function of desired or bargained wage changes.

booms[3], real wages and inflation increase considerably, limiting vacancy posting and employment creation; in recessions, shocks are mainly absorbed through a strong decline in vacancy posting and employment, while the reaction of inflation is smaller. Second, we investigate whether and to what extent the presence of downward wage rigidities help to explain the asymmetric business cycle of many OECD countries where long and smooth expansions are followed by sharp but short recessions. Finally, we analyze how the implications for monetary policy change when real wages are downwardly rigid.

In the rest of this paper, we first present some evidence on the importance of asymmetries in labor market dynamics. In Section 3, 4 and 5 we outline a monetary model with frictional labor markets and downward wage rigidity. Section 6 discusses the baseline calibration. The main results are described and commented in Section 7-9. Section 10 contains the main conclusions.

2 Data Analysis: are asymmetries important in labor markets?

The motivation for this paper lies in two pieces of evidence. The response of labor market variables to positive and negative shocks, in particular of unemployment and vacancies, is very different. Unemployment increases sharply during a recession and is only slowly reduced during an expansionary period, for vacancies recessions lead to a strong drop. The second piece of evidence relates to the fact that business cycles of industrialized economies exhibit strong asymmetries; short and deep recessions are followed by long but smooth expansions. In this section we briefly review these two regularities.

2.1 Asymmetries in labor market variables: vacancies, unemployment and wages

To establish some basic facts about asymmetries in labor market variables over the business cycle, Table 1 reports the mean, the standard deviation, the skewness and the kurtosis of the growth rates of key variables for five countries: France, Germany, the UK, the US and the Euro Area[4]. All data is quarterly and covers the period from 1970:Q1 to 2006:Q4[5].

Table 1 shows some important regularities in labor market variables across countries. First, the average growth rate in real wages is quite high in all countries and positively skewed[6]. Second, vacancy growth rates are always negatively skewed. Third, the growth rate of the unemployment rate is always and quite strongly positively skewed. Possible trend components

[3] In the paper we will discuss different types of shocks. In this discussion the boom is identified as a positive shock to the growth rate of productivity; the opposite holds for a recession.

[4] The data goes from 1970:Q1 to 2006:Q4. The series for the Euro Area are from the AWM Dateset. All the other series are taken from the OECD dataset except for the series of vacancies for France, which is from the dataset prepared by McCallum and Smets for the "Wage Dynamics Network", and the vacancy series for the US, which is from the FRED dataset. We have controlled for outlier in the series of real wages and output for Germany.

Δw_t is computed as the annual percentage change in real wages, i.e. as $\Delta w_t = \log \frac{W_t}{W_{t-4}} \frac{P_{t-4}}{P_t}$. The price level is the GDP deflator. Δv_t, Δu_t, $\Delta \pi_t$, and Δy_t are computed as log deviation over the previous quarter.

[5] The only exception is the vacancy series for France, which starts from 1981Q1.

[6] The only exception is Germany, where the unification creates a structural break in wage series.

		Mean	St.Dev	Skewness	Kurtosis
FR	Δw_t	1.43	1.86	0.35	2.55
	Δv_t	1.37	6.28	**-1.34**	7.04
	Δu_t	0.87	3.21	**1.49**	7.34
	Δp_t	1.27	1.09	0.86	3.86
	Δy_t	0.59	0.53	-0.22	3.82
DE	Δw_t	1.14	2.08	-0.32	4.75
	Δv_t	-0.18	7.67	**-0.49**	4.44
	Δu_t	1.91	5.65	**0.77**	3.22
	Δp_t	0.70	0.64	0.83	3.40
	Δy_t	0.58	1.00	0.64	6.02
UK	Δw_t	1.27	2.31	0.21	2.89
	Δv_t	0.58	9.56	**-1.09**	5.52
	Δu_t	0.38	3.74	**0.87**	3.96
	Δp_t	1.67	1.55	1.56	6.00
	Δy_t	0.59	0.95	0.43	8.29
USA	Δw_t	0.91	1.54	0.41	3.40
	Δv_t	-0.49	6.01	**-0.82**	3.97
	Δu_t	0.05	4.95	**1.49**	6.21
	Δp_t	1.00	0.64	1.09	3.50
	Δy_t	0.76	0.83	-0.11	4.90
EA	Δw_t	1.59	1.83	1.02	3.44
	Δv_t	n.a.	n.a.	**n.a.**	n.a.
	Δu_t	1.06	3.45	**1.83**	10.87
	Δp_t	1.37	0.93	0.64	2.46
	Δy_t	0.61	0.58	-0.42	3.90

Table 1: Moments of growth rates of wages, vacancies, unemployment, prices and output for five countries: France Germany, United Kingdom, the US and the euro area.

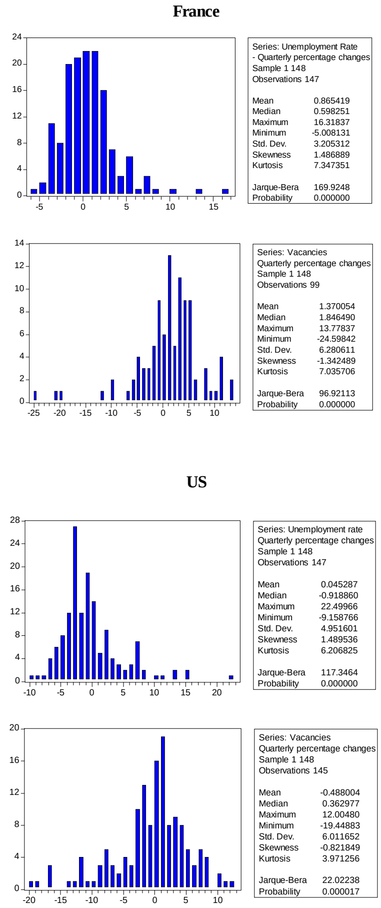


Figure 1: Vacancies and Unemployment Changes in US and France.

in the variables due to demographic changes are captured by the mean of these variables. The strong link between unemployment and vacancies through the Beveridge curve, which indicates a strong negative correlation between both variables seems helps to explain the opposite type of skewness between them. The negative skewness for vacancies implies that vacancies fall sharply by large amounts, instead the positive skewness of unemployment indicates that this variable increases strongly in some rare occasions and rarely decreases strongly. Figure 1 show visually these asymmetries for France and the US.

Vacancy posting tends to increase in small steps and decreases by a large amounts. The opposite is true for the unemployment rate. The results regarding output growth are less clear-cut: the skewness of output growth is negative for some countries, and positive for others, but always low. The features presented here indicate some intrinsic asymmetry in the labor market. An argument put forward by Davis, Haltiwanger and Schuh (1996) relates to job destruction through plant closure and restructuring in times of recession. This margin by itself causes an important source of asymmetry. Shimer (2005) showed that the main margin of adjustment over the US business cycle is at the matching margin between employees and employers. The underlying Mortensen-Pissarides matching model does not exhibit an asymmetry by itself. In this paper we argue that the presence of downwardly rigid wages is one potential explanation of the asymmetries in the observed quantities. Following a negative shock wages adjust only sluggishly which reduces the incentives for firms to open vacancies by a large margin leading to a strong rise in unemployment and to an increase in inflation. In the case of a positive shock, instead, wages adjust quickly absorbing possible profits firms can make. This leaves firms with small incentives to open vacancies in expansionary periods and employment builds up only slowly. The effect on output however is small because, as we will see, other variables (hours in our case) absorb part of the asymmetry in the behavior of wages, reacting more in expansions than in recessions.

2.2 Turning Point Analysis

An alternative point of view on business cycles can be obtained by identifying turning points in the evolution of economic activity. Harding and Pagan (2002) propose an adaptation of the automatic algorithm designed by Bry and Boschan (1971) to identify expansions and recessions, with results which are very similar to the NBER reference cycle for the US[7]. The approach, which is closely related to the Burns and Mitchell (1946) methodology, is characterized by two key advantages. First, it is directly applied to the raw data in levels and does not require any type of filtering. Frequency filters may wash out part of the cyclical asymmetries. Second, the procedure measures the duration, the amplitude and the cumulative change over a cycle, and documents asymmetries between expansionary and declining phases of the cycle for each variable. This allows to answer not only to questions about the volatility of business cycle, but also to connected questions like "how long" and, more importantly, "how deep" are recessions.

With this analysis we identify the specific moment of a turning point, and once these are identified we compute the following statistics:

- "Average Duration Peak to Peak" (PP) or "Average Duration Through to Through" (TT) represent the average length of a business cycle.
- "Average Duration Peak to Through" (PT) or "Average Duration Through to Peak" (TP) captures the average length of time spent in a recession (peak to through) or during expansion (through to peak). The ratio of these two indicates the asymmetry in the length of expansionary and contractionary phases.
- "Average Growth Rate Peak to Troughs" (GPT) or "Average Growth Rate Troughs to Peaks" (GTP) represent the average growth rate of output in a recession (peak to through)

[7] The algorithm can be described as follows:

1) Smooth the reference serie y_t with a series of filters in order to eliminate outliers, high frequency or irregular variations. Call y_t^{sm} the smoothed series. 2) Use a dating rule to determine a potential set of turning points. The rule we have used is: $\triangle^2 y_t^{sm} > 0$ (< 0) , $\triangle y_t^{sm} > 0$ (< 0) , $\triangle y_{t+1}^{sm} < 0$ (> 0) , $\triangle^2 y_{t+1}^{sm} < 0$ (> 0). 3) Use a censuring rule to ensure that peaks and throughs alternate and that the duration and the amplitude of phases is meaningful. See Harding and Pagan (2002) and Canova (2007) for an explanation and a discussion of this methodology.

or in a expansion (through to peak). Again, the ratio indicates the asymmetry in growth rates between recessions and expansions.

- “Cumulative percentage change” in expansions and recessions capture the total change in output over a phase of the cycle[8].

Table 2 presents the results when applying the dating algorithm to GDP.

	Duration				Ratio	Growth Rates		Ratio	Cumulative %Δ	
	PP	TT	PT	TP	$\frac{TP}{PT}$	GPT	GTP	$\frac{GTP}{GPT}$	PT	TP
EA	35.50	36.00	34.00	2.00	17.00	0.70	-0.72	0.98	-1.44	23. 8
US	22.33	21.33	19.33	2.75	7.03	0.99	-0.86	1.16	-2. 36	19.14
France	72.00	74.00	70.00	3.00	23.33	0.61	-0.63	0.96	-1. 89	42. 7
Germany	28.50	24.00	25.00	3.00	7.14	0.92	-0.50	1.84	-1. 5	23.0
UK	34.00	35.00	29.00	5.00	5.80	0.72	-0.90	0.81	-4. 5	20. 88

Table 2: Business Cycles Characteristics in Selected Countries

The business cycle in European countries appears longer but smoother when compared to the American one. This confirms, in a different sample and time period, the results by Reichlin and Giannone (2006). The average duration of the cycle is around 22 quarters in the US but more than 35 quarters in the Euro Area. In both cases expansions last much more than recessions, but while in the US expansions are longer than recession by a factor of 7, in the Euro Area this ratio amounts to 17. The average growth rate in expansions is 0.70% per quarter in the Euro Area and 1.07% in the US, while during recessions quarterly GDP declines by 0.78% per quarter in the US and 0.72% in the EA. The relative "intensity" of expansions and recessions ($\frac{GTP}{GPT}$) is above one in the US but below one in the EA.

Looking at the other economies in our sample one can note significant variations in business cycle characteristics across countries, suggesting structural differences behind the behavior of output over the cycle. In the last part of the paper, we will apply the same algorithm to our model to analyze how different institutional characteristics of the economy are likely to affect the shape, duration and intensity of business cycles.

The turning point analysis is tailor-made for the analysis of GDP time series. Nevertheless it is also possible to apply the algorithm to stationary series as an alternative to the immediate moments of the series. We will analyze the asymmetries of labor market variables also through this lens in future.

3 The Model

In order to capture the asymmetric features of the labor market we set up a New Keynesian model featuring frictional labor markets and asymmetric wage adjustments. The aim is to develop a parsimonious version revealing the mechanism through which downwardly rigid wages

[8]In percent of GDP in the first quarter of the phase.

affect the different variables over the business cycle. At this stage it does not include capital, though this might strengthen the asymmetries and generate more persistence in the spirit of den Haan, Ramey and Watson (2000).

3.1 The labor market

Let m_t denote the newly formed firm–worker matches in the labor market. Their number depends on the measure of vacancies v_t and job seekers u_t following a constant return to scale matching technology:

$$m_t = \bar{m} u_t^{\vartheta} v_t^{1-\vartheta},$$

where $\bar{m} > 0$, $\vartheta \epsilon (0,1)$ and $u_t = 1 - (1-\rho) n_{t-1}$ is the number of *searching workers* at the beginning of period t. Notice that, following Blanchard and Galì (2008), Thomas and Zanetti (2008) and Ravenna and Walsh (2008) among others, we assume that workers hired in a period start producing before the end of the period. We believe the instantaneous-hiring assumption is more plausible given the quarterly frequency of our model[9].

The probability for the firm to fill an open vacancy is

$$q_t = \frac{m_t}{v_t} = \bar{m} \theta_t^{-\vartheta}$$

where $\theta_t = \frac{v_t}{u_t}$ denotes labor market tightness. The probability that a worker looking for a job is matched with an open vacancy is

$$s_t = \frac{m_t}{u_t} = \theta_t q(\theta_t).$$

Employment evolves following a process of job matching and destruction. A fraction ρ of employment relationships is destroyed in every period t and a number m_t becomes immediately operative. The law of motion is thereby

$$n_t = (1-\rho) n_{t-1} + m_t. \tag{1}$$

Firms and workers take the matching probabilities as given. Alternative representations are achieved in terms of job–finding probabilities s_t or vacancy filling q_t :

$$\begin{aligned} n_t &= (1-\rho) n_{t-1} + u_t s_t \quad (2) \\ &= (1-\rho) n_{t-1} + v_t q_t. \quad (3) \end{aligned}$$

For future reference, we also define *(after-hiring) unemployment* as the fraction of searching workers that remain unemployed after hiring takes place:

$$ur_t = 1 - n_t \tag{4}$$

[9]See Thomas and Zanetti (2008) for a brief discussion of the advantages of the contemporaneous hiring assumption in a model with quarterly frequency.

3.2 Household optimization

Each household is thought of as a large extended family which contains a continuum of members with names on the unit interval. In equilibrium, some members are employed and others not: to avoid distributional issues, we assume that consumption is pooled inside the family and that family members perfectly insure each other against fluctuations in consumption due to the employment status. The representative household maximizes a standard time–separable lifetime utility, which depends on the household's consumption and disutility of work

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma}}{1-\sigma} - \chi \frac{h_t^{1+\phi}}{1+\phi} n_t \right]$$

Households own all firms in the economy and face the following per period budget constraint expressed in real terms:

$$C_t + \frac{B_{t+1}}{P_t R_t} = n_t w_t^R h_t + (1-n_t)\, b_t + \frac{B_t}{P_t} + D_t - T_t,$$

where C_t is a standard Dixit-Stiglitz consumption bundle with elasticity of substitution ϵ, P_t the aggregate price level and R_t the gross nominal interest rate of the nominal bond B_t. Total household income is the sum of the wage income earned by employed family members $w_t^R n_t h_t$, the benefits earned by the unemployed $b_t = bA_t$ and the family share of aggregate profits from retailers and matched firms(D_t), net of government lump-sum taxes(T_t)[10].

Consumption maximization leads to the standard Euler condition:

$$C_t^{-\sigma} = \beta R_t \mathbb{E}_t \left[\frac{C_{t+1}^{-\sigma}}{\Pi_{t+1}} \right]$$

The net value of employment (W_t) as opposed to unemployment (U_t) is

$$W_t - U_t = w_t^R h_t - b_t - \frac{\chi}{\lambda_t} \frac{h_t^{1+\phi}}{1+\phi} + (1-\rho)\, \mathbb{E}_t \left[\beta_{t+1} (1-s_{t+1}) (W_{t+1} - U_{t+1}) \right] \qquad (5)$$

where $\beta_{t+1} = \beta \frac{\lambda_{t+1}}{\lambda_t}$ is the stochastic period-per-period discount factor within the economy. The net value of employment for the household is the income from working h_t hours net of the unemployment benefits that are earned in periods of unemployment and net of the disutility of working h_t hours, plus the expected continuation value from the employment relationship.

3.3 Supply side

There are two sectors of production in the economy. Firms in the wholesale sector produce the intermediate homogeneous good in competitive markets using labor as the only input. This output is sold to retailers who are monopolistic competitive. Retailers transform the homogeneous goods one for one into differentiated goods at no cost. Price rigidities, in the form of quadratic costs of adjusting prices, arise in the retail sector, while search and matching frictions in the intermediate goods' sector.

[10]Notice that when productivity grows along the balanced growth path, also the unemployment benefits grow at the same rate. This guarantees that unemployment benefits are constant along the balanced growth path.

3.4 Final good and Retailers

There is a measure one of monopolistic wholesalers indexed by z on the unit interval, each of them producing one differentiated good, that is aggregated by the household to become the final composite good:

$$Y_t = \left[\int_0^1 Y_t^F(z)^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}} \tag{6}$$

Final output may either be transformed into a single type of consumption good or used to pay for price adjustment costs. The aggregate resource constraint is thus given by:

$$C_t = Y_t\left(1 - \Gamma_t\right)$$

where, as in Krause and Lubik (2007), the costs of vacancy posting are assumed to be distributed across aggregate households.

Due to imperfect substitutability across goods, the demand function for each wholesaler for its product is:

$$Y_t^F(z) = \left(\frac{p_t(z)}{P_t}\right)^{-\epsilon} Y_t,$$

and the price index P_t is

$$P_t = \left[\int_0^1 p_t\left(z\right)^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}. \tag{7}$$

Retailers share the same technology, which transforms one unit of intermediate goods into one unit of wholesale goods, so that $Y_t^F\left(z\right) = Y_t\left(z\right)$. Firms in the retail sector purchase intermediate goods from wholesale producers at nominal price $P_t\varphi_t$ and convert it into a differentiated good sold to households and wholesale firms. We introduce nominal rigidities for retailers assuming firms face a quadratic cost of adjusting prices. The representative firm chooses prices to solve the following maximization problem:

$$\max_{P_t(z)} \; E_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0}\left[\frac{P_t(z) - P_t\varphi_t}{P_t} - \Gamma_t\right] Y_t(z)$$

subject to the demand function $Y_t(z)$ and the adjustment cost function $\Gamma_t = \frac{\psi}{2}\left(\frac{P_t(z)}{P_{t-1}(z)} - 1\right)^2$. The first order condition with respect to the firm's price $P_t\left(z\right)$ gives:

$$\Gamma_t'\Pi_t = \epsilon_t\left(\varphi_t + \Gamma_t\right) - \left(\epsilon_t - 1\right) + \beta\mathbb{E}_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\frac{Y_{t+1}}{Y_t}\Gamma_{t+1}'\Pi_{t+1}\right],$$

where $\Pi_t = \frac{P_t(z)}{P_{t-1}(z)} = \frac{P_t}{P_{t-1}}$ and we used the fact that, in equilibrium, all firms set the same price. The price setting behavior of the retail firms is independent of the labor hiring by the wholesale firms, it only depends on the cost of the intermediate good φ_t combined with convex price adjustment costs[11].

[11] Notice that under flexible prices ($\Gamma_t = \Gamma_t' = 0$) optimal price setting requires:

$$\frac{P_t\left(z\right)}{P_t} = \frac{\epsilon}{\epsilon-1}\varphi_t = \mu_p\varphi_t$$

3.4.1 Wholesale firms and the labor market

Each firm in the intermediate goods sector produces according to the production function[12]:

$$Y_t = A_t n_t \left(z_t h_t\right)^{\alpha}$$

with constant returns to employment n_t. We distinguish between a permanent (A_t) and a transitory (z_t) productivity shock, which are respectively determined by

$$\begin{aligned} \ln z_t &= \rho_a \ln z_{t-1} + \varepsilon_t^z \quad (8) \\ g_{a,t} &\equiv \frac{A_t}{A_{t-1}} = \left(1-\rho_a\right) g_a + \rho_a g_{a,t-1} + \varepsilon_t^{ga} \quad (9) \end{aligned}$$

where $g_{a,t} \equiv \frac{A_t}{A_{t-1}}$ represents the productivity growth rate with steady state level g_a, while ε_t^{ga} is an i.i.d. technology shock. The ε_t^z shock shifts technology above or below the balanced growth path of productivity growth while a ε_t^{ga} shock accelerates or decelerates the growth rate of productivity which has permanent effects on the level of productivity. The two shocks may therefore have potentially very different implications due to the persistence for productivity.

The intermediate good is sold to retailers at the relative price φ_t in real terms. In order to find a worker, firms must actively search for workers in the unemployment pool. The idea is formalized by assuming that firms post vacancies. The cost of posting a vacancy, in units of consumption goods, is $\kappa_t = \frac{\kappa}{\lambda_t}$, where κ is the utility cost from search services and $\frac{\kappa}{\lambda_t}$ the corresponding cost in terms of the consumption good. Notice that these costs are time-varying and, more importantly, consistent with a balanced growth path.

The representative firm maximizes the expected sum of discounted profits:

$$\max_{v_t, n_t} \mathbb{E}_t \left\{ \sum_{j=0}^{\infty} \beta_{t+j} \left[\varphi_{t+j} A_{t+j} n_{t+j} \left(z_{t+j} h_{t+j}\right)^{\alpha} - w_{t+j}^R h_{t+j} n_{t+j} - \kappa_{t+j} v_{t+j} \right] \right\}$$

subject to the sequence of law of motions of labor (3). The first–order conditions with respect to vacancies and labor respectively give

$$\begin{aligned} \frac{\kappa_t}{q_t} &= J_t \\ J_t &= \varphi_t Y'_{n,t} - w_t^R h_t + (1-\rho)\, \mathbb{E}_t \left[\beta_{t+1} J_{t+1}\right] \quad (10) \end{aligned}$$

The first equation denotes the free entry condition for vacancy posting that equalizes vacancy posting costs and the expected returns to a vacancy with J_t being the value function of a job

Since firms are identical, in equilibrium firms choose prices to maintain a constant mark-up over the marginal cost:

$$\varphi_t = \frac{\epsilon - 1}{\epsilon} = \frac{1}{\mu_p}$$

[12] Since all firms are equal in equilibrium, in the following to simplify the notation we avoid firm specific's subscripts.

for a firm at time t. Combining both conditions leads to the job creation condition:

$$\frac{\kappa_t}{q_t} = \varphi_t A_t (z_t h_t)^\alpha - w_t^R h_t + (1-\rho)\mathbb{E}_t\left[\beta \frac{\lambda_{t+1}}{\lambda_t}\frac{\kappa_{t+1}}{q_{t+1}}\right] \tag{11}$$

The free entry condition for job creation states that the costs for posting a vacancy equates the expected payoffs from an employment relationship. These consist of the earnings from the product of the single worker net of the wage payments, and includes the continuation value represented by next period's free entry condition.

3.5 Wage determination

Wages and hours are jointly determined in a framework of decentralized Nash bargaining. Let $W_t - U_t$ be the value of an employment relationship for the household in period t. The household's expected return from a job is given by the marginal value of employment (5), derived from the household's optimization. A realized job match yields a rent equal to the sum of the expected search costs of the firm and the worker. We assume the Nash real wage w_t^N is determined according to the maximization of the following Nash criterion where the surplus of each agent is given by the marginal value of unemployment measured in terms of consumption goods:

$$\arg\max_{\{w_t, h_t\}} \left[J_t^{1-\eta}(W_t - U_t)^\eta\right]$$

where η is the bargaining power of workers. The FOC give one condition for hours worked and a second one for hourly wages:

$$\alpha\varphi_t A_t z_t^\alpha h_t^{\alpha-1} = \frac{\chi}{\lambda_t} h_t^\phi \tag{12}$$

$$w_t^N h_t = b_t + \frac{\chi}{\lambda_t}\frac{h_t^{1+\phi}}{1+\phi} + \frac{\eta}{1-\eta}\left\{\frac{\kappa_t}{q_t} - \beta(1-\rho)\mathbb{E}_t\left[\frac{\lambda_{t+1}}{\lambda_t}(1-s_{t+1})\frac{\kappa_{t+1}}{q_{t+1}}\right]\right\} \tag{13}$$

Notice that by combining equation (11) and (12) we can write φ_t, the marginal costs faced by retailers, as

$$\begin{aligned} MC_t &= \varphi_t = \frac{1}{\alpha}\frac{\chi}{\lambda_t}\frac{h_t^{1+\phi-\alpha}}{A_t z_t^\alpha} \\ &= \frac{1}{A_t (z_t h_t)^\alpha}\left\{w_t^R h_t + \frac{\kappa_t}{q_t} - (1-\rho)\mathbb{E}_t\left[\beta_{t+1}\frac{\kappa_{t+1}}{q_{t+1}}\right]\right\} \end{aligned}$$

These conditions simply state that at optimum the cost of producing a marginal unit of output by adding an extra hour of work must be equal to the hourly expected cost of producing the marginal unit of output by adding an extra worker[13]. Firms choose either margin depending on the nature of the shock and on its persistence.

[13] See also Ravenna and Walsh (2008). Notice that by combining expression (13) with the free entry condition we get the equation pinning down the employment level under flexible wages $\left(w_t^R = w_t^N\right)$, the so–called job–creation condition:

$$\frac{\kappa_t}{q_t} = (1-\eta)\left(\varphi_t A_t z_t^\alpha h_t^\alpha - \frac{\chi}{\lambda_t}\frac{h_t^{1+\phi}}{1+\phi} - b_t\right) + \beta(1-\rho)\mathbb{E}_t\left[\frac{\lambda_{t+1}}{\lambda_t}\frac{\kappa_{t+1}}{q_{t+1}}(1-\eta s_{t+1})\right]$$

3.6 Real Wage Rigidity

Real wage rigidity is introduced by employing a version of Hall's (2005) notion of wage norm. A wage norm may arise as a result of social conventions that constrain wage adjustment for existing and newly hired workers. One way to model this is to assume that the real wage is a weighted average of the Nash bargained wage w_t^N and a wage norm $\bar{w}$, which is simply assumed to be the wage prevailing in the last period, w_{t-1}^R adjusted for average productivity growth g_a[14]. Specifically, we assume the real wage to be determined as follows

$$w_t^R = \left(w_t^N\right)^{\gamma(\Omega_t)} \left(w_{t-1}^R g_a\right)^{1-\gamma(\Omega_t)} \tag{14}$$

$$\frac{w_t^R}{w_{t-1}^R g_a} = \left(\frac{w_t^N}{w_{t-1}^R g_a}\right)^{\gamma(\Omega_t)} \tag{15}$$

where $\gamma(\Omega_t) \equiv \gamma\left(\frac{w_t^N}{w_{t-1}^R g_a} - 1\right)$ is an index of the real wage rigidity present in the economy, with $0 \leq \gamma(\Omega_t) \leq 1$. With $\gamma = 0$ wages in period t are last period's wages indexed by productivity growth of the balanced growth path. Instead, if $\gamma = 1$ wages are entirely flexible and determined through the Nash bargain between employee and employer.

In order to capture in a very simple and intuitive way the presence of downward wage rigidities, we assume that the index of real wage rigidities depends on the wage growth between last period's real wage and current Nash-bargained wage level. If the Nash bargained wage is above last period's real wage a large weight is attributed to the Nash wage (γ close to 1) while in the prospect of wage cuts, the relative weight shifts in favour of last period's wage to keep wages up. We choose the following functional specification:

$$\gamma(\Omega_t) = \gamma\left(\frac{w_t^N}{w_{t-1}^R g_a} - 1\right) = \left(1 + \tau_2 \exp\left[-\tau_1\left(\frac{w_t^N}{w_{t-1}^R g_a} - 1\right)\right]\right)^{-1}.$$

The functional form describes a logistic function and with the asymmetry parameter τ_1, with $\tau_1 = 0$ implying no asymmetry, and the parameter τ_2 determines the mean value. To reproduce the often used setup by Hall (2005) of $\gamma = 0.5$, we use in our specification $\{\tau_1, \tau_2\} = \{1, 0\}$. Figure 2 depicts γ as function of the Nash bargained wage growth, whereby $\tau_2 = 1$ indicates low wage rigidity and $\tau_1 = 3$ implies higher wage rigidity on average. As can be seen, for the chosen parameterization the action takes place at $\pm 3\%$ of desired wage growth. If wages ought to increase by 3%, γ takes values of above 0.8, indicating high weights for the Nash bargained wage. In the opposite case of -3% growth, wages are very rigid and a weight above 0.9 is given to last period's wage.

3.7 Monetary Policy

To close the model we specify monetary policy. We assume the Central Bank sets the short term nominal interest rate by reacting to the average inflation and employment levels in the

[14] The adjustment for average productivity growth is needed to make the model consistent with the balanced growth path. Otherwise, the real wage received by workers would lag the desired one and in the deterministic steady state the real wage would be lower than the Nash bargained wage. See Shimer (2008) for a similar assumption.

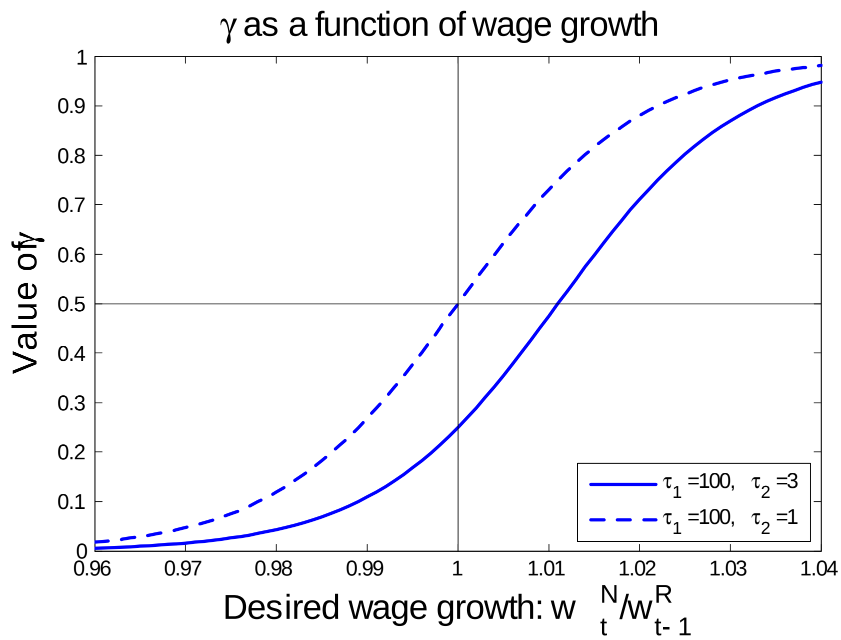


Figure 2: The parameter for wage rigidity as a function of bargained real wage growth. Higher wage growth implies higher levels for γ implying lower wage rigidity. Potential wage cuts lead to lower levels of γ and thereby stronger wage rigidity. The functional form follows a logistic function. Two parameterisations are depicted: $\tau_1 = 1$ represents weak wage rigidity, $\tau_2 = 3$ represents strong wage rigidity.

economy. More specifically, the central bank adopts an augmented Taylor type rule for the nominal interest rate:

$$r_t = (r_{t-1})^{\omega_i} \left[\left(\frac{P_t}{P_{t-1}} \right)^{\omega_\pi} \left(\frac{N_t}{\bar{N}} \right)^{\omega_n} \right]^{1-\omega_r} \varepsilon_t^m$$

Consistently with empirical evidence, we assume that monetary policy displays a certain degree ω_r of interest rate smoothing[15]. The parameters ω_π and ω_n are the response coefficients of inflation and the employment. The term ε_t^m captures an *i.i.d* monetary policy shock.

3.8 The steady growth path

Since the model exhibits balanced growth, all non-stationary variables need to be detrended. For that purpose, we transform the variables as follows:

$$\begin{aligned} \bar{X}_t &= \frac{X_t}{A_t} \quad for \quad X = A, Y, C, w, I \\ \bar{X}_t &= X_t, \quad for \quad X = n, h, r, i, P, \varphi, v, q, p \\ \bar{X}_t &= X_t A_t, \quad for \quad X = \lambda \end{aligned}$$

For the analysis of turning points we use the trending variables again, which are transformed back into levels using the same procedure.

[15] See, e.g, Clarida, Gali and Gertler (1999).

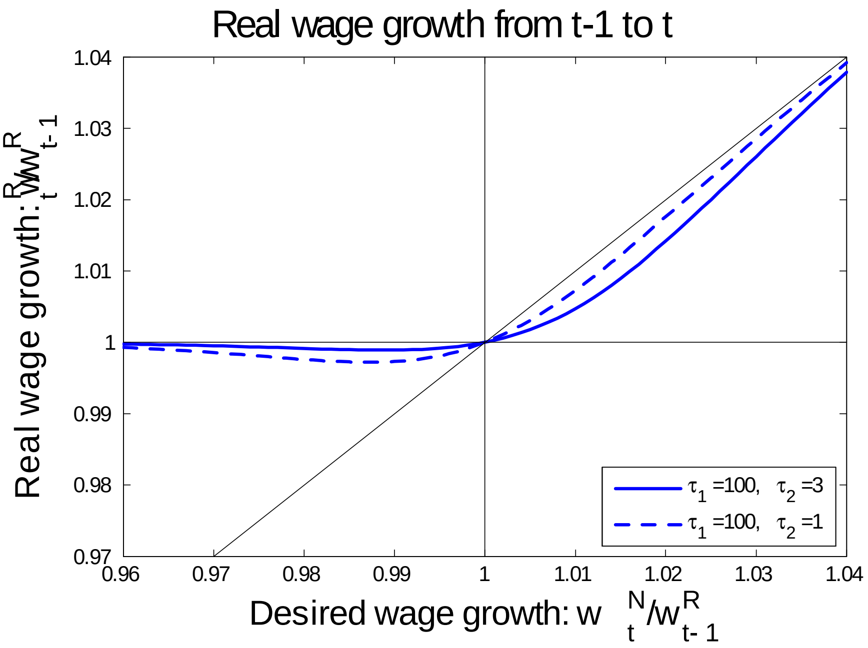


Figure 3: The change in real wages as a function of desired wage changes. With wage increases the Nash bargained wage is predominant, in the case of wage cuts, past period's wages are taken and wage growth is zero. The figure depicts the case without steady state wage growth.

4 Calibration

As a main reference for the calibration of the model we follow Christoffel, Kuester, Linzert (2008) and Blanchard and Gali (2008). Three sets of parameters can be identified for the calibration. The first regards parameters in the standard New Keynesian models, the second block of variables is linked to the frictional labor market, and the third set deals with the specification of the asymmetry in wage adjustments.

Regarding the parameters of the New Keynesian models, the discount factor β is set to 0.992 in a quarterly fashion in order to obtain an interest rate of about 4%. We assume separable utility function with log specification in consumption to account for long-run constancy in hours, and trending productivity requires utility in consumption to be logarithmic ($\sigma = 1$). The Frisch elasticity of labor supply is set to 1, a widely used value. Furthermore we set the elasticity of output with respect to hours worked to 2/3 ($\alpha = 0.66$) reflecting a labor share of roughly the same size. The price mark-up charged by firms is 10% which implies an elasticity of substitution of intermediate goods of $\epsilon = 11$, a value in line with the empirical estimations by Christopoulos and Vermeulen (2007). The degree of price rigidity of $\psi = 50$ in the quadratic cost adjustment corresponds to a value of 65% of firms not changing their prices in one quarter in a Calvo setup, which alternatively means 18% of firms do not change priceswithin one year. For the monetary policy we use a simple rule reacting to inflation with an elasticity ω_π of 1.5 and a persistence in interest rates $\omega_R = 0.85$.

For the parameters relating to the frictional labor market, we specify the elasticity of job matches with respect to vacancies to $\vartheta = 0.5$, in line with Petrongolo and Pissarides (2007) estimation of matching functions. The workers' relative bargaining power η is set to 0.5, as standard value in the literature due to the lack of reliable information on bargaining strengths of employees and employers.

The labor market is calibrated to the Euro Area, with a steady state unemployment of $u = 9\%$ and a job finding rate per quarter set to 0.25. Combining these two values with a constant participation rate normalized to 1, steady state separation rate per quarter is $\rho = 3.3\%$. This reflects the relatively rigid labor markets in Europe compared to the US. The implied efficiency in the matching function is $\sigma_m = 0.47$. As in Konya and Krause (2008), we set the unemployment benefits parameter set to $b = 0.6$, which represents in steady state a replacement ratio $b/w = 0.66$.

In the baseline calibration, following Campolmi and Faia (2008) and Blanchard and Galì (2008) among others, the degree of real wage rigidity γ in steady state is assumed to be equal to 0.5, implying a value of $\tau_1 = 1$. The parameter determining the asymmetry in the adjustment of wages is set to $\tau_2 = 100$.

Regarding the shock processes, we set the standard deviation of monetary policy shocks to 0.1 percent, consistent with the estimates by Christoffel , Coenen G. and A. Warne (2008). The average growth rate is set to $g_a = 1.005$, implying an annual average growth rate of around 2%, a value which is in line with the average growth rate of labor productivity and GDP in the euro area. The persistence parameter on the growth process is set to $\rho_a = 0.85$ and its standard deviation to $\sigma_a = 0.12$ percent. Once transformed at the monthly frequency, these values are the same of the ones used by Shimer (2008); moreover, they are very similar to the ones estimated by Christoffel, Coenen and Warne (2008) for the euro area. The persistence and standard deviation of the transitory productivity shock z_t are set to $\rho_a = 0.95$ and $\sigma_a = 0.005$, values which are standard in the literature. Notice that under our baseline calibration and all three shocks the model gives a standard deviation of labor productivity $\frac{y_t}{n_t}$ around its HP trend that is only slightly lower than the one estimated on the euro area (0.55 instead of 0.65).

5 Dynamics

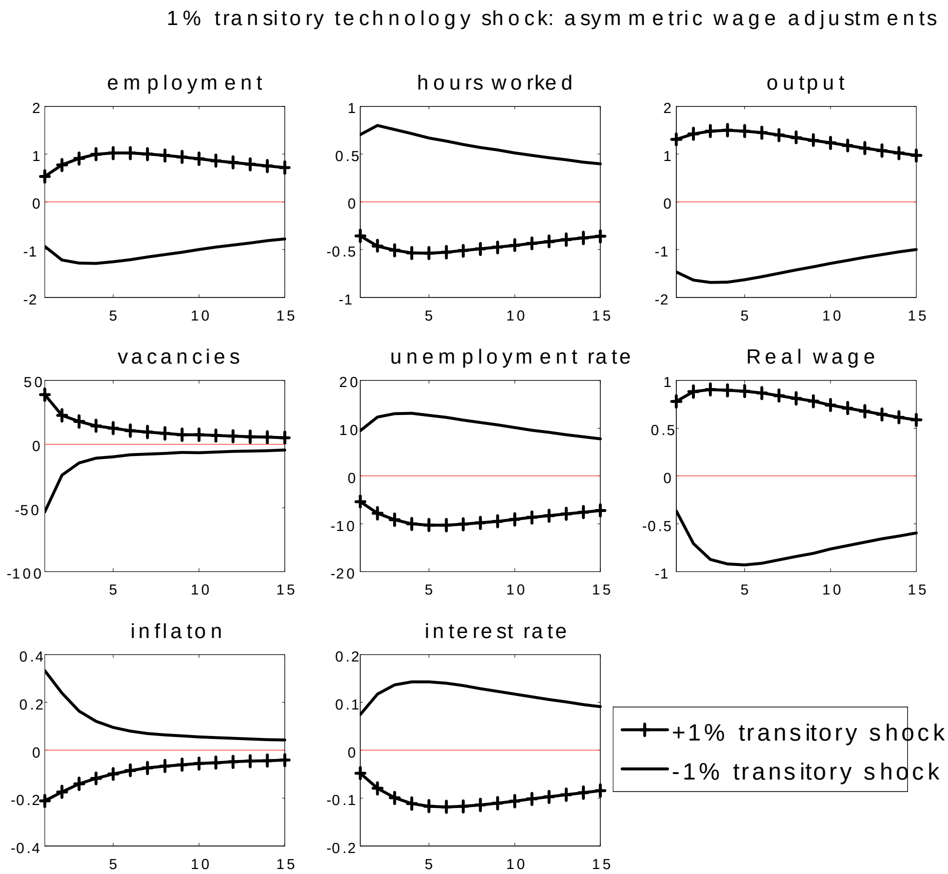
In order to highlight the mechanism through which downard real wage rigidity affects the different variables, we analyze the dynamic response to three types of shocks: a shock to transitory technology which raises/decreases productivity above/below the balanced growth path. This affects the level of productivity with respect to the balanced growth path in a transitory manner. The second shock is to the growth rate of productivity affecting permanently the level of output and other trending variables. Finally, the third shock regards monetary policy.

Figure 5 presents the dynamic response following a transitory technology shock of 1%, which represents two standard deviations. With contemporaneous hiring employment increases on impact after a positive shock, firms have incentives to hire more workers to take advantage of the improved production possibilities while hiring costs remain at low levels. Due to increased productivity recruiting is relatively cheap and employment rises. Vacancies increase by a large

Parameter	Value	Calibration
β	0.992	Discount factor: annual interest rate of 4%
σ	1	Log-utility for balanced growth
ϕ	1	Inverse Frisch elasticity of labor supply
α	0.66	Labour share
$\frac{\epsilon}{\epsilon-1}$	1.1	Price-markup: 10%, Elasticity of subst.ϵ: 11
ψ	50	Price rigidity
ω_π	1.5	Monetary policy response to inflation
ω_R	0.85	Interest rate smoothing
η	0.5	Worker's bargaining power
ϑ	0.5	Search elast. matching fct.
ρ	0.033	Exog. job separation rate (country specific)
s	0.25	Job-finding rate
b	0.6	Unemployment benefits, Replacement rate
τ_1	1	Wage rigidity in steady state, implies $\gamma = 0.5$
τ_2	100	Degree of asymmetry
g	0.5%	Quarterly growth rate of productivity
ρ_a	0.85	Persistence of permanent technology shock
ρ_z	0.92	Persistence of transitory technology shock
σ_a	0.12%	Standard deviation of permanent shock
σ_z	0.5%	Standard deviation of transitory shock
σ_m	0.1%	Standard deviation of monetary shock

Table 3: Calibration of the model's parameters.

margin and unemployment falls. Hours worked, instead, respond by a decline due to two reasons. Hours worked directly affect marginal costs of firms, a reduction in the number of hours each employee works increases the productivity of each single worker which is only passed on partially to the employee through higher wages. A second reason for the negative response is the substitution between leisure and consumption of the household through the marginal rate of substitution. Overall, the effect following a positive transitory productivity shock is to substitute the intensive margin of labor adjustment to the extensive margin in order to exploit the increased productivity. Total output adjusts only by a little more than the size of the productivity increase,which is 1%, due to the opposite contributions of hours worked and employment.



A 1% shock to transitory productivity reflecting a size of 2σ.

We assumed asymmetric wage adjustments for wage growth and wage cuts. From the impulse-response functions we observe the near to immediate increase in real wages after a positive productivity shock, but after a negative shock, wages decrease only slowly. Nevertheless, they reach the minimum level after four quarters. The asymmetric rigidity takes as reference last quarter's wage. Compared to the frequency of wage negotiations of more than one year it is in fact a relatively flexible setup. Nevertheless the consequences on vacancy posting and unemployment become very visible. The number of vacancies drops sharply after a negative shock creating a strong increase in the unemployment rate. Unemployment in this setup is not generated by an increase in job destruction during contractionary periods as analyzed by David, Haltiwanger and Schuh (1996), although this might in some periods be an important margin for labor adjustment. In our setup the job destruction rate is constant over the entire adjustment, though the number of job separations depends on the stock of employed workers. Instead of the job destruction margin, the effects from asymmetric wage adjustments lead to an asymmetric response for vacancies which in turn affects employment and unemployment. It is thereby the matching margin which is asymmetric and generating the asymmetry between boom and busts.

In terms of quantities, real wages adjust by double the amount following a positive compared to a negative shock and this implies that unemployment adjusts by a similar ratio. In the opposite case of a negative productivity shock wages have difficulties adjusting downward and unemployment rises strongly. Due to the fact that a negative productivity shock combined with relatively high wages implies that labor costs are high, it is a bad time to invest in employees and subsequently vacancies drop by a large margin. Finally, the effects on inflation are also asymmetric: a positive productivity shock reduces marginal costs of the firms but not by the same amount as it increases following a negative productivity shock. Again, the reason is that marginal costs caused by wages adjust very differently following a positive and negative shock. In the end also interest rate responses are asymmetric, though only by a small degree.

Overall we conclude for a transitory technology shock that the main margin of adjustment following a positive and a negative productivity shock is very different. The response after a positive shock is mainly through the price margin, inflation and wages increase quickly, but the quantitative adjustment is limited, especially employment builds up only slowly. In the opposite case of a negative productivity shock, wages are rigid, the quantities need to adjust by large amounts. This is especially visible for vacancies and unemployment. IN addition, the intensive labor margin is relatively important due to the fact that hiring employees is considered as a long term investment, but as the effects of the transitory shock are limited in time, the hours margin is preferred. In the next part we analyze a shock to permanent productivity. This earns differing results for the intensive and extensive margin of adjustment as well as for monetary policy.

The second shock that we analyze, a shock to productivity growth of 2 standard deviations, has overall similar effects than a transitory shock. We therefore concentrate on the differences in the dynamic response. Most importantly, a growth acceleration leads to a permanently higher level of output and wages. It therefore implies a much stronger adjustment on the extensive employment margin instead of the intensive hours worked margin due to its permanent nature. The differences between positive and negative shocks are marked especially for the responses of unemployment and vacancies and is qualitatively similar to that following a transitory shock. But the response of inflation and interest rates is very different to the one of a transitory shock. A positive transitory shock reduces inflation because marginal costs decline in comparison to the balanced growth path. These lower costs are passed on over the mark-up to the pricing of the final good. In the case of a permanent growth shock inflation accelerates. The intuition behind is the fact that marginal costs are now higher than along the new balanced growth path which exhibits a higher permanently higher level of productivity. During wage negotiations both sides, employees and employers, take the productivity growth rate into consideration increasing wages already early over the transition path. This brings it above the BGP level and spurs inflation. The monetary response is to slow economic activity down to contain inflation by increasing interest rates by a small amount.

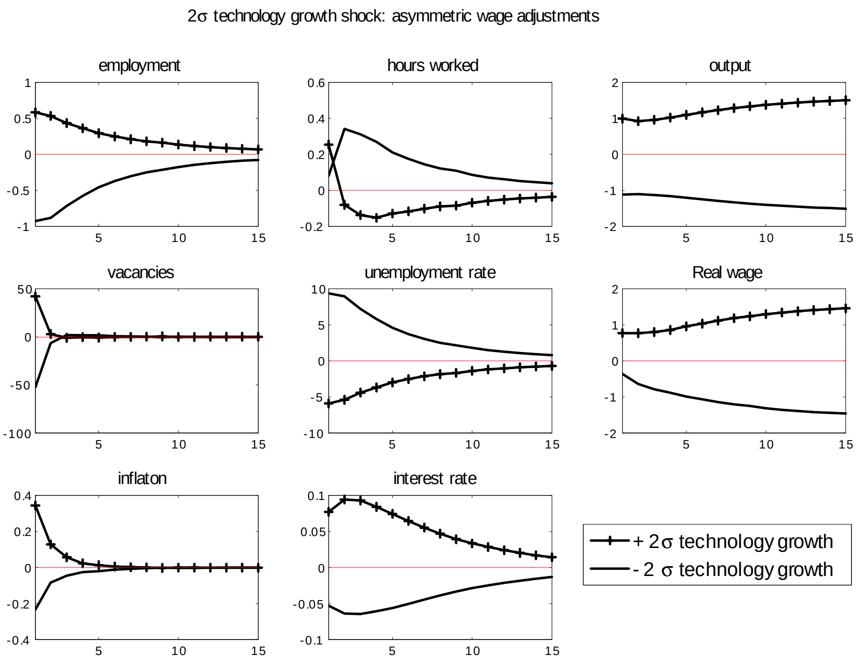


Figure 4: Shocks to the growth rate of productivity implying a permanently higher level of productivity along the Balanced growth path. We consider an acceleration and deceleration of 0.24% (2σ) on impact.

Finally we analyze in figure 5 a monetary shock. The most striking feature is that the asymmetry plays only a minor role for most variables. The monetary shock is modelled as an iid shock and propagates only through the persistence in the monetary response. As employment decisions are seen as a long-term investment, the effect is small. Nevertheless, the intensive margin, i.e. hours worked, as well as wages are affected asymmetrically by the shock to interest rates.

With the analysis of the impulse responses we conclude that the asymmetry for employment variables unfolds its strongest effects following a highly persistent technology shock as is the case of a shock on the growth rate of productivity. Less persistent shocks, such as a transitory shock or a shock to monetary policy affect more strongly the intensive margin of labor, wages and prices without influencing the other quantities.

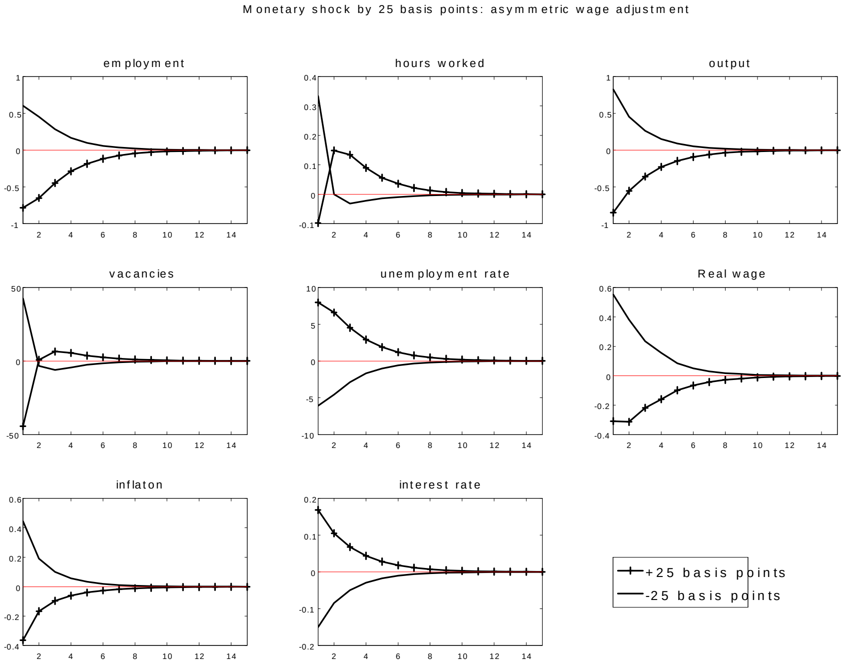


Figure 5: Impulse response functions followinga positive and a negative monetary policy shocks of 25 basis points (reflecting a size of 2.5σ).

6 Downward Wage Rigidities and the Business Cycle

How do different labor market institutions affect the size, shape and intensity of business cycles? To answer this question, we simulate the model under different institutional setups, transform the obtained data series into levels and apply the dating algorithm described in Section 2. We distinguish 5 cases: a US calibration, a calibration for the Euro area, high wage rigidity, downward real wage rigidity and price rigidity.

In the first case we consider an economy with relatively flexible labor markets which may resemble the US economy. The labor market is calibrated as in Blanchard and Galì (2008) setting the steady state job-finding rate to 0.7 and the unemployment rate to 5 percent. The simulated cycle does not appear to be too far from the one identified from the data. The average duration of the cycle (PP) is around six years. Of this, five years are years of expansions (TP) while recessions (PT) only last 4 quarters on average. During an average recession GDP falls by 2.6 percent, while during an expansion it increases by almost 16 percentage points. The Table also reports the growth rates of employment and hours during the various phases of the cycle. Interestingly, in the model during a recession the destruction of jobs is larger than the decline of output, the reason being that the reduction in employment is partly offset by a concomitant increase in hours worked by employed workers. The results are shown in Table 4.

The second case considers a more rigid labor market specification. The job-finding rate

Case		Duration					Avg. Growth Rates			Cumul. %Δ	
		PP	PT	TP	$\frac{TP}{PT}$		GPT	GTP	$\frac{GTP}{GPT}$	PT	TP
1.	*US calib.*	24.59	4.24	20.35	4.80	y_t	-0.61	0.77	1.26	-2.59	15.67
	$\bar{u} = 5\%, \bar{s} = 0.7$					n_t	-0.93	0.18	0.19	-3.95	3.64
	$\gamma = 0.5$					h_t	0.49	-0.08	0.16	2.06	-1.62
2.	*EU Calib.*	29.50	4.73	24.77	5.23	y_t	-0.24	0.67	2.75	-1.14	16.64
	$\bar{u} = 9\%, \bar{s} = 0.25$					n_t	-0.49	0.07	0.15	-2.32	1.79
	$\gamma = 0.5$					h_t	0.17	-0.03	0.15	0.82	-0.64
3.	*High RWR*	23.30	4.29	19.01	4.44	y_t	-0.46	0.73	1.59	-1.98	13.92
	EU, $\gamma = 0.25$					n_t	-0.70	0.13	0.18	-3.01	2.38
						h_t	0.31	-0.05	0.15	1.34	-0.86
4.	*DRWR*	29.15	4.25	24.90	5.85	y_t	-0.60	0.69	1.14	-2.56	17.08
	$\gamma = 0.5$, $\tau_2 = 100$					n_t	-0.76	0.08	0.10	-3.24	1.96
						h_t	0.33	-0.03	0.09	1.38	-0.70
5.	*High Price stick.*	29.50	4.38	25.12	5.73	y_t	-0.30	0.69	2.31	-1.30	17.24
	$\gamma = 0.5, \tau_2 = 100$					n_t	-0.55	0.08	0.15	-2.36	2.08
	$\psi = 100$					h_t	0.22	-0.03	0.13	0.94	-0.71

Table 4: Labour Market Institutions and the Business cycle

is reduced to 0.25 and the unemployment rate to 9 percent, values that represent the more rigid European labor markets. In section 2 we described the European business cycle which is longer and smoother than the American one. By changing the calibration we reproduce this finding. The cycle lasts on average more than seven years of which more than six years are expansions. The average growth rates during expansions and recessions is much smaller, it is therefore smoother. GDP increases by almost 17 points during an expansion and decreases only by a little more than 1 percent during a recession. The difference between the rigid and the flexible economy appears even more strikingly if one compare the evolution of employment of hours and employment over the cycle, which are much less volatile in the EU calibration. This confirms the results in Abbritti and Weber (2008), which claim that differences in labor market structures are an important determinant of the shape, intensity and volatility of business cycles across OECD countries.

The third case considers a higher degree of steady state wage rigidity using the EU calibration. Here we increase the value of the parameter τ_2 from 1 to 3, which implies a change in the steady state value for γ from 1/2 to 1/4. The real wage thereby depends to 3/4 of last period's wage. As in Abbritti and Weber (2008), a higher degree of real wage rigidities shortens considerably the length of the business cycle, which is now one year and a half shorter (from 29 to 23 quarters), recessions are also shorter but more intense. The average loss of output during a recession is almost doubled, from -1.14 to -1.98 percent. Real wage rigidity shifts the adjustment margin from prices to quantities, and the latter affect the length of business cycles. A higher degree of wage rigidity also shifts the margin of adjustment from hours worked to employment and directly influences the length of the cycle.

In the fourth case we introduce downward real wage rigidity with $\tau_2 = 100$ and a steady state value of 0.5 for γ. When comparing the downward rigid case with the relevant non-asymmetric parametrization of the rigid European labor market we note that the overall length of the business cycle is hardly affected. But the presence of downward wage rigidities deepens recessions. The average growth rate during a quarter in recession more than doubles, from -0.24% in the absence of downward wage rigidities to -0.60% when wage cuts take place only slowly. The cumulative loss in output in a recession is more than doubled (from -1.14 to -2.56) while the cumulative loss of employment increase by almost 50 percent, from -2.32 to -3.24. Notice that these effects would be even stronger under the US calibration (not reported): in a flexible economy the cumulative loss of output would be -3.09 and the cumulative loss of employment -4.68. Downward wage rigidities lead to more pronounced recessions through their effects on employment without affecting the length of the business cycle.

Finally, to investigate the role of price stickiness, we increase the relevant parameter ψ from 50 to 100 in the last case. A higher degree of price stickiness does not alter expansionary periods but reduces considerably the deepness of recessions when comparing the cases 4 and 5. This result certainly needs further investigation.

In section 2 we described the business cycle by the moments of the growth rates of output, wages, vacancies and unemployment. Robust findings related to the skewness of vacancies and unemployment. In table 5 we describe the moments for the same variables with and without downward wage rigidities. For ease of exposition we restrain ourselves to the EU calibration characterizing more rigid labor markets. In the absence of downward wage rigidity hardly any asymmetry is found for the growth rates of the different variables. By introducing downward wage rigidity the model is able to replicate the positive skewness of unemployment changes and the negative skewness of vacancy posting we observe in real world data. As a result of the opposing responses of hours worked and employment following technology shocks the skewness of output is well contained. As becomes obvious from the table, the results hinge on a strong asymmetry in wage changes. The skewness is difficult to be matched with empirical wage series as the quality of these aggregate series varies over time periods.

Case			Mean	Median	St Dev	**Skew.**	Kurt.
2.	*EU Calib.*	Δy_t	0.50	0.51	0.97	**0.02**	2.96
	$\gamma = 0.5$	Δu_t	0.00	0.01	0.59	**-0.06**	3.03
		Δh_t	0.00	0.01	0.36	**-0.01**	3.04
		Δw_t	0.50	0.50	0.48	**0.01**	2.94
		Δv_t	0.00	0.00	1.59	**-0.01**	3.13
4.	*DRWR*	Δy_t	0.50	0.55	1.00	**-0.27**	3.17
	$\gamma = 0.5$, $\tau_2 = 100$	Δu_t	-0.00	-0.09	0.64	**0.79**	4.41
		Δh_t	0.00	-0.02	0.40	**0.28**	3.81
		Δw_t	0.50	0.37	0.56	**1.29**	6.13
		Δv_t	0.03	0.03	0.01	**-0.25**	3.35

Table 5: Downward Wage Rigidities and Asymmetries

7 Size of Recessions and Monetary Policy

How does monetary policy affect the length and the deepness of the business cycle? To answer this question, we compare four simple variants of our monetary policy rule, which we rewrite here for convenience:

$$r_t = (r_{t-1})^{\omega_i} \left[\left(\frac{P_t}{P_{t-1}} \right)^{\omega_\pi} \left(\frac{N_t}{\bar{N}} \right)^{\omega_n} \right]^{1-\omega_r}$$

In the first regime, the central bank responds to inflation but not to employment changes ($\omega_\pi = 1.5$, $\omega_n = 0$). In the second, we increase considerably the response to inflation ($\omega_\pi = 5$, $\omega_n = 0$) making it a strong inflation targeter. In the third case the central bank responds mildly to employment changes ($\omega_\pi = 1.5$, $\omega_n = 0.25$), while it responds more firmly to employment fluctuations in the fourth case ($\omega_\pi = 1.5$, $\omega_n = 0.5$).

Table 6 shows the results obtained by using the dating algorithm under the different monetary policy for an economy characterized by rigid labor markets and downward wage rigidity. In order to focus on the stabilization properties we neglect monetary policy shocks and set their standard deviation to 0[16].

Regime			Duration				Growth Rates			Cumul. %Δ	
			PP	PT	TP	$\frac{TP}{PT}$	GPT	GTP	$\frac{GTP}{GPT}$	PT	TP
1.	ω_π= 1.5	y_t	29.39	4.02	25.37	6.31	-0.42	0.67	1.61	-1.68	17.04
	ω_n= 0	n_t					-0.60	0.06	0.11	-2.42	1.64
		h_t					0.28	-0.03	0.11	1.14	-0.78
		π_t					0.04	-0.00	0.12	0.15	-0.11
2.	ω_π= 5	y_t	26.23	4.01	22.39	5.58	-0.59	0.69	1.18	-2.36	15.52
	ω_n= 0	n_t					-0.71	0.10	0.13	-2.86	2.13
		h_t					0.34	-0.05	0.13	1.38	-1.02
		π_t					0.02	-0.00	0.08	0.09	-0.04
3.	ω_π= 1.5	y_t	44.06	4.39	39.67	9.03	-0.36	0.60	1.67	-1.59	23.97
	ω_n= 0.25	n_t					-0.52	0.03	0.05	-2.28	1.06
		h_t					0.14	-0.01	0.07	0.60	-0.40
		π_t					0.01	-0.01	0.82	0.03	-0.21
4.	ω_π= 1.5	y_t	46.11	3.62	42.50	11.75	-0.35	0.58	1.68	-1.27	24.52
	ω_n= 0.5	n_t					-0.45	0.02	0.04	-1.64	0.84
		h_t					-0.09	0.02	0.24	-0.33	0.93
		π_t					-0.19	0.03	0.16	-0.68	1.29

Table 6: Different monetary policy regimes and the Business cycle in an economy with downward rigid wages and a European style rigid labour market.

The exact specification of monetary policy has a strong influence on the length and amplitude of business cycle. We consider regime 1 as our benchmark in which monetary reacts exclusively

[16] This is the reason why the results of this section under the first regime are slightly different from the results of the previous section.

and mildly to inflation. The business cycle exhibits an average length of more than seven years. A central bank that responds more strongly to inflation as in regime 2, reduces the business cycle length by shortening the expansionary phase. At the same time recessions become deeper, both in per quarter growth rates as well as in terms of the cumulative loss in output. The explanation lies in the trade–off between inflation and employment stabilization following a productivity shock in the presence of wage rigidities (Blanchard and Galì, 2007). By focusing exclusively on inflation in a very determined way, the central bank stabilizes inflation only at the cost of higher employment volatility. When, on top of that, wages are more rigid downwards than upwards, this trade-off is felt more intensely exactly when it hurts more, that is during a recession. Indeed, under our calibration the cumulative loss during a recession increases by more than 50%.

The business cycle becomes much longer and smoother when the central banks responds mildly to employment fluctuations (Regime 3, $\omega_\pi = 1.5$, $\omega_n = 0.25$). The average duration of the cycle extends to 11 years, due to an increase of the expansionary phase by more than three years (14 quarters), while recessions continue to last 4 quarters. The cumulative growth from trough to peak extends from 17 to 24%.

When the monetary authority responds strongly to employment changes (Regime 4), recessions get shorter and smoother and expansions longer. This comes, however, at the cost of much higher inflation variability. To see this, turn to Table 7, which shows the distribution of the growth rates of the key variables of the model under the different regimes. If the central bank focuses exclusively on stabilizing inflation, output and unemployment volatility are high and the asymmetry in the wage adjustment is absorbed through the asymmetric behavior of labor market variables like unemployment and hours[17]. The response of inflation and interest rate is quite symmetric under these regimes. The central bank can reduce output and unemployment volatility, and spread the burden of the adjustment between prices and quantities by reacting mildly to employment changes. Under Regimes 3 and 4 the volatility of output growth and unemployment is significantly reduced, but this come at the cost of higher inflation and interest rate volatility. Inflation and interest rates become positively skewed, while the skewness of unemployment, wages, output and hours is reduced. Finally, comparing regime 3 and 4 one can notice that putting too much weight on employment stabilization may increase both output and inflation volatility. All these results certainly call for further investigation.

8 Conclusions

Labor markets are at the core of adjustments over the business cycle. In addition they intrinsically bear an element of asymmetry through lengthy hiring processes and potentially short and abrupt firing events. In addition, empirical evidence suggests that downward real wage rigidity is present in numerous European countries. This paper investigates to what degree downward rigidity affects the observed asymmetry of the business cycle. Our findings may be divided into three groups: the difference between the European and the US business cycle, the implications of

[17] All the variables in the Table are computed as log deviations from previous period's value except for vacancies and unemployment, which are computed as $\Delta u_t = u_t - u_{t-1}$ and $\Delta v_t = v_t - v_{t-1}$

Regime			Mean	Median	StDev	Skewness	Kurtosis
1.	$\omega_\pi = 1.5, \omega_n = 0$	Δy_t	0.50	0.54	0.92	-0.24	3.10
		Δp_t	-0.01	-0.01	0.28	0.15	3.07
		Δi_t	-0.00	-0.00	0.05	0.08	3.03
		Δu_t	0.00	-0.06	0.55	0.70	4.16
		Δh_t	0.00	-0.02	0.35	0.49	4.09
		Δw_t	0.50	0.39	0.50	1.22	5.96
2.	$\omega_\pi = 5, \omega_n = 0$	Δy_t	0.50	0.59	1.00	-0.47	3.45
		Δp_t	0.00	-0.00	0.09	0.02	3.38
		Δi_t	0.00	0.00	0.07	0.02	3.23
		Δu_t	0.00	-0.10	0.61	0.97	5.12
		Δh_t	0.00	-0.03	0.34	0.82	5.09
		Δw_t	0.50	0.39	0.53	1.09	5.26
3.	$\omega_\pi = 1.5, \omega_n = 0.25$	Δy_t	0.50	0.49	0.59	-0.03	3.23
		Δp_t	0.60	0.47	0.95	0.79	3.83
		Δi_t	-0.00	-0.01	0.14	0.31	3.74
		Δu_t	-0.00	-0.02	0.36	0.46	3.96
		Δh_t	0.00	-0.01	0.44	0.16	4.43
		Δw_t	0.50	0.45	0.36	0.75	4.58
4.	$\omega_\pi = 1.5, \omega_n = 0.5$	Δy_t	0.50	0.52	0.68	-0.43	4.94
		Δp_t	1.83	1.44	1.91	1.14	4.65
		Δi_t	0.00	-0.03	0.30	0.49	5.13
		Δu_t	0.00	-0.04	0.43	0.61	5.01
		Δh_t	0.00	-0.01	0.59	0.24	6.11
		Δw_t	0.50	0.45	0.37	0.67	4.42

Table 7: Asymmetries and Monetary Policy

downward wage rigidity on other variables, and the effects of different monetary policy regimes on the length and the asymmetry of business cycles.

The US business cycle is shorter and steeper than the European one. From our analysis this can be mainly explained by the flexibility in the adjustment of employment in the US and less by potential differences in the degree of real wage rigidity. In fact, real wage rigidity shifts the burden of adjustment form prices to quantities and shortens thereby the length of the business cycle. Downward wage rigidity does not affect the overall length of business cycles but deepens recessions due to reduced amount of employment.

Introducing downward wage rigidity into matching models generates next to an asymmetric response of wages also asymmetric effects on unemployment and vacancies similar in its extent as observed in the data. As wages are downwardly rigid, recessions are times when firms are especially reluctant in hiring new employees as these are relatively expensive. Hence, labour market quantities adjust by large amounts, while prices adjust sluggishly. Instead, expansionary periods are characterized by fast growing wages and prices reducing the adjustment through the quantitative margin. The main implication for the business cycle is that recessions become more pronounced and foregone output increases.

Through the separation of quantities and prices, different monetary regimes affect expansionary and contractionary periods differently. Inflation targeting, i.e. the focus on prices instead of quantities, affects especially the expansionary part of the business cycle. Stronger inflation targeting thereby shortens the overall length of a business cycle by reducing the expansionary phase, leaving the contractionary phase unaltered. If monetary policy takes output gap into consideration, in our case differences of employment to its steady state value, it affects the contractionary phase. A normative implication is that prices are indicators a central bank should take into account during expansionary phases, while changes in quantity are more important during recessions.

This analysis has focused mainly on output and labour market variables when comparing the effects of institutional features for the business cycle. In order to proceed when ranking positive or detrimental effects the effects on welfare need to be assessed. This is a natural extension to the current assessment. In addition, to be more realistic and to assess possible spillover from the labour market on the real side of the economy a version with capital is necessary. We expect this to generate more asymmetric responses in investment activity and in the propagation of wage asymmetries.

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