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Italian Labour Frictions and Wage Rigidities in an Estimated DSGE *

Josué Diwambuena † Raquel Fonseca ‡ Stefan Schubert §

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Abstract

This paper investigates how Italian labour market institutions influence business cycle fluctuations. We apply a DSGE model that features Italian labour market rigidities and we estimate the latter on Italian data using Bayesian techniques to assess the effects of demand, supply, and labour market shocks on the macroeconomy, and to measure their significance for economic fluctuations. Our results show: First, technology, time preference and wage bargaining shocks are key drivers of economic fluctuations across horizons. Second, matching efficiency and wage bargaining shocks are significant sources of unemployment and vacancies fluctuations but their role is limited for output fluctuations. Third, labour market relaxation policies have only marginally contributed to the reduction in unemployment. Last, accounting for wage rigidities influences labour market dynamics and helps the model to fit data well. We, therefore, urge policymakers to support additional changes in labour market institutions.

Keywords: DSGE, Labour market frictions, Bayesian estimation, Italy.

JEL codes: E24, E32, C51, C52.

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†Corresponding author. Free University of Bozen-Bolzano. jdiwambuena@unibz.it. The author gratefully acknowledges financial support from the Free University of Bozen-Bolzano PhD Fellowship.

‡Address: ESG-University of Quebec at Montreal and CIRANO. fonseca.raquel@uqam.ca.

§Address: Free University of Bozen-Bolzano. StefanFranz.Shubert@unibz.it.

1 Introduction

The Italian labour market is characterized by several rigidities including among others inflexible wages, high restrictions against firms layoffs, and long duration of unemployment spells. Over the last two decades, Italy has undergone three main recessions[1] and in response to these, it has advocated a battery of structural reforms aimed at making its labour market more flexible through for instance decentralizing wage bargaining mechanisms, reducing employment protection, improving job matching efficiency and mitigating the duality of its labour market (see Garibaldi and Taddei, 2013; Schrader and Ulivelli, 2017; and Pinelli et al., 2017 for a survey on reform packages).

The 2008 global financial crisis (GFC) has exacerbated the fragility of the Italian labour market and has called for policy responses including structural reforms and further labour market liberalization policies to alter the daunting employment and output trends (Fana et al., 2016, Marino and Nunziata, 2017). The Italian economy has been brutally hit by the double-dip recession causing deep contractions in GDP and massive destruction of jobs and productive capacity. Fana et al. (2016) note that the Italian unemployment rate soared from 6.7 percent in 2006 to 12.7 percent in 2014; during the same period, Italian GDP fell by 7.1 percent and its productive capacity by 25 percent.

In the wake of the 2008 GFC, the Italian government introduced a set of policy interventions to counterbalance the devastating trends occasioned by this negative shock. In fact, labour market flexibility emerged as a top priority among structural reforms set by the European Commission for Southern European countries (Cirillo et al., 2017, p. 10). In 2015, the Italian government introduced the "Job Act" labour market deregulation in order to reduce unemployment and job instability, foster competitiveness and high productivity via the reallocation of labour across firms and sectors (Catalano and Pezzolla, 2017; Fana et al., 2016).

The Job Act encompasses several relaxation policies aimed at enhancing job matching efficiency, and cushioning labour market segmentation via notably the weakening of firing costs for open-ended contracts and the elimination of restrictions regarding the use of temporary contracts, thereby softening employment protection legislation (Fana et al., 2016; Cirillo et al., 2017). Cirillo and Guarascio (2015) claim that softening firing restrictions during recessionary phases may lead to a plunge in internal demand as a result of a drop in employment and the weakening of workers bargaining power. Despite some improvement in labour market outcomes, unemployment remains

[1] These recessions lasted, respectively, from February 2001 to July 2003, from March 2008 to May 2009, and from June 2011 to April 2013 (Marino and Nunziata, 2017, p. 2).

higher than the pre-crisis levels (Marino and Nunziata, 2017).

In this paper, we aim to answer empirically the following questions: (1) Are labour market institutions really important for macroeconomic dynamics? (2) What are the effects of structural shocks originating from changes in labour market institutions on the macroeconomy and how do they feedback to labour market dynamics? (3) How important are labour market shocks in explaining economic fluctuations?

Our paper is related to a growing macroeconomic literature that investigates how labour market institutions affect business cycle fluctuations within the context of dynamic stochastic general equilibrium (DSGE) models that feature search and matching frictions in the labour market (see section 3 on the related literature for further discussion)[2].

For Italy, we find few studies that assess the role of labour market institutions for business cycle fluctuations within this class of DSGE models. Catalano and Pezzolla (2017) is a notable exception. Recently, studies rely on Bayesian estimation techniques to estimate structural parameters of this class of DSGE models and to quantify the contribution of shocks for economic fluctuations (e.g. Christoffel et al., 2009; Gertler et al., 2008; Lubik, 2009; Sala et al., 2008; Albertini et al., 2012; Faccini et al., 2013; Furlanetto and Groshenny, 2016a; Zhang, 2017). This is the most relevant literature for this paper.

