Macroeconomic implications of Downward Wage Rigidities*

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Abstract

Growth of unemployment, employment, vacancies and wages exhibit strong asymmetries between expansionary and contractionary phases of the business cycle. This is also very apparent during the crisis of 2008-2009 for the US and European countries. In this paper we analyse to what degree downward wage rigidities in the bargaining process affect other variables of the labour market, output, inflation and monetary policy. For this we introduce downward wage rigidities in a monetary DSGE model with search and matching frictions in the labor market. We find that the presence of downward wage rigidities triggers substantial asymmetries for all labour market variables and is also transmitted to investment, output and inflation. During booms wages increase easily limiting in this way vacancy posting and employment creation. Labour costs grow due to the rise in wages and this transmits to price setting and inflation. During contractions nominal wages decrease slowly, shifting the burden of adjustment to employment and hours worked, whereas the reaction of inflation is smaller. The introduced asymmetry also helps to explain the asymmetric business cycle of many OECD countries where long and smooth expansions with low growth rates are followed by sharp but short recessions with large negative rates.

JEL classification: E31; E52; C61.

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

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1 Introduction

Wage and employment adjustments in the US and in Europe exhibited strong asymmetries before and during the current economic crisis. Nominal wages have grown hand in hand with inflation before the crisis, but decoupled from inflation dynamics starting in 2008Q3. This phenomenon is not restrained to this crisis. Indeed, ample evidence from the Wage Dynamics Network suggests that nominal and/or real wages in the European Union are downwardly rigid. This paper argues that wage setting is not only at the core of labour market adjustments, but, in addition, shapes the dynamics and asymmetries of other variables over the business cycles.

Our empirical analysis for five industrialized countries reveals that the response of labor market variables to positive and negative shocks, in particular of unemployment and vacancies, is very asymmetric. Unemployment increases sharply during a recession and reduces slowly during an expansionary period, while vacancies fall strongly during recessions. This asymmetry in the response of labor market variables is transmitted to other business cycles variables and lead at the level of aggregate output to short and deep recessions followed by long and smooth expansions. The analysis of business cycle patterns, initiated by Burns and Mitchell (1946), has focused mainly on the asymmetry of GDP, with inconclusive results as summarized by Harding and Pagan (2002). As we will show, however, other variables exhibit strong asymmetries in their cyclical adjustment, including wages, unemployment, vacancies and investment, and only aggregate output is characterized by a weaker degree of asymmetry. A special focus is on the differing adjustment of hours and employment over the cycle.

In the matching literature pioneered by Diamond, Mortensen and Pissarides (1982) the adjustment of wages for new and existing employment relationships has been at the center of analyses for understanding labor market dynamics. Shimer (2005) and Hall (2005) call for wage rigidity as an important factor in explaining vacancy and unemployment volatility. Blanchard and Galì (2008) and Christoffel and al. (2008) identify wage rigidity as an important transmission mechanism from labor markets to inflation. We exploit both channels together to understand how observed asymmetries in the labour market affect the economy at large.

Recent empirical research on wage dynamics has highlighted the presence of nominal and/or real downward wage rigidities in a large number of countries. In the context of the International Wage Flexibility Project, Dickens et al. (2007) document asymmetries in wage setting in a number of countries using micro-economic data on wage changes. Within the context of the Eurosystem Wage Dynamics Network, Du Caju et al. (2008) confirm and update some of these findings, quantifying the extent of downward wage rigidity across a number of European countries. By using more aggregate wage data Holden and Wulfsberg (2008a, 2008b) confirm the existence of both nominal and real downward wage rigidities at the industry level for many of overall 19 OECD countries over the period 1973–1999. Real wage rigidity can be understood as the combination of indexation, either formalized or informal, and nominal downward wage rigidity with respect to that level of indexation. In some countries within the EMU indexation of wages to consumer prices is institutionalized. Indexation in itself fosters wage rigidity, but in many cases the application is often different during times of rising and declining inflation, especially if inflation is low or negative. Barnichon (2009) draws the attention on the asymmetries in job flows, i.e. job-destruction and job creation, and finds a strong importance for job destruction at business cycle turning points, beyond those documented in Shimer (2007) and Elsby et al. (2009).

In this paper we analyze, in a simple but rigorous New Keynesian framework with a Mortensen-Pissarides matching framework for the labour market, the macroeconomic implications of downward wage rigidities for labor market dynamics, inflation, output and monetary policy. Specifically we address the questions to what degree the asymmetry of nominal and/or real wages translates into asymmetries of other variables. Which variables counteract the wage asymmetry and what degree of asymmetry is visible at the level of GDP and inflation?

Kim and Ruge-Murcia (2009) indicate strong asymmetries 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. Fahr and Smets (2008) extend this to real downward wage rigidity in a setup of a monetary union, with particularly detrimental effects for competitiveness in a country with downwardly rigid real wages. Their paper builds on a model with monopolistic wage setters à la Erceg, Henderson and Levin (2000). Benigno and Ricci (2008) model the greasing effects in an extreme manner whereby wages can never be cut and highlight the effects on the slope of the long–run Philips curve.

In this paper, frictional labour markets are introduced to better capture and document differing effects on hours and employment, and to study the interaction of labor market institutions with downward wage rigidities. Wages face asymmetric pecuniary adjustment costs, borne by the firm, but wages are bargained over the joint match surplus firms and employees generate. These adjustment costs are low for either nominal or real wage increases, whereas wage cuts of the same magnitude induce higher adjustment costs[1]. This modelling device captures in intuitive and simple terms the downward wage rigidity documented by many empirical papers. We also compare to what degree symmetric adjustment costs capture asymmetries and show that the asymmetries are generally small and tend towards the wrong direction for some variables.

The contribution of this paper is threefold. First, we introduce asymmetry in the adjustment of 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, output, inflation and monetary policy. We find that the presence of downward wage rigidities introduces an important asymmetry in the business cycle: during booms[2], 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

[1] Specifically, the asymmetry is inserted through a linex adjustment cost function dependent on either nominal or real wage increases.

[2] 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.

short recessions. We find that downward wage rigidities indeed correctly explain the directions of the asymmetries over the business in qualitative terms, though the quantitative results probably require further alternative sources of asymmetries over the business cycle.

Finally, we find that symmetric monetary shocks in the context of a Taylor rule have asymmetric effects on labour markets, output and also inflation. Expansionary shocks with reductions in interest rates lead to growth in nominal wages and prices, but has only limited effects on real variables. Instead, contractionary shocks affect more strongly the real side of the economy. This asymmetry is due to the fact that nominal wages are reduced slowly, but inflation reacts faster downward, raising thereby real wages and having detrimental effects on vacancy posting, employment and output.

In the rest of this paper we first present evidence on the importance of asymmetries in labor market dynamics in Section 2. Section 3 outlines a monetary model with frictional labor markets and downward wage rigidity. Section 4 discusses the baseline calibration and the main results are described in Section 5, after which we conclude in Section 6.

2 The extent of labor market asymmetries

2.1 The crisis 2008-2009

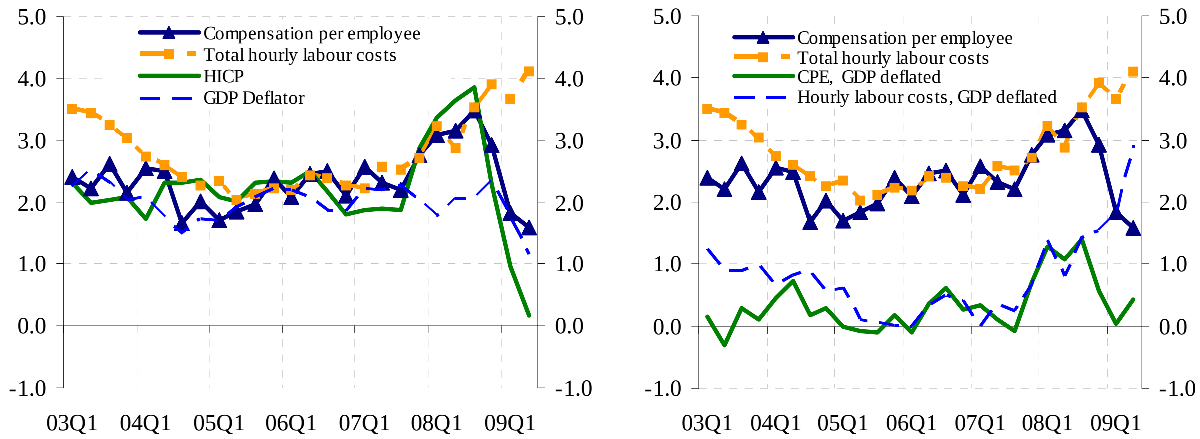

Table 1: Source: Eurostat. The evolution of labour cost indicators in the euro area. Annual growth of Compensation Per Employee (CPE) and Hourly Labour Costs in nominal and GDP deflated terms.

The economic crisis of 2008-2009 highlights the very heterogeneous response of national labour markets in Europe and the US. Some countries, such as Ireland, Spain and the US, have responded on the extensive margin with very unusual labor shedding; others, such as Germany and Italy, have responded more on the intensive margin adjusting hours per employee. At the same time the response of hourly wages is very diverse across these countries with strong increases in Germany, Austria and Belgium. In addition to these cross-country differences of adjustment, an asymmetry is observed before and after the incept of the crisis in 2008Q3. Up to the end of 2008 wages, measured as compensation per employee, have been increasing in line with inflation rates, but have seen only small adjustments thereafter of one to two percentage points at the euro area level (see Figure 1). Part of this decline is due to the adjustment of hours worked per employee. Instead, the growth rate of the GDP deflator and also HICP, declined steeply. What is more, nominal hourly labour costs have actually increased further, which implies together with decelerating prices, accelerating real hourly wage developments.

The response of employment and hours completes the picture of asymmetries in the opposite direction. Employment has been building up steadily since its trough in 2003, and hours worked have moved closely linked to overall employment. In 2008 an abrupt change reduces employment and especially hours with exceptional speed as depicted in Figure 2.

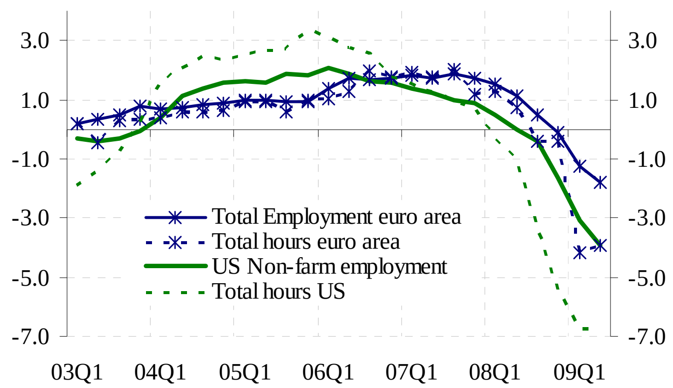

Table 2: Source: Eurostat and Bureau of Labour Statistics and author's calculations for euro area hours worked. The evolution of employment and hours in annual growth rates (in percent).

This asymmetry of the labour market, whereby wages tend to rise faster in upswings than they fall in downturns, while employment and hours rise slowly, but fall quickly, is not restricted to the most recent episode. Instead, it is a common feature over a long sample as we will document below. The potential sources for these differences lie in the labor market institutions, identified by employment protection legislations, the design of unemployment insurance scheme, the level of wage negotiations, and active labour market policies. We explore here the wage adjustment channel, taking downward nominal wage rigidity as the main source for this asymmetry.

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

The adjustment of labor market variables over the business cycle is very different during expansionary and contractionary phases of the labour market. This is particularly true for unemployment and vacancies. Unemployment increases sharply during a recession and is only slowly reduced during an expansionary period, for vacancies recessions lead to a strong drop. To shed some light on this issue, Figure 3 shows visually the distribution of quarterly vacancies and unemployment changes for France and the US.

[3]

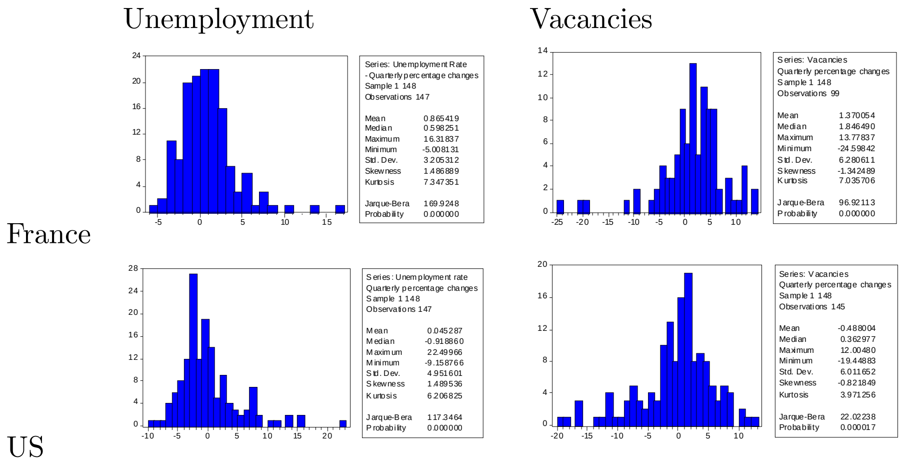

Table 3: Skewness in quarterly growth rates of unemployment and vacancies

The empirical distributions of vacancy and unemployment growth rates rates are both clearly skewed, but in opposite directions. Vacancy growth rates are strongly negatively skewed, while the distribution of unemployment changes is strongly positively skewed. Vacancy postings tend to increase in small steps but drops occasionaly by large amounts. The opposite is true for unemployment changes with rare large scale increases, and frequent small declines. The mean of the distributions captures implicitly trend components due to demographic changes. The opposite skewness of the two distributions highlights the strong link between unemployment and vacancies through the Beveridge curve.

Conducting this analysis for other countries confirms this empirical regularity. We expand the list of variables to analyze in Table 4 to establish a common set of findings regarding the skewness of the business cycles for five countries: France, Germany, UK, US and the euro area[4]. All data is quarterly and covers the period from 1970:Q1 to 2006:Q4[5]. Other moments are reported in the appendix.

A couple of observations are worth highlighting. First, vacancy growth rates are negatively skewed in all considered countries. Second, the growth rate of the unemployment rate is strongly positively skewed for all countries. Third, nominal and real wages are positively skewed, to the exception of nominal wage growth in Germany which is strongly affected by the reunification. The presence of differing degrees of skewness in wage growth indicates heterogeneity in the degree of downward wage rigidities across these countries, as it has been found in studies using micro-data. Fourth, investment and share prices are negatively skewed. Finally, the skewness of

[3] A similar picture is obtained using German or UK data and for the euro area unemployment series. Unfortunately we do not have vacancy data for the euro area as a whole, we therefore choose France as representative of European labor markets.

[4] 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 outliers in the series of real wages and output for Germany.

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

Skewness	EA	USA	UK	DE	FR
Δw_t^N	0.50	0.26	1.52	0.00	0.64
Δp_t	0.45	1.02	1.54	0.75	0.55
Δw_t^R	0.99	0.51	0.41	0.78	0.22
Δinv_t	-0.58	-0.53	-0.11	1.29	-0.47
$\Delta shares_t$	na	-0.69	-1.08	-0.43	-0.30
Δv_t	**na**	**-0.35**	**-0.85**	**-0.79**	**-1.71**
Δu_t	**1.40**	**1.12**	**0.79**	**1.08**	**1.22**
Δh_t	na	0.01	0.27	0.83	-0.15
Δy_t	-0.22	-0.53	-0.71	0.07	0.02

Table 4: Skewness in annual growth rates of selected macro variables

output and hours is ambiguous and generally smaller than that of unemployment or vacancies. Overall, these statistics seem to point to the presence of important asymmetries over the business cycle. These asymmetries may point to key structural features that shape the behaviour of industrialized economies.

In this paper we argue that the presence of downwardly rigid wages is one important 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 firm profits. 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 other variables (hours and investment) absorb part of the asymmetry in the behavior of wages and dilute part of the negative effect of downward wage rigidity on employment and output.

2.3 Turning Point Analysis

An alternative possibility to analyze business cycles is to identify 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[6]. The procedure is based on a univariate analysis and focuses on duration, amplitude and cumulative changes over a cycle, and documents asymmetries between expansionary and contractionary phases of the cycle. This allows to answer not only questions about the volatility of business cycle, but also questions on the length and depth of recessions.

[6] 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.

With this analysis we identify the dates of a series' turning point, and once identified we compute the following statistics:

- The "Average Duration Peak to Peak" (PP) or "Average Duration Trough to Trough" (TT) represents the average length of a business cycle.
- The "Average Duration Peak to Trough" (PT) captures the average length of time spent in a recession or "Average Duration Trough to Peak" (TP), which is the length of expansions. 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 during recessions or during expansions. The ratio indicates the asymmetry in growth rates between recessions and expansions.

Table 5 presents the results when applying the dating algorithm to GDP.

Output	Duration (quarters)			Growth Rates (annualized)		Growth Rates dev. from mean	
	Cycle	Exp.	Rec.	Exp.	Rec.	Exp.	Rec.
EA	36.00	34.00	2.00	2.80	-2.88	0.36	-5.32
US	22.33	19.33	2.75	3.96	-3.56	0.92	-6.48
France	73.00	70.00	3.00	2.44	-2.52	0.08	-4.88
Germany	28.00	25.00	3.00	3.68	-2.00	1.28	-4.32
UK	34.00	29.00	5.00	2.88	-3.60	0.92	-5.96

Table 5: Turning point analysis for trough to peak (expansion) and peak to trough (contraction) for output. Analysis obtained with Harding-Pagan algorithm

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 annualized growth rate during expansions is 2.80% in the Euro Area and 3.96% in the US, while during recessions quarterly GDP declines by 2.88% in the EA and 3.56% per in the US. The relative "intensity" of expansions and recessions is above one in the US but below one in the EA. We define US cycles as more violent than European ones due to the stronger contractions during recessions.

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 labour market are likely to affect the shape, duration and intensity of business cycles.

Finally, notice that, as pointed out by Harding and Pagan (2002), asymmetries in the GDP cycle do not necessarily imply a need for an asymmetric model: as we will show later, a linear model with linear trend is quite successful in generating data with long expansions and short recessions, but the asymmetry in the remaining labour market variables cannot be captured by linear or symmetric models.

Table 6 presents the results when applying the dating algorithm to employment. Following McKay and Reis (2008), we eliminate the trend in employment - which would complicate cross-country comparisons and the comparison with the model - by detrending the data with the HP(1600) filter.[7]

Employment	Duration (quarters)			Growth Rates (annualized)		Growth Rates dev. from mean	
	Cycle	Exp.	Rec.	Exp.	Rec.	Exp.	Rec.
EA	19.67	12.50	8.00	0.12	-0.84	0.28	-0.68
US	18.43	10.43	8.00	0.72	-1.32	0.72	-1.32
France	15.00	9.00	6.22	0.32	-1.12	0.48	-0.96
Germany	22.00	12.40	10.67	0.40	-1.04	0.60	-0.84
UK	15.63	8.22	7.25	0.48	-1.32	0.52	-1.28

Table 6: Turning point analysis for trough to peak (expansion) and peak to trough (contraction) for employment. Analysis obtained with Harding-Pagan algorithm

Despite considerable cross-country differences, we conclude that the employment cycle is characterised by important asymmetries: expansions are longer than recessions, but recessions are much more violent, which confirms the finding by McKay and Reis (2008) for the US. The fact that employment exhibits an asymmetry in addition to the one found by GDP indicates that the labor market may be a source of the asymmetries found in the series for other variables. We focus here exclusively on the asymmetry induced by downward wage rigidity, but others may exist, such as the differing speed of hiring and training or job destruction.

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 à la Mortensen-Pissarides and asymmetric wage adjustments. The aim is to develop a parsimonious version revealing the mechanism through which downwardly rigid wages affect the different variables over the business cycle.

[7] McKay and Reis (2008) detrended the data with the Rotemberg's adjusted HP filter. We tried both filtering methods. Results are very similar.

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. The probability for a firm to fill an open vacancy is q_t and the probability to find a job is s_t:

$$\begin{aligned} q_t &= \frac{m_t}{v_t} = \bar{m}\theta_t^{-\vartheta} \\ s_t &= \frac{m_t}{u_t} = \theta_t q(\theta_t) \end{aligned}$$

where $\theta_t = \frac{v_t}{u_t}$ denotes labor market tightness. Employment evolves according to a law of motion including job matches and exogenous job destructions. A fraction ρ of employment relationships is destroyed in every period t and a number m_t becomes immediately operative:

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

Unemployment is the fraction of searching workers that remain unemployed after hiring takes place:

$$ur_t = 1 - n_t$$

3.2 Households

Each household is thought of as a large extended family with a continuum of members on the unit interval. Consumption is pooled inside the family and family members perfectly insure each other against employment fluctuations. The representative household maximizes a time–separable lifetime utility, including consumption and disutility of work, compatible with trend growth.

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

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

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

where C_t is a 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 includes the wage income earned by all employed family members working h_t hours, $w_t^R n_t h_t$. In addition, the household earns unemployment benefits $b_t = bA_t$, growing with the rate of productivity growth, interest payments on capital and the claims on non-contingent bond holdings. Finally, it receives the family share of aggregate profits from retailers and matched firms (D_t), net of lump-sum taxes (T_t). Investment i_t net of investment adjustment costs increases the level of capital, whereas it depreciates with rate δ

$$K_t = (1-\delta) K_{t-1} + i_t - T(i_t, K_t).$$

The first-order conditions deliver

$$\begin{aligned} C_t^{-1} &= \beta R_t \mathbb{E}_t \left[\frac{C_{t+1}^{-1}}{\Pi_{t+1}} \right] \\ \left[1 + T'_{I_t}\right] &= Q_t \\ Q_t &= \beta \frac{\lambda_{t+1}}{\lambda_t} \left[r_{t+1}^k - T'_{K_t} + (1-\delta) Q_{t+1} \right] \end{aligned}$$

representing the Euler equation and Tobin's Q for investment decisions. We assume a quadratic adjustment cost function

$$T(i_t, K_t) = \frac{\Theta}{2} \left(\frac{I_t}{K_{t-1}} - \delta' \right)^2 K_{t-1}$$

where $\delta' = g - 1 + \delta = \frac{I}{K}$ in steady state.

3.3 Firms

There are two sectors of production in the economy. Firms in the wholesale sector produce the intermediate homogeneous good in competitive markets using labor and capital. In this sector of intermediate goods search frictions together with convex wage adjustment costs exist. Monopolistic retailing firms transform the intermediate goods into differentiated final goods at no cost. Price rigidities arise in the retail sector.

3.3.1 Final good firms

A measure one of monopolistic retailers indexed by z produce differentiated goods, which are aggregated in a Dixit-Stiglitz manner with elasticity ϵ to the final composite good:

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

The demand for each retailer for its product is

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

where P_t is the aggregate price index

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

Retailers transform one unit of intermediate goods into one unit of differentiated wholesale goods with production function $Y_t^F(z) = Y_t(z)$. For this they 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 at price $P_t(z)$. The representative firm chooses prices to solve the following maximization problem:

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

subject to the demand function $Y_t(z)$. $\beta_t = \beta^t \frac{\lambda_t}{\lambda_0}$ is the stochastic discount factor. The price adjustment cost function is $\Gamma_t = \frac{\chi^p}{2}\left(\frac{P_t(z)}{P_{t-1}(z)} - \Pi^*\right)^2$, with Π^* being trend inflation (here normalized to 1).

The first order condition with respect to the firm's price $P_t(z)$ earns a version of the Philips curve:

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

where $\Pi_t = \frac{P_t}{P_{t-1}}$ as all retailers operate identical technology and set the same price in equilibrium. The two-tier production setup implies that the price setting of retail firms is independent of labor hiring by wholesale firms, but instead depends exclusively on the cost of intermediate goods φ_t and price adjustment costs.

This final good may be used for consumption, investment, price or wage adjustment or vacancy posting costs. The aggregate resource constraint is thus given by:

$$C_t + i_t = Y_t(1 - \Gamma_t) - c^w_t w_t h_t n_t - \kappa_t v_t$$

3.3.2 Wholesale firms and the labor market

Firms in the intermediate goods sector use employment and capital as inputs in a constant returns to scale production function[8]:

$$Y_t = Z_t(A_t n_t h_t)^{\alpha}(k_{t-1})^{1-\alpha}.$$

Firms post vacancies at cost $\kappa_t = \kappa A_t$ to be matched with searching workers following the laws of motion in Section 3.1. These costs are consistent with a balanced growth path. The intermediate good is sold to retailers at the relative price φ_t.

Wholesale firms face convex costs for adjusting wages, similar to the price adjustment costs in the retail sector, except for being asymmetric:

$$c^w_t\left(W^N_t\right) = \frac{\chi^w}{\psi^2}\left\{\exp\left[-\psi\left(\frac{W^N_t}{W^N_{t-1}}\Pi^{-\nu}_t - g\right)\right] + \psi g\left(\frac{W^N_t}{W^N_{t-1}}\Pi^{-\nu}_t - g\right) - 1\right\} \quad (2)$$

The asymmetry in the linex adjustment cost function is determined by ψ. With $\psi \to 0$, the cost function is identical to a quadratic adjustment cost specification

$$\lim_{\psi\to 0} c^w_t\left(W^N_t\right) = \frac{\chi^w}{2}g^2\left(\frac{W^N_t}{W^N_{t-1}}\Pi^{-\nu}_t - g\right)^2$$

[8] In equilibrium all firms are identical. We therefore simplify notation and avoid firm specific subscripts.

In addition, ν determines the degree of wage indexation to actual inflation. With $\nu = 0$ adjustment costs are with respect to nominal wages, whereas $\nu = 1$ indicates full indexation and represents real wage rigidity. Figure 1 presents a visual representation of the adjustment cost functions, including the symmetric and asymmetric case around zero inflation, and the asymmetric case around the value of 2%.

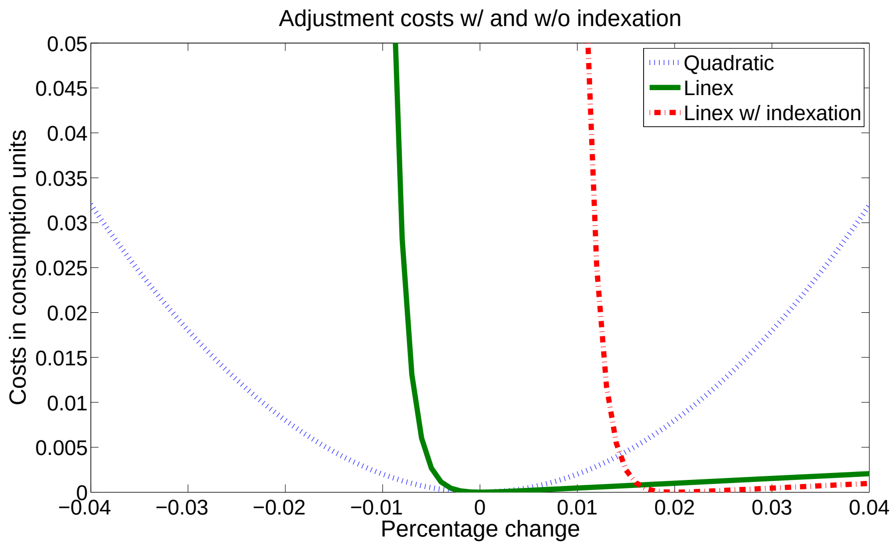

Figure 1: Different specifications of adjustment cost curves. The dotted line represents a symmetric adjustment cost function as used for prices, the continuous line depicts an asymmetric cost function as used for nominal asymmetric wage adjustments and the dashed-dotted line is an asymmetric adjustment cost function as used for asymmetric real wage adjustment costs with an example of underlying indexation around 2% inflation. The steady state level of inflation is determined endogenously.

The representative firm chooses vacancies and capital to maximize the expected sum of discounted profits:

$$\max_{v_t,k_t} \mathbb{E}_t \sum_{j=0}^{\infty} \beta_{t+j} \Big[\varphi_{t+j} Z_{t+j} \left(A_{t+j} n_{t+j} h_{t+j} \right)^{\alpha} k_{t+j-1}^{1-\alpha} \\ - r_{t+j} K_{t+j-1} - w_{t+j}^{R} h_{t+j} n_{t+j} \left(1 + c_{t+j}^{w} \right) - \kappa_{t+j} v_{t+j} \Big]$$

subject to the law of motion for labor (1) and wage adjustment costs (2). Wages and hours are determined in a bargaining between the worker and the firm (described below)

The first order condition earns the demand for capital, whereby the marginal product of capital equates the interest rate

$$\left(1 - \alpha\right) \varphi_t \frac{Y_t}{K_{t-1}} = r_t^k,$$

and the free-entry condition for vacancies:

$$\frac{\kappa_t}{q_t} = \alpha \varphi_t \frac{Y_t}{n_t} - w_t^R h_t \left(1 + c_t^w\right) + \left(1 - \rho\right) \mathbb{E}_t \left[\beta_{t+1} J_{t+1}\right],$$

whereby expected vacancy posting costs equate the expected value from a filled vacancy. This consists of the revenues from output net of wage costs and wage adjustment costs and in addition the expected continuation value of the job next period.

3.4 Wage determination

Wages are determined through a bargaining scheme between workers and employers. Following Hall and Milgrom (2008), Lechthaler, Merkl and Snower (2008), and Carllson and Westermark (2008) the threat point for workers and employers is their respective value during a halt in production, be it through strike or look-out. The bargaining scheme represents a situation whereby the breakdown in negotiation does not lead to a separation in the job relationship, but instead only to a postponement in production, without affecting the job status next period. In the next period negotiations take place again and production may or may not resume. This setup alters the surplus over which employers and workers bargain compared to the original Mortensen-Pissarides setup.

We distinguish two employer's and two employee's values, in the case production takes place or not (with tilde). The surplus of the firm when producing and not producing are

$$\begin{aligned} J_t &= \alpha\varphi_t\frac{Y_t}{n_t} - w_t^R h_t\left(1+c_t^w\right) + (1-\rho)\,\mathbb{E}_t\left[\beta_{t+1}J_{t+1}\right] \\ \tilde{J}_t &= 0 + (1-\rho)\,\mathbb{E}_t\left[\beta_{t+1}J_{t+1}\right]. \end{aligned}$$

The difference is

$$J_t - \tilde{J}_t = \alpha\varphi_t\frac{Y_t}{n_t} - w_t^R h_t\left(1+c_t^w\right),$$

which is effectively the surplus the employment generates in the current period. Similarly, for the worker the surplus while working and not working is

$$\begin{aligned} E_t &= w_t^R h_t - \frac{\chi}{\lambda_t}\frac{h_t^{1+\phi}}{1+\phi} + \mathbb{E}_t\beta_{t+1}\left[(1-\rho)\,E_{t+1} + \rho b_{t+1}\right] \\ \tilde{E}_t &= b_t + \mathbb{E}_t\beta_{t+1}\left[(1-\rho)\,W_{t+1} + \rho b_{t+1}\right] \end{aligned}$$

The net value of employment for the household is the income from working h_t hours net of labour disutility and of the unemployment benefits that are earned in periods when the employed is not working:

$$E_t - \tilde{E}_t = w_t^R h_t - \frac{\chi}{\lambda_t}\frac{h_t^{1+\phi}}{1+\phi} - b_t.$$

The firm and the employee bargain jointly over hours worked and nominal wages, taking as given the price level, which is determined by retail firms.

$$\arg\max_{\left\{W_t^N, h_t\right\}}\left[\left(J_t - \tilde{J}_t\right)^{1-\eta}\left(E_t - \tilde{E}_t\right)^{\eta}\right],$$

where η is the bargaining power of workers. The first order conditions of the maximization lead to FOCs for hours and wages

$$
\begin{aligned}
\left[1+c_t^w+\frac{\partial c_t^w}{\partial W_t^N}W_t^N\right]\frac{\chi}{\lambda_t}h_t^{\phi} &= \alpha^2\varphi_t\frac{y_t}{n_t h_t}+\left[\left(\frac{\partial c_t^w}{\partial W_t^N}W_t^N\right)w_t^R\right] \\
w_t^R h_t\left[1+c_t^w+(1-\eta)\frac{\partial c_t^w}{\partial W_t^N}W_t^N\right] &= \eta\left(\alpha\varphi_t\frac{y_t}{n_t}\right)+(1-\eta)\left(\frac{\chi}{\lambda_t}\frac{h_t^{1+\phi}}{1+\phi}+b_t\right)\left[1+c_t^w+\frac{\partial c_t^w}{\partial W_t^N}W_t^N\right]
\end{aligned}
$$

where $\Pi_t^W=\frac{W_t}{W_{t-1}}$ is nominal wage inflation, $\Pi_t=\frac{P_t}{P_{t-1}}$ is price inflation and

$$
\frac{\partial c_t^W}{\partial W_t^N}=\frac{\chi^W}{\psi}\frac{1}{\Pi_t^{\nu}W_{t-1}^N}\left\{1-\exp\left[-\psi g\left(\frac{W_t^N}{W_{t-1}^N}\frac{1}{\Pi_t^{\nu}}-g^{\nu_2}\right)\right]\right\}.
$$

In addition the following identity holds:

$$
\frac{w_t^R}{w_{t-1}^R}=\frac{W_t^N}{W_{t-1}^N}\frac{P_{t-1}}{P_t}=\frac{\Pi_t^W}{\Pi_t},
$$

where Π_t^w is wage inflation and Π_t is price inflation. The wage and hour equations highlight the role played by adjustment costs and are the terms in square brackets in the eqaution above. They introduce a wedge into the frictionless arbitrage equations, in which marginal product of labour equates marginal disutility of working, and wages are a linear combination of productivity and the outside value of workers.[9]

3.5 Shocks, Fiscal and Monetary Policy

We distinguish between a permanent (A_t) and a transitory (z_t) productivity shock, which are respectively determined by

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

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. shock to the technological growth rate. 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.

Finally, the monetary authority sets the short term nominal interest rate by reacting to the average inflation and employment levels in the economy. More specifically, the central bank adopts an augmented Taylor type rule for the nominal interest rate

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

[9] The wage can be freely renegotiated in every period, the level of adjustment costs relates today's wage to past wages and generates a smooth adjustment. Yet, due to the fact that the surplus over which is bargained does not contain any forward–looking elements, the current wage is not constraining future wage decisions.

Consistently with empirical evidence we assume that monetary policy displays a certain degree ω_r of interest rate smoothing (see Clarida, Gali and Gertler (1999)). 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.

4 Calibration

Preferences. Time is taken as quarters. The discount factor β is set to 0.992 in order to obtain an interest rate of about 4%. The utility function is assumed to be log in consumption ($\sigma = 1$), a value compatible with a balanced growth path. The parameter governing the Frisch elasticity of labor supply, ϕ, is set to 5, a value in line with the empirical micro estimates[10]. The price mark-up charged by firms is 20% which implies an elasticity of substitution of intermediate goods of $\epsilon = 6$.

Production. The elasticity of output with respect to total hours is set to 2/3 ($\alpha = 0.66$) reflecting a labor share of roughly the same size. The depreciation rate of capital is set to $\delta = 0.03$, while the investment adjustment cost on investment is set to $\Theta = 6$ as in Moyen and Sahuc (2005).

Labor market. In the baseline calibration, 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 0.3. Combining these two values with a constant participation rate normalized to 1, the separation rate per quarter is $\rho = 0.048$. This reflects the relatively rigid labor markets in Europe compared to the US. The job filling rate q is set to 0.9 while the implied efficiency in the matching function is $\sigma_m = 0.52$. The unemployment benefits parameter is set to $b = 0.85$, which represents in steady state a replacement ratio $b/w = 0.68$. We specify the elasticity of job matches with respect to vacancies to $\vartheta = 0.5$, in line with Petrongolo and Pissarides (2007)'s estimation of matching functions. The workers' relative bargaining power η is set to 0.5, a standard value in the literature due to the lack of reliable information on bargaining strengths of employees and employers.

Price and wage rigidities. Under symmetric adjustment, the parameters governing the degree of price and wage rigidities are respectively χ^p and χ^w. Following Fahr and Smets (2008), we set these parameters to $\chi^p = \chi^w = 45$. The parameter ruling asymmetric wage adjustments is ψ. Symmetric wage adjustment is characterized by $\psi = 0$ while, following Fahr and Smets (2008), we set $\psi = 800$ for the asymmetric case. Notice that this value is much lower than the one estimated by Kim and Ruge-Murcia (2009) for the US economy. In the baseline calibration, we set the degree of wage indexation ν to 0, which implies we mainly focus on nominal wage rigidity.

Shocks and monetary policy. Regarding the shock processes, we set the standard deviation of monetary policy shocks to 0.1 percent, consistent with the estimates by Christoffel, Coenen and Warne (2008). The average growth rate is set to $g_a = 1.004$, implying an annual average growth rate of around 1.6%, a value which is in line with the average growth rate of labor

[10] See Trigari (2009) for a brief discussion.

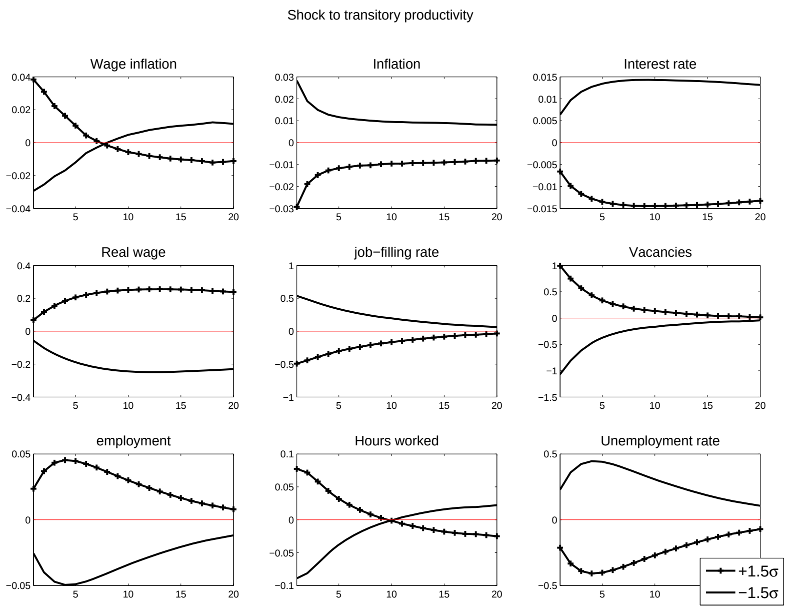

Figure 2: Dynamic response following positive and negative tranistory technology shocks of 1.5 standard deviations.

productivity and GDP per person 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 (2010); 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 $\sigma_a = 0.003$, similar to the values used in Zanetti (2008) and to the ones estimated by Thomas and Zanetti (2009).

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 $\omega_R = 0.85$.

5 Results

5.1 Impulse responses

The issue of downward nominal wage rigidity may be best understood by highlighting the dynamic responses of different macro variables following positive and negative shocks. We analyze three types of shocks: a shock to transitory technology which perturbs the level of productivity around the balanced growth path. A second shock perturbs the growth rate of productivity affecting permanently the level of output and other trending variables. Both these shocks exhibit auto–regressive persistence. Finally, a third shock regards monetary policy and is intended to capture demand effects.

The question is to what degree the asymmetry in the wage setting process between increases and cuts transmits to the adjustment of other variables. Do other variables absorb and counteract the asymmetry from wage adjustments or do they reinforce the asymmetry of the labour market?

Following a positive transitory technology shock, marginal productivity increases, followed by a simultaneous increase in nominal and real wages, whereas prices fall due to the lower marginal costs for firms. The effects of a positive and negative shocks on the other variables is limited as depicted in Figure 2. Wage inflation accelerates more after a positive shock than it decelerates after a negative shock, but this translates very weakly to other variables. Hence, overall transitory technology shocks have only small effects for the asymmetry of other variables. It is to note that labour input, both hours and employment, co-move initially: firms engage in stronger hiring activity through vacancy posting and the intensive margin of hours is used to exploit the initial higher productivity by substituting work intensity from the future to the present.

The transitory shock induces inter–temporal substitution to take place. This substitution is less relevant in the case of a permanent technology shocks. The shock accelerates or decelerates the growth rate of potential output. This implies that, after a positive shock, the state of the economy is below the final balanced growth path of the economy and the dynamic responses are also affected by catching up effects.

Following a permanent increase in productivity nominal wage inflation accelerates immediately to adjust wages to the improving productivity as depicted in Figure 3. At the same time, inflation picks up as well. This is because current marginal costs are above the long-term future levels. Real wages adjust upward because nominal wage inflation is stronger than price inflation. Following a deceleration in productivity growth, instead, the adjustment margins are very different . As wages are downward rigid, the downward adjustment takes place sluggishly. The response of inflation is negative and appears to be symmetric to the positive shock. Price inflation declines by more than wage inflation and consequently real wages initially increase like in the case of a positive productivity growth shock. The adjustment margin following the two shocks is thus different. A positive shock induces more wage adjustments, whereas a negative shock induces price adjustments. This asymmetric adjustment is found in a similar manner during the current downturn, described in the introduction.

The asymmetry of wage adjustments induces asymmetric responses on the remaining labour market variables. The fast increase in real wages following a positive shock reduces firms profits and firms' incentives to hire new workers. The reaction of vacancy openings is thereby strongly muted, the level of employment remains nearly stagnant and hours work increase initially, though only mildly. In the case of a decline in productivity levels, firms' profits drop strongly as real wages are held up, and reduces vacancy creation with highly detrimental effects on employment and unemployment. The adjustment of hours worked after a positive and a negative shock is similar in its pattern with a strong adjustment in the first period together with wage inflation, but the levels are different. After a positive shock no further change is observed, i.e. the remaining adjustment occurs through employment changes. Instead, following a negative shock, hours worked remain subdued persistently for a prolonged period of time.

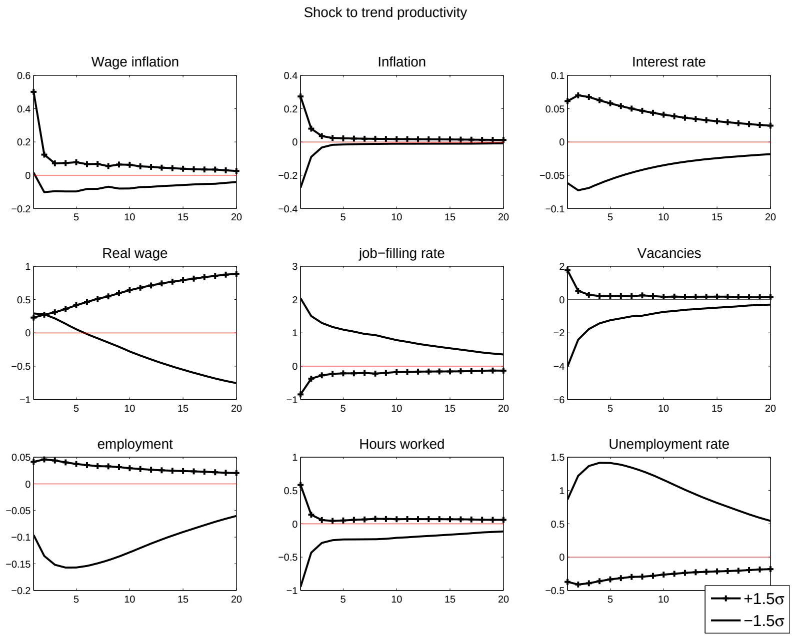

Figure 3: The Figure shows the response to a 1.5 st. dev. permanent productivity shock.

A third exercise involves a monetary policy shock, i.e. the interest rate setting by the monetary policy is tighter or looser than the Taylor rule would imply. A positive shock has expansionary effects because it leads to a monetary policy loosening. This generates strong effects on nominal wage inflation, particularly because hours worked increase and the marginal disutility of working leads to higher wage claims, see Figure 4. Also inflation increases because marginal production costs increase and the firms pass these costs on to the consumers in form of higher prices. With nominal wages increases being stronger than inflation, real wages increase. On the real side the expansionary monetary policy generates initially slightly more employment and increases hours worked.

In the opposite case, with contractionary monetary policy, aggregate demand declines and inflation decreases symmetrically to the expansionary shock. But the response of wages is very much muted and consequently, due to the decline in inflation, real wages actually increase. The inherent asymmetry of real hourly wages following a contractionary monetary policy shock has strong repercussions on vacancies, hours, and employment. Particularly unemployment increases strongly.

Overall, we find that expansionary monetary policy mainly affects nominal variables (inflation, wage inflation), whereas contractionary monetary policy in the presence of downward wage rigidity affects more strongly real variables (real wages, unemployment). It may thereby be that a source of business cycle asymmetries is monetary policy itself.

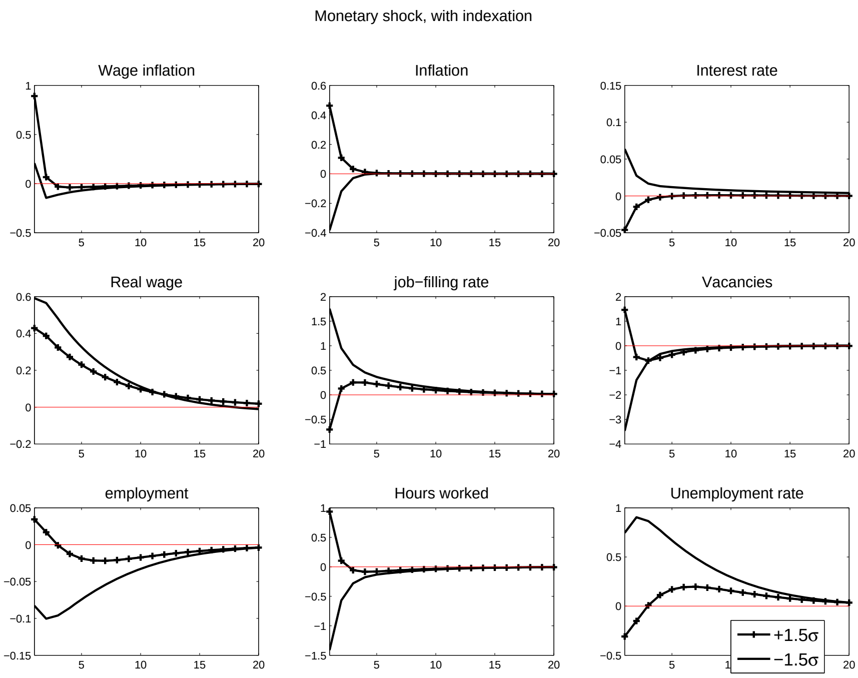

Figure 4: Response to a 1.5 st. dev. monetary policy shock

5.2 Moments and Asymmetry

In the first part of the paper, dealing with the empirical facts, we documented the presence of important asymmetries in the adjustment of labor market and macro variables over the business cycle. Here, we compare the data to a model of symmetric wage adjustment costs and to a model of asymmetric adjustment costs. We simulate the model with and without asymmetries in wage adjustment costs to obtain the simulated statistics comparable to those in the empirical part[11].

	output Δy_t	hours Δh_t	hourly wages ΔW_t^N	wages per employee $\Delta\left(W_t^N h_t\right)$	investm. Δinv_t	unemp. Δu_t	vacanc. Δv_t
EA data	**-0.42**	**n.a.**	**n.a.**	**1.02**	**-0.58**	**1.83**	**n.a.**
Model: symmetric	-0.07	-0.01	-0.22	-0.01	-0.05	-0.11	0.03
Model: With DNWR	**-0.46**	**-0.12**	**1.83**	**1.48**	**-0.26**	**0.95**	**-2.32**

Table 7: Skewness of quarterly growth rates of different variables

The model with symmetric adjustment costs exhibits only little skewness as reported in the second row in Table 7. The reported skewness stems from non–linearities in the production and utility function. The direction of skewness in the case of wages and unemployment are pointing in the opposite direction of the empirical measures.

Introducing asymmetric wage adjustment costs, and thereby accounting for downward rigidity in the wage negotiation process, not only corrects the direction of skewness, but the magnitudes are also overall consistent. The source of the asymmetry lies in the wage bargaining process, which implies that hourly wages exhibit a strong degree of positive skewness, i.e. wages grow strongly, but decline little. The same happens for unemployment. Most surprisingly is the strong effect on vacancy postings. This may be explained by the fact that vacancies express incentives for hiring from a discounted stream of future surplus. This discounting magnifies the response. Finally, the effects on aggregate output are muted, and incidentally match quite well with the empirical measure of skewness.

The effects of asymmetric wage adjustments are not limited to the growth rates of the variables. In fact, with employment as the main input for production, aggregate output has been shown to be strongly affected. Can asymmetries in the wage setting process also affect the length of employment cycles, where expansion are long and smooth and recessions are short and violent? For this Table 8 presents the average length of employment cycles found in the data and generated in the models with symmetric or asymmetric costs. The metric used compares the length from trough to peak, denoted as expansion, and from peak to trough, referred to as recession. The symmetric model is unable to generate any degree of asymmetry in the duration between expansionary and recessionary phases observed in the data. Instead, introducing asymmetric adjustment costs leads to longer cycles driven by longer expansionary

[11] The model was simulated with 100,000 observation. The underlying shocks are calibrated as explained in Section 4.

periods. Overall, though, the asymmetry generated by the model falls short of the empirically observed one.

	Duration (quarters)			Growth Rates dev. from mean	
	Cycle	Exp.	Rec.	Exp.	Rec.
EA Data	**19.67**	**12.50**	**8.00**	**0.28**	**-0.68**
Model: No DWR	15.16	7.58	7.56	0.12	-0.12
Model: DNWR	**16.20**	**8.98**	**7.19**	**0.20**	**-0.36**

Table 8: Turning Point Analysis for Euro Area

Regarding the violence of recessions, measured by the negative growth rates during these periods, asymmetric wages do indeed generate more violent downturns, but again, still short of the empirical observation

5.3 Labour Market Rigidities and the Business Cycle

Further to the analysis above, we apply our framework to reflect two differing labour markets, the American and the European one and to assess the implications of downward wage rigidity on cycle length, asymmetry and violence of recessions. It may be that different labour market institutions interact with the presence of downward wage rigidities to generate adverse effects on business cycle dynamics in terms of output.

For the comparison we focus on particularly two distinctive features: job turnover and wage rigidity. The American labour market was characterized for a long period of time by high turnover and low unemployment rates, whereas many European labour markets have much lower turnover rates, but higher unemployment. We capture this difference by assuming a differing steady state unemployment rate and differing job finding rates between the two regions. European labour markets face a steady state unemployment rate of 9% with a job finding rate of 30% per quarter, whereas the American job market has a steady state unemployment rate of 5% and a job finding probability of 70% per quarter. Regarding wage rigidity, captured by the parameter ψ, American labour markets are characterized by relatively flexible wages with little downward rigidity, whereas European ones are more downwardly rigid.

From these benchmark European and American labour markets we now conduct counterfactuals by introducing real wage rigidity (symmetric) for the American labour market and increasing downward wage rigidity for the European calibration. Overall this gives four cases, for which we document the turning point analyses in Table 9.

The baseline calibrations reflect the fact that US cycles are shorter and more violent in terms of growth rates than European cycles which tend to be longer and smoother. Comparing the results from the model to the data, the cycles appear longer than in the data, this may be due to the fact that the amplification mechanism in the model is too weak or alternatively that the shock sizes are too small compared to the steady state growth rate[12]. The asymmetry in the

[12] Notice however that this is hardly surprising, given that we calibrated the shock processes to the euro area.

	Duration			Growth Rates		
	Cycle	Exp.	Rec.		Exp.	Rec.
US baseline	32.1	28.6	3.7	y_t	2.08	-2.08
				n_t	0.08	-0.84
				h_t	0.32	-2.56
US High RWR	30.3	26.3	3.9	y_t	2.16	-2.12
$v = 1$				n_t	0.12	-0.96
				h_t	0.40	-2.76
EU baseline	41.2	37.7	3.4	y_t	1.92	-1.92
				n_t	0.00	-0.24
				h_t	0.28	-2.66
EU DNWR	32.4	28.2	4.3	y_t	2.16	-3.04
$\psi = 800$				n_t	0.04	-0.72
				h_t	0.48	-4.24
EU data	36.0	34.0	2.0	y_t	2.80	2.88
				n_t	0.30	-0.92
				h_t	n.a.	n.a.

Table 9: Labour Market Rigidities and the Business Cycle: Turning Point Analysis for different model specifications. Measures for lengths are in quarters, and growth rates are annualized

length of expansionary and recessionary phases is well captured for both calibrations.

By raising the degree of real wage rigidity in the US calibration, cycles become shorter and more intense. The shortening is due to the reduction in the length of expansionary periods by 2 quarters. The growth rates for expansionary and contractionary phases are increased slightly for all three variables, output, employment, and hours worked. From this we infer that higher wage rigidity in Europe per se does not represent the source of the differing business cycle characteristics between the US and the euro area.

Turning to the European calibration with a more sclerotic labour market in terms of lower turnover and higher unemployment the cycles are longer and less volatile in terms of growth rates. The driving force behind this difference is found in the strongly muted adjustment of employment during recessions. At the same time the adjustment of hours worked becomes slightly more important. Overall the lower turnover rates mute the cycle slightly. It becomes also clear that the sclerotic nature of European labour markets substantially helps to explain the difference in business cycle dynamics between the two regions without reference to differences in the degree or asymmetry of wage rigidity.

Nevertheless, introducing downward wage rigidity strongly alters the picture of the cycle pattern. The European cycle becomes shorter due to the strong reduction in the expansionary phase, while at the same time recessions lengthen. More importantly, recessions turn out to be very violent in terms of output loss. The average contraction rate during recessions is about 3%, mainly driven by the reduction in hours worked and less through the decline in employment. Hours worked reduce by more than 4% in an average recession, whereas employment only by less than 1%.

Taking all this evidence together, it appears, that the combination of employment protection and wage adjustment asymmetries are at the heart of strong asymmetries between expansions and recessions. Stronger employment protection and lower job-finding rates lead to lower turnover rates, making employment adjustments more rigid. More sclerotic labour markets lengthen and smoothen the business cycle if wages adjust symmetrically. But in combination with downward wage rigidities cycles become shorter and the adjustment during recessions becomes very violent. The strong reduction in hours worked due to increasing real wages is ultimately the driver of the strong decline in output during a recession.

6 Conclusion

Downward wage rigidities are important for shaping the dynamics of the business cycle. Symmetric models have focused on second moments, but cannot capture numerous facts of the third moments, strongly present especially in labour markets. Indeed, accounting for asymmetries in the adjustment of wages allows to also understand asymmetries in the adjustment of single variables over the business cycle, such as employment, unemployment, vacancies and eventually also output.

The asymmetric adjustment cost in the wage bargaining process within a matching model makes wages increase less costly and thereby faster than wage cuts. This core asymmetry directly affects the incentives for creating vacancies on the side of the firm and also influences the decision of hours per employee. During an expansion the fast increase in wages mutes vacancy creation and hence employment compared to a situation with symmetric rigidity. During a recession the effects on the real side are more extreme: real wage increases due to negative inflation rates combined with nominal wages that are kept up. Here vacancy reacts with a steep fall leading to strong increases in unemployment.

This mechanism is present particularly for permanent productivity but also for monetary policy shocks. In fact, a contractionary monetary policy, representing a demand shock in the model, acts primarily on inflation rates. Prices adjust downward more promptly than wages and hence are the main drivers behind real wage adjustments, especially their initial increase. During the current crisis a very similar pattern is observed. Consumer prices and the GDP deflator have decelerated or even declined, whereas nominal wage measures did less or even increased as in the case of hourly labour costs. The policy implications, particularly for monetary policy are very strong: contractionary and expansionary monetary policies have very different effects on the type of variables that they affect. An expansionary policy appears to affect more strongly nominal variables, such as price and wage inflation, leaving the adjustment of real variables muted. Instead, contractionary monetary policy has a large impact on real variables: real wages, unemployment and job creation.

A comparison of the US and the European business cycle reveals shorter and more volatile cycles for the US. The model analysis reveals that it is the combination of sclerotic labour markets together with the downward wage rigidities that leads to the most apparent differences between the two regions. Downward wage rigidity affects the length of expansionary phases more than the length of contractionary ones, but at the same time increases output drops during recessions. The sclerotic nature in European labor markets shields employment, but due to the presence of downward wage rigidity hours worked need to adjust by more.

Overall, downward wage rigidities are only one source for asymmetries over the cycle, with only limited influence on the length of cycles. Extensions building upon complementarities between wages or employment and other variables may further increase the impact. In this respect a more detailed modelling of capital accumulation and its utilization as already advocated by den Haan, Ramey and Watson (2000) in the context of job destruction may amplify asymmetries.

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8 Appendix: Moments

The following tables reports the moments of the annual growth rates of key macro variables for five countries: France, Germany, the UK, the US and the Euro Area[13]. The original data is quarterly and covers the period from 1970:Q1 to 2006:Q4[14].

Euro area	Mean	Median	St.Dev	Skewness	Kurtosis
Δw_t^N	7.14	6.22	4.75	0.50	1.93
Δp_t	5.50	4.74	3.48	0.45	1.87
Δw_t^R	1.64	1.26	1.83	0.99	3.38
Δinv_t	2.01	2.28	3.47	-0.58	2.91
$\Delta shares_t$	na	na	na	na	na
Δv_t	na	na	na	na	na
Δh_t	na	na	na	na	na
Δu_t	4.25	3.38	10.29	1.40	6.42
Δy_t	2.41	2.47	1.54	-0.22	3.08

France	Mean	Median	St.Dev	Skewness	Kurtosis
Δw_t^N	6.58	4.33	4.90	0.64	2.05
Δp_t	5.06	3.24	4.02	0.55	1.95
Δw_t^R	1.51	1.15	1.87	0.22	2.84
Δinv_t	2.17	2.72	4.09	-0.47	2.76
$\Delta shares_t$	8.03	11.42	21.72	-0.30	2.46
Δv_t	5.78	7.19	18.18	-1.71	8.48
Δu_t	3.49	3.15	9.80	1.22	6.64
Δh_t	-0.73	-0.72	0.84	-0.15	4.30
Δy_t	2.32	2.23	1.47	0.02	2.69

Germany[15]	Mean	Median	St.Dev	Skewness	Kurtosis
Δw_t^N	3.87	3.32	3.71	0.00	4.04
Δp_t	2.99	2.76	2.27	0.75	3.30
Δw_t^R	1.32	0.81	1.74	0.78	2.97
Δinv_t	2.02	1.99	6.21	1.29	7.30
$\Delta shares_t$	5.58	6.04	19.98	-0.43	3.45
Δv_t	-0.96	4.78	25.87	-0.79	3.54
Δh_t	-0.86	-0.98	0.69	0.83	4.56
Δu_t	8.45	2.92	20.51	1.08	3.56
Δy_t	2.09	2.08	1.78	0.07	2.87

[13] 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.

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

[15] To eliminate the outliers due to German reunification, observations that are above or below 4 standard deviations from the median are set equal to the median.

UK	Mean	Median	St.Dev	Skewness	Kurtosis
Δw_t^N	8.22	7.15	5.48	1.52	6.04
Δp_t	6.64	5.34	5.25	1.54	5.09
Δw_t^R	1.59	1.25	2.12	0.41	2.90
Δinv_t	2.67	2.67	5.56	-0.11	3.74
$\Delta shares_t$	8.50	11.55	19.43	-1.08	7.29
Δv_t	2.33	8.84	31.20	-0.85	4.40
Δh_t	-0.42	-0.39	1.31	0.27	4.05
Δu_t	1.21	-1.08	13.17	0.79	3.59
Δy_t	2.32	2.60	2.07	-0.71	5.04

US	Mean	Median	St.Dev	Skewness	Kurtosis
Δw_t^N	5.17	4.84	2.13	0.26	2.19
Δp_t	4.01	3.27	2.36	1.02	2.97
Δw_t^R	1.16	1.06	1.36	0.51	3.55
Δinv_t	3.81	4.61	5.82	-0.53	3.26
$\Delta shares_t$	7.92	9.66	13.90	-0.69	3.56
Δv_t	-1.36	0.00	18.54	-0.35	3.01
Δh_t	-0.16	-0.14	0.57	0.01	2.57
Δu_t	-0.19	-4.67	15.05	1.12	4.11
Δy_t	3.08	3.35	2.11	-0.53	3.51