Regarding structural features of the labour market we consider in this paper, we follow Abbritti and Weber (2010) and distinguish two groups of labour market institutions: (i) unemployment rigidities which capture institutions such as employment protection legislation, hiring costs and the matching technology that limit the flows in and out of unemployment; and (ii) real wage rigidities, which represent all institutions regarding wage indexation and the wage bargaining mechanism and legislation which influence the responsiveness of real wages to economic activity.

Our paper introduces these two types of Italian labour market rigidities in the following ways: First, we account for a weakening in employment protection legislation and thus an improvement in labour reallocation in the Italian labour market through a matching efficiency shock that triggers an increase in the efficiency at which the aggregate labour market matches vacant jobs with unemployed workers.

Second, we introduce a weakening in firing costs via a disturbance that augments firms' bargaining power during wage negotiations. Last, we account for real wage rigidities through (i) a collective

[2]Seminal studies include Merz (1995); Andolfatto (1996); Den Haan et al. (2000) who mainly calibrate these models.

wage bargaining mechanism, and (ii) the existence of inflexible (sticky) real wages.

Accounting for Italian labour market frictions in a general equilibrium business cycle model is important in order to appraise the macroeconomic effects of shocks originating from the labour market on the macroeconomy, and to measure their significance for economic fluctuations. From a policy viewpoint, quantifying the relevance of labour market shocks is crucial since this may help policymakers design appropriate economic policies and maintain macroeconomic stability.

The contribution of this paper is twofold. First, we develop a neoclassical DSGE model that incorporates search and matching frictions in the labour market and structural features of the Italian labour market. Second, we estimate our model on Italian data using Bayesian techniques in order to examine the macroeconomic effects of demand, supply, and labour market shocks on the macroeconomy, and to quantify their contribution for economic fluctuations.

Our methodology enables us to estimate key structural parameters of the Italian labour market and unobservables shocks. Our estimated model includes seven structural shocks (i.e. the neutral technology shock, the investment-specific technology shock, the government spending shock, the time preference shock, the labour supply shock, the matching efficiency shock and the wage bargaining shock) and seven observables.

Our results are as follows. We estimate a higher inverse Frisch elasticity, thereby suggesting that employment is more volatile along the extensive margin rather than the intensive margin. We find the firm's bargaining power to be 0.79. This suggests that firms receive a great share of the surplus arising from the employment contract.

We estimate the degree of wage persistence to be 0.98. This reflects the fact that wages are highly sticky in Italy. Our forecast error variance decomposition results show that both technology shocks (i.e neutral and investment-specific), the time preference shock and the wage bargaining shock are among the largest drivers of economic fluctuations across horizons as in Faccini et al. (2013). Moreover, labour market shocks (i.e. the matching efficiency shock and the wage bargaining shock) account for an important fraction of unemployment and vacancies fluctuations but their role is marginal for business cycle fluctuations.

Results emerging from our historical decomposition indicate that investment supply-side policies and consumption demand-side policies are among the main drivers that contributed to output's expansion, unemployment reduction and vacancies expansion during the sample period. In contrast, productivity-enhancing policies have not been very effective in expanding output and vacancies, and in reducing unemployment.

We find that labour market relaxation policies have only marginally contributed in shrinking unemployment throughout the sample period. In view of these results, our main message to policymakers is that they should (i) support additional changes in the labour market institutions, (ii) improve productivity-enhancing supply-side policies and (iii) strengthen investment supply-side policies.

Finally, in order to investigate to what extent accounting for real wage rigidities may be important for labour market dynamics, we simulate short-run macroeconomic dynamics both in the presence and the absence of wage stickiness. Our findings support that wage rigidities significantly influence labour market dynamics and helps the model fit the data well.

The rest of this paper is structured as follows. Section 2 provides the economic background on the Italian economy. Section 3 summarizes the related literature. Section 4 sets-up the model environment. Section 5 describes the the estimation approach and the data. Section 6 analyzes the sources of macroeconomic fluctuations. Section 7 concludes and derives some policy suggestions.

2 Economic Background

The structural issues of the Italian labour market includes among others a low participation level of women and young people, great regional disparities between the North-Center vs. the South regions, high skill mismatch resulting from the discrepancy between the demand for and the supply of labour, and a highly centralized rigid wage collective bargaining system (Ciccarone et al., 2016; Adda et al., 2017; Schrader and Ulivelli, 2017).

Figure 1 presents the evolution of the unemployment rate and the job vacancy rate (vacancies) in Italy from 2004Q1 to 2018Q2. On the left vertical axis, we present unemployment dynamics in percentage points. Unemployment rate is the percentage ratio of unemployed people (15-64 years old) to the labour force (15-64 years old). On the right vertical axis, we exhibit the job vacancies dynamics.

The job vacancy rate comes from the VELA survey run by the Italian Institute of Statistics (Istat) and it is defined as the percentage ratio between vacancies and the sum between vacancies and occupied posts (Lucarelli et al., 2011, p.5). The unemployment dynamics is characterized by three episodes. The unemployment rate turns around 8.5 percent between 2004Q1 and 2011Q1 and reaches its lowest value (6.1 percent) in 2007Q1. Then, it rose from 8.5 percent in 2011Q4 to almost 13 percent in 2013Q4. During the 2008 GFC, the annual total unemployment and the youth unemployment skyrocketed to 12.7% and 40% in 2014 respectively (eurostat, 2018). After the crisis, it has dropped to below 11 percent in 2018Q2. Vacancies are highly volatile, remain relatively low and evolve around 1 percent over the entire period. The patterns of the aggregate unemployment is often attributed to the outcomes of labour market reforms[3].

The Job Act, the most recent reform, was put forth by the Italian government in 2015. The Job Act builds on the "Fornero reform"[4] and aimed at enhancing job matching efficiency in Italy (Pinelli et al., 2017; Schrader and Ulivelli, 2017).

In the aftermath of the Job Act, Pinelli et al. (2017) note that the number of permanents contracts significantly increased, labour market segmentation diminished while job matching efficiency was enhanced. Since the inception of the Job Act, the unemployment rate has been trending downwards though higher than pre-crisis levels while vacancies have been trending upwards. These important changes that occur in the Italian labour institutions (compared to other euro area labour markets) since the outset of the Job Act indicate potential shifts in the Italian Beveridge curve. Similar patterns have been observed by Bonthuis et al. (2016) in many European countries[5]. In light of this discussion, we model this shift in the Italian Beveridge curve through a matching efficiency shock and we investigate how the latter affects business cycle fluctuations in Italy.

[3]Pinelli et al. (2017) note that after the Treu Package (1997) and the 2003 Biagi Law reforms; employment growth rose on average to 1.4 percent per year between 1997-2007 while the unemployment rate dropped to 6.1 percent in 2007. These outcomes indicated that reforms responded to firms' demand for flexibility in contractual agreements. However, they reduced incentives to invest in education and firm-specific skills and encouraged employment of low-skill workers, thereby leading to a dual or segmented labour market (Larch, 2004; Daveri and Parisi, 2015; Rosolia and Torrini, 2016).

[4]The Fornero reform was aimed at relaxing employment protection legislation for permanent contracts, reducing labour market duality and proposing the design of a universal unemployment benefit system (Schrader and Ulivelli, 2017).

[5]Bonthuis et al. (2016) think that this could suggest shifts in the European Beveridge curve.

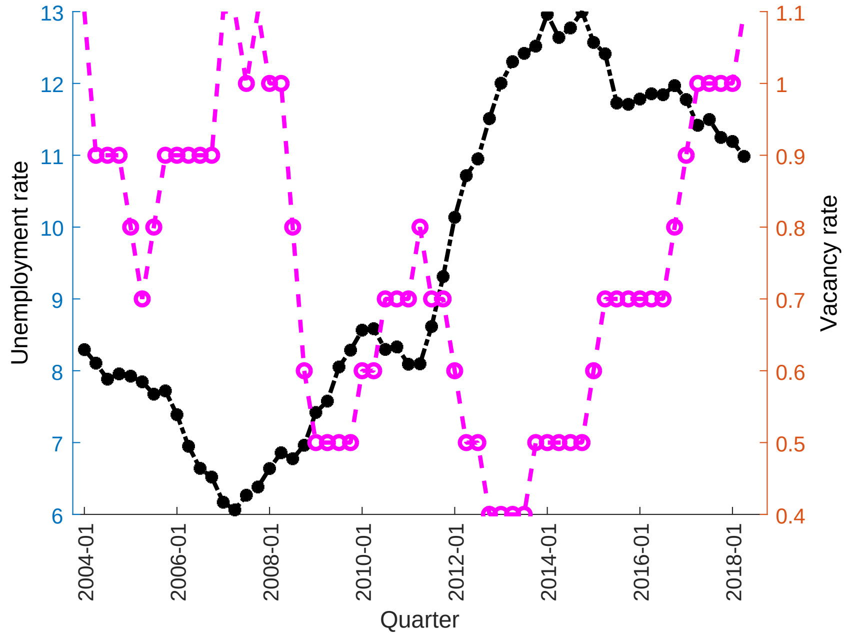

Figure 1: Unemployment rate and vacancies in Italy (2004Q1-2018Q2). On the left vertical axis, we plot unemployment rate. On the right vertical axis, the evolution of job vacancy rate is plotted.

3 Related Literature

There exists by now a growing literature that examines the role of labour market institutions for business cycle fluctuations within the context of DSGE models with labour market frictions. Seminal studies by Merz (1995), Andolfatto (1996), Den Haan et al. (2000) mainly simulated neoclassical DSGE models calibrated for the US economy. Other relevant studies include among others Langot (1994) for France, Fonseca and Muñoz (2003) for Spain, Cheron et al. (2004) for the US, Vasilev et al. (2016) for Bulgaria[6].

Recently, many studies estimate structural parameters and shocks of this class of DSGE models with Bayesian techniques (e.g. Christoffel et al. (2009) for the euro area; Christoffel et al. (2006) for Germany; Albertini et al. (2012) For New-Zealand; Faccini et al. (2013) for the UK; Jakab and Kónya (2016) for Hungary; Krause et al. (2008), Lubik (2009), Gertler et al. (2008), Sala et al. (2008), Furlanetto and Groshenny (2016a), Chahrour et al. (2016), Zhang (2017) for the US; Justiniano and Michelacci (2011) for a mix of countries). This is the most relevant literature for our paper. As an example, using a small open economy NK-DSGE model estimated for New Zealand,

[6]Studies using New Keynesian-DSGE (NK-DSGE) models include among others Walsh (2003), Blanchard and Galí (2010), Krause and Lubik (2007) and Trigari (2006) for the US, Lechthaler et al. (2010) for Europe.

Albertini et al. (2012) show that the estimated model is able to match the volatility of labour market variables; and that most of the variability in labour market dynamics (i.e unemployment rate and vacancies) is explained by the matching efficiency shock although its role is marginal for business cycle fluctuations.

Faccini et al. (2013) estimate a NK-DSGE model on UK data and find that technology shocks are among the largest drivers of macroeconomic volatility, and allowing for wage rigidities helps the model fit data more closely. Furlanetto and Groshenny (2016a) investigate the macroeconomic consequences of the matching efficiency shock[7] with a focus on the US Great Recession (GR)[8]. They document that the relevance of matching efficiency shocks is limited in normal times but is amplified during the Great Recession(GR).

Furlanetto and Groshenny (2016a) add that matching efficiency shocks are the dominant drivers of the natural unemployment fluctuations while demand and investment-specific technology shocks account for sizable share of unemployment fluctuations. Zhang (2017) demonstrates that the unemployment benefit shock accounts for 30 percent of variability in the US unemployment rate in the long-run. Zhang (2017) shows that in the absence of the unemployment benefit shock, matching efficiency shocks are the dominant drivers of unemployment fluctuations.

For Italy, we identify few studies that evaluate the role of labour market institutions for business cycle fluctuations within this class of DSGE models (Maffezzoli, 2001; Destefanis and Fonseca, 2007; Cardullo and Guerrazzi, 2013; Catalano and Pezzolla, 2017). Maffezzoli (2001) develops a non walrasian neoclassical DSGE model that features endogenous growth through learning-by-doing and equilibrium unemployment characterized by monopolistic unions. Catalano and Pezzolla (2017) simulate a medium-scaled open economy NK-DSGE model that features dual labour markets (named Prometeia DSGE) to assess the macroeconomic consequences of labour market reforms included in the Job Act. Peracchi et al. (2004) use a matching function and apply microeconomic techniques to estimate labour market transitions in Italy and Spain. Destefanis and Fonseca (2007)

[7]Several studies attribute the rise in the unemployment rate in many developed countries to the low degree of efficiency of labour markets (Bernanke, 2010; Kocherlakota, 2010). The following factors are regarded as responsible for the low matching efficiency: the drop in search intensity by workers as a result of extended unemployment benefits (Valletta et al., 2010); the fall in firm recruiting intensity (Davis et al., 2010); skill mismatch (Sahin et al., 2011); geographical mismatch (Nenov, 2012); shifts in the composition of the unemployment pool due to the presence of a large proportion of long-term unemployed people and permanents layoffs (Barnichon and Figura, 2011).

[8]Furlanetto and Groshenny (2016a) define matching efficiency or mismatch shocks as reallocation shocks as long as they capture some form of mismatch (in skill, geography or other dimension), shifts or structural changes in the labour market.

re-parameterize a matching function as a Beveridge curve and estimate it to evaluate the impact of the Treu Act reform on Italy's labour market. Cardullo and Guerrazzi (2013) introduce segmented labour markets with on-the-job search in a canonical search and matching model to understand unemployment and vacancies dynamics in Italy.

Finally, there is an emerging literature that appraises the role of labour market dynamics using structural VAR (SVAR) models (e.g. Peersman and Straub, 2009 for the euro area; Foroni et al., 2018 and Benati and Lubik, 2014 for the US; Di Giorgio and Giannini, 2012 for Italy).

4 The Model

The basic environment is a standard closed economy neoclassical DSGE model with labour market frictions as in Andolfatto (1996) and Merz (1995). Labour market frictions are in the spirit of Mortensen and Pissarides (1994) and Mortensen and Pissarides (1999). We slightly modify Cheron et al. (2004) to account for wage rigidities as in Hall (2005), a key feature of the Italian labour market. There are three types of agents: households, firms and the fiscal authority. Consumption and savings decisions are taken at the representative household level. Households are ex-post heterogeneous as they face idiosyncratic shocks in the labour market but they have full unemployment insurance against income loss. On the production side, all firms produce output using the same technology and inputs. The unique role of the fiscal authority is to collect lump-sum taxes to finance government consumption. Time is discrete and goes from zero to infinity.

4.1 Labour Market Frictions

The economy is populated by a continuum of agents whose mass is normalized to one. n_t denotes the number of employed people at beginning of period t. $1 - n_t$ denotes the number of unemployed people. Following Mortensen and Pissarides (1999), the number of new matches m_t occurs through a Cobb-Douglas matching technology that relates the total number of unfilled vacancies v_t and the total number of unemployed people $1 - n_t$.

$$m_t = \varsigma_t v_t^{\gamma} (e(1 - n_t))^{1-\gamma} \tag{1}$$

where $\gamma \in (0, 1)$ denotes the matching elasticity with respect to unfilled vacancies. $e > 0$ denotes a constant job search effort by the unemployed household. ς_t denotes an exogenous time-varying matching efficiency shock that evolves as:

$$\ln \varsigma_t = (1-\rho_\varsigma)\ln \bar{\varsigma} + \rho_\varsigma \ln \varsigma_{t-1} + \epsilon_t^\varsigma \tag{2}$$

where $\rho_\varsigma < 1$ and $\varepsilon_t^\varsigma \sim \mathcal{N}(0, \sigma_\varsigma)$ $\forall t$. $\bar{\varsigma}$ denotes the steady-state level of the matching efficiency shock. Equation (2) shows that the matching efficiency shock is an autoregressive process of order one AR(1). It is defined as a weighted average of the long-run value of the matching efficiency shock and its past realizations plus the disturbance term. Many studies in the literature have investigated the role of the matching efficiency shock for business cycle fluctuations (e.g. Furlanetto and Groshenny, 2016a; Krause et al., 2008; Albertini et al., 2012; Zhang, 2017; Beauchemin and Tasci, 2014; Justiniano and Michelacci, 2011)

Our positive matching efficiency shock should be interpreted as a disturbance that improves the effectiveness at which the aggregate labour market matches vacant positions with unemployed workers. Thus, the matching efficiency shock enhances labour reallocation and reduces the degree of skill or geographical mismatch in the labour market. Labour market tightness θ_t is defined as the ratio of unfilled vacancies to unemployment. The probability of filling up vacant positions $q(\theta_t)$ and the probability of finding employment by the unemployed worker $f(\theta_t)$ are all functions of θ_t:

$$q(\theta_t) = \frac{m_t}{v_t} = \varsigma_t e^{1-\gamma}\left(\frac{1-n_t}{v_t}\right)^{1-\gamma} \tag{3}$$

$$f(\theta_t) = \theta_t q(\theta_t) = \varsigma_t e^{1-\gamma}\left(\frac{v_t}{1-n_t}\right)^{\gamma} \tag{4}$$

$$\theta_t = \frac{v_t}{1-n_t} \tag{5}$$

$q(\theta_t)$ is a decreasing function of θ_t whereas $f(\theta_t)$ is an increasing function of θ_t. There are externalities associated with the activities of firms and workers in the labour market. Ceteris paribus: (i) an increase in the number of vacancies drops the probability of filling up vacant positions but raises the probability of finding employment; (ii) a rise in the number of unemployed people shrinks the probability of finding employment but improves the probability of filling up vacant positions. The dynamics of aggregate employment is as follow:

$$n_{t+1} = (1-s)n_t + m_t \tag{6}$$

where n_{t+1} denotes employment in the next period, $(1-s)n_t$ denotes those who remain employed during the current period and $s \in (0,1)$ denotes an exogenous job separation rate.

4.2 Households

The representative household consists of a continuum of identically and infinitely lived agents who insure each other completely against idiosyncratic employment risks. A share of employed household n_t works h_t "hours" each period while the remaining share of unemployed household $1-n_t$ searches for vacant positions in the labour market with searching effort e. As in Cheron et al. (2004), depending on the status (employed or unemployed) in the labour market, the per-period separable utility function between consumption c_t^i and leisure ℓ_t^i of the household, with $(i = n, u)$, is:

$$U^n(c_t^n, \ell_t^n) = \ln(c_t^n) + \Upsilon_t^n \tag{7}$$

$$U^u(c_t^u, \ell_t^u) = \ln(c_t^u) + \Upsilon^u \tag{8}$$

where: $\Upsilon_t^n = \vartheta_t \psi_1 \frac{(1-h_t)^{1-\eta}}{1-\eta}$ and $\Upsilon^u = \psi_2 \frac{(1-e)^{1-\eta}}{1-\eta}$ with $\psi_1, \psi_2, \eta > 0$. c_t^n and c_t^u denote consumption when employed and unemployed respectively. Υ_t^n and Υ^u denote utility costs that depend on the household's status in the labour market. Costs are assumed constant across the business cycle and impose that $\Upsilon^u > \Upsilon_t^n$ to capture the fact that the value of leisure is greater for the unemployed than the employed worker. ϑ_t is an exogenous time-varying labour disutility shock as in Faccini et al. (2013) and that evolves according to:

$$\ln \vartheta_t = (1-\rho_\vartheta) \ln \bar{\vartheta} + \rho_\vartheta \ln \vartheta_{t-1} + \epsilon_t^\vartheta \tag{9}$$

Where $\rho_\vartheta < 1$ and $\varepsilon_t^\vartheta \sim \mathcal{N}(0, \sigma_\vartheta)$ $\forall t$. $\bar{\vartheta}$ denotes the long-run value of the labour disutility shock. The representative household invests in capital whose law of motion is given by:

$$k_{t+1} = (1-\delta)k_t + \varepsilon_{i,t} i_t \tag{10}$$

$\varepsilon_{i,t}$ denotes an exogenous time-varying investment-specific technology shock as in Faccini et al. (2013) and evolves according to:

$$\ln \varepsilon_{i,t} = (1-\rho_{\varepsilon_i}) \ln \bar{\varepsilon_i} + \rho_{\varepsilon_i} \ln \varepsilon_{i,t-1} + \epsilon_t^i \tag{11}$$

Where $\rho_{\varepsilon_i} < 1$ and $\epsilon_t^i \sim \mathcal{N}(0, \sigma_i)$ for $\forall t$. $\bar{\varepsilon_i}$ denotes the long-run value of the investment-specific technology shock. The budget constraint is given by:

$$n_t c_t^n + (1 - n_t) c_t^u + k_{t+1} = (1 - \delta + r_t) k_t + w_t h_t n_t + \Pi_t - t_t \tag{12}$$

where w_t denotes the hourly real wage, $w_t h_t n_t$ denotes the aggregate labour income, r_t denotes the return rate on capital, Π_t denotes profits received from firms and t_t is the lump-sum tax paid to the government. $\beta \in (0, 1)$ denotes the discount factor. Denoting the state-space of the household by $W(S_t^H)$ with $S_t^H = \{k_t, n_t, \varepsilon_{i,t}, \vartheta_t, \varphi_t\}$, the recursive problem of the household can be written as:

$$W(S_t^H) = \max_{c_t^n, c_t^u, k_{t+1}, h_t} \left\{ [n_t U^n(c_t^n, \ell_t^n) + (1 - n_t) U^u(c_t^u, \ell_t^u)] + \beta \varphi_t E_t[W(S_{t+1}^H)] \right\} \tag{13}$$

subject to the budget constraint and the employment dynamics at the household's level. Letting λ_t, ϕ_t denoting the Lagrangian multipliers associated to the budget constraint and the employment dynamics at the household's level, the optimal conditions with respect to c_t^n, c_t^u and k_{t+1} are:

$$\lambda_t = U_1^n(c_t^n, \ell_t^n) \tag{14}$$

$$\lambda_t = U_1^u(c_t^u, \ell_t^u) \tag{15}$$

$$\lambda_t = \beta \varphi_t E_t[\lambda_{t+1}(1 - \delta + r_{t+1})] \tag{16}$$

φ_t denotes an exogenous time preference shock that evolves as:

$$\ln \varphi_t = (1 - \rho_\varphi) \ln \bar{\varphi} + \rho_\varphi \ln \varphi_{t-1} + \epsilon_t^\varphi \tag{17}$$

where $\rho_\varphi < 1$ and $\varepsilon_t^\varphi \sim \mathcal{N}(0, \sigma_\varphi)$ $\forall t$. $\bar{\varphi}$ denotes the long-run value of the time preference shifter. Equations (14-15) imply that the marginal utility of consumption must be equal to the shadow price associated to the budget constraint. Given the assumption of complete markets, it follows that $c_t^u = c_t^n = c_t$. Replacing this into (14 or 15) implies that $\lambda_t = 1/c_t$. Equation (17) is the standard Euler conditions that describes the trade-off between consumption and investment decisions. The optimal choice of hours worked is determined in sub-section 4.4. In the appendix A.1, we set-up the household's problem and derive the optimal conditions step by step.

4.3 Firms

There is a continuum of firms of measure one. All firms produce output using a Cobb-Douglas technology with capital (k_t) and labour ($n_t h_t$) as inputs.

$$y_t = a_t k_t^{\alpha} (n_t h_t)_t^{1-\alpha} \tag{18}$$

a_t denotes an exogenous total factor productivity (TFP) shock that evolves as:

$$\ln a_t = (1-\rho_a)\ln \bar{a} + \rho_a \ln a_{t-1} + \epsilon_t^a \tag{19}$$

where $\rho_a < 1$ and $\varepsilon_t^a \sim \mathcal{N}(0, \sigma_a)$ $\forall t$. $\bar{a}$ denotes the long-run value of the TFP shock. The law of employment at the firm's level is:

$$n_{t+1} = (1-s)n_t + q(\theta_t)v_t \tag{20}$$

where n_{t+1} denotes the firm's employment level in the next period. v_t denotes the number of unfilled vacancies posted by firms. The firm's problem is dynamic since it maximizes the discounted value of future profits and take employment decisions regarding future number of workers n_{t+1} taking the number of current workers n_t as given. The firm incurs linear vacancy posting costs ω by posting unfilled vacancies in the labour market. All firms take the job filling rate $q(\theta_t)$ as given. Letting $\Upsilon(S_t^F)$ with $S_t^F = \{n_t, a_t\}$ denoting the state-space of the firm, the recursive problem of the firm becomes:

$$\Upsilon(S_t^F) = \max_{k_t, v_t, n_{t+1}} \left\{ a_t k_t^{\alpha} (n_t h_t)^{1-\alpha} - w_t h_t n_t - \omega v_t + \beta \varphi_t E_t[(\lambda_{t+1}/\lambda_t)\Upsilon(S_{t+1}^F)] \right\} \tag{21}$$

subject to the employment dynamics at the firm's level. Letting $\beta\varphi_t E_t[\lambda_{t+1}/\lambda_t]$ denoting the firm's discount factor. Letting μ_t denoting the Lagrangian multiplier associated to the firm's employment dynamics, the optimal conditions with respect to k_t, v_t and n_{t+1} are:

$$r_t = \alpha \frac{y_t}{k_t} \tag{22}$$

$$\mu_t = \frac{\omega}{q(\theta_t)} \tag{23}$$

$$\mu_t = \beta \varphi_t E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \left((1-\alpha)\frac{y_{t+1}}{n_{t+1}} - w_{t+1} h_{t+1} + (1-s)\mu_{t+1} \right) \right] \tag{24}$$

Equation (22) states that the return rate on capital is equal to the marginal product of capital (MPK). Equation (23) conditions the shadow value of employment to be equal to the cost of filling up vacant positions times the average vacancy duration. Substituting equation (23) into (24) gives rise to the job creation condition (JCC):

$$\frac{\omega}{q(\theta_t)} = \beta\varphi_t E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \left((1-\alpha)\frac{y_{t+1}}{n_{t+1}} - w_{t+1}h_{t+1} + (1-s)\frac{\omega}{q(\theta_{t+1})} \right) \right] \tag{25}$$

Equation (25) shows that the marginal value of employing an additional worker must be equal to the expected marginal benefit (the difference between expected productivity and real wages) plus its expected continuation value. In the appendix A.2, we explain the firm's problem in-depth and derive the optimal conditions step by step.

4.4 Nash Bargaining Wage Determination

Real wages $w_t^{NB}h_t$ are determined through a collective Nash bargaining mechanism between the firm and the worker. In this negotiation, both parties share the joint surplus of the match (Pissarides, 2000). Letting ξ_t denoting the time-varying bargaining power, the optimal condition of the splitting rule is given by $(1-\xi_t)\Upsilon_2(S_t^F) = \xi_t \left(W_2(S_t^H)/\lambda_t \right)$ where $\Upsilon_2(S_t^F)$ denotes the firm's surplus and $W_2(S_t^H)/\lambda_t)$ denotes the worker's surplus expressed in terms of goods (Andolfatto, 1996). The worker's surplus is given by:

$$\begin{aligned} W_1(S_t^H) = & \left\{ \lambda_t \left(w_t h_t + c_t^u - c_t^n \right) + (1-s)\beta\varphi_t E_t[W_1(S_{t+1}^H)] \right\} \\ & - \left\{ (U^u(c_t^u, \ell_t^u) - U^n(c_t^n, \ell_t^n)) + f(\theta_t)\beta\varphi_t E_t[W_1(S_{t+1}^H)] \right\} \end{aligned} \tag{26}$$

Equation (26) shows that the marginal value of employment for the worker is given by the difference between the value of employment (real wages plus the expected continuation value of workers who remain employed) and the value of being unemployed (the current utility gain in leisure plus the expected continuation value of labour market search). The firm's surplus is given by:

$$\Upsilon_2(S_t^F) = \left\{ (1-\alpha)\frac{y_t}{n_t} - w_t h_t + (1-s)\beta\varphi_t E_t[(\lambda_{t+1}/\lambda_t)\Upsilon_2(S_{t+1}^F)] \right\} \tag{27}$$

Equation (27) exhibits that the marginal value of employment for the firm is equal to the marginal product of labour (MPL) minus real wages plus the expected continuation value of a match. Real wages obtained after solving the Nash-bargaining problem are:

$$w_t^{NB} h_t = (1-\xi_t)\left[(1-\alpha)\frac{y_t}{n_t} + \frac{\omega v_t}{1-n_t}\right] + \xi_t\left[\frac{U_t^u - U_t^n}{\lambda_t}\right] \tag{28}$$

where $\xi_t = \xi\varpi_t$ as in Furlanetto and Groshenny (2016a). ξ is the steady-state value of the wage bargaining power shock. ϖ_t denotes an exogenous time-varying wage bargaining shock that evolves as:

$$\ln\varpi_t = (1-\rho_\varpi)\ln\bar{\varpi} + \rho_\varpi \ln\varpi_{t-1} + \epsilon_t^\varpi \tag{29}$$

where $\rho_\varpi < 1$ and $\varepsilon_t^\varpi \sim \mathcal{N}(0,\sigma_\varpi)$ $\forall t$. $\bar{\varpi} = \xi$. Equation (29) states that real wages are a weighted average of the MPL and the worker's reservation option. The term weighted by the worker's bargaining power $1-\varpi_t$ includes the MPL and the firm's continuation value that depends on labour market tightness. The term weighted by the firm's bargaining power ϖ_t includes the worker's reservation option which depends utility gain in leisure expressed in units of consumption $[(U_t^u - U_t^n)/\lambda_t]$. In the appendix A.3, the Nash-bargaining problem is explained in details. Keeping with standard practice in the literature, real wages and hours are assumed to be determined simultaneously and that the determination of hours is always efficient (Trigari, 2009). From the splitting rule of the Nash bargaining problem, it follows that the total surplus S_t is the sum of the two surpluses:

$$S_t = \Big(W_2(S_t^H)/\lambda_t\Big) + \Big(\Upsilon_2(S_t^F)\Big) \tag{30}$$

The optimal choice of hours worked h_t is determined by maximizing the total surplus with respect to hours and taking the MPL $F_{2,t} = \alpha y_t / n_t h_t$ as given. It follows that:

$$\frac{1}{\lambda_t}\frac{\psi_1\vartheta_t}{(1-h_t)^\eta} = (1-\alpha)\frac{y_t}{n_t h_t} \tag{31}$$

Equation (31) states that the optimal allocation of hours is reached when the marginal rate of substitution (MRS) is equal to the MPL.

4.5 Wage Rigidities

Sudden changes or substantial shifts in the aggregate wage level are not observed in the European labour market (Christoffel and Linzert, 2005). Likewise, in Italy, wages are very sticky and are not easily adjusted within quarters. In the Nash bargaining framework, real wages are adjusted every period and thus exhibit some degree of flexibility in real wages. Consequently, the Nash-bargaining real wages are regarded as flexible real wages in the literature. The Nash bargaining negotiation mechanism has been deeply criticized in the literature for failing to match the volatility of labour market dynamics (Shimer, 2005). To address Shimer (2005)'s puzzle, we introduce wage rigidities as in Hall (2005)[9]. Hall (2005) models current real wages as a weighted average of previous real wages and target real wages (i.e. the Nash bargaining real wages):

$$w_t = \rho_w w_{t-1} + (1 - \rho_w) w_t^{NB} \tag{32}$$

where $\rho_w \in (0, 1)$ denotes the degree of wage persistence. w_t denotes the actual real wages while w_t^{NB} denotes the flexible real wages.

4.6 Fiscal Authority

Government expenditure includes government consumption. Government revenue mainly comes from lump-sum taxes. The government budget constraint is always balanced:

$$g_t = t_t \tag{33}$$

where t_t denotes lump-sum taxes collected from the households. g_t is an exogenous time-varying government consumption that evolves according to:

$$\ln g_t = (1 - \rho_g) \ln \bar{g} + \rho_g \ln g_{t-1} + \nu_g \tag{34}$$

where $\rho_g < 1$ and $\nu_g \sim \mathcal{N}(0, \sigma_g)$ $\forall t$. $\bar{g}$ denotes the long-run value of government consumption-to-output ratio.

[9]Previous studies mostly relied on the Nash bargaining wage negotiation to derive the equilibrium real wage. However, this feature is not without critiques in the literature (Shimer, 2005)[10]. Other mechanisms are proposed in the literature. For example, Hagedorn and Manovskii (2008) who suggest to calibrate a low bargaining power value for workers, Trigari (2006) introduces the right to manage bargaining mechanism; Hall and Milgrom (2008) and Gertler and Trigari (2009) introduce strategic wage bargaining; Pissarides (2009) proposes to apply Nash bargaining behavior to new jobs only.

4.7 Resource Constraint

Output must equal the private consumption, the private investment and the government consumption. Costs related to vacancy posting reduce the amount of resources available in the economy.

$$y_t = c_t + i_t + g_t + \omega v_t \tag{35}$$

5 Bayesian Estimation

We estimate our model with Bayesian techniques (see An and Schorfheide, 2007 for an in-depth discussion on DSGE estimation). First, we solve the model by log-linearizing its equilibrium conditions around a non-stochastic steady-state (Uhlig, 1999) (see the appendix C). Second, we apply the Kalman filter to evaluate the likelihood function. Third, we obtain the posterior distributions by combining the priors and the likelihood function. In what follows, we discuss the data and the selection of priors used in the estimation. Our estimation is carried out using Dynare toolbox version 4.5.7 (Adjemian et al., 2011). In the appendices A.4-A.5, we present the equilibrium conditions and the steady-state conditions respectively.

5.1 Data

We use the following quarterly Italian data as observables: real GDP, private consumption, private investment, real wages, unemployment rate, vacancies and total hours. All data are seasonally adjusted and expressed in natural logs. We use the GDP deflator to express national accounts data in real terms. We transform national accounts data into per capita terms by dividing by a measure of population 15-64 years old. The sample is from 2004Q1 to 2018Q2. The beginning of the sample is constrained by data on vacancies. Further details regarding data sources can be found in the appendix B.

To avoid the issue of stochastic singularity as discussed in Pfeifer (2014)[11], our model includes seven structural shocks and seven observables. We include the following shocks: the neutral technology shock, the matching efficiency shock, the preference shock, the labour supply shock, the government consumption shock, the wage bargaining shock and the investment-specific technology shock. We filter our observables using the one-sided HP Filter (Stock and Watson, 1999) with a

[11] Pfeifer (2014) offers a guide to specifying observation equations for the estimation of DSGE models.

smoothing parameter of 1600. Figure 13 in the appendix D presents the filtered variables used in the estimation.

5.2 Priors

Keeping up with standard practice in the literature, we fix a number of parameters (agnostic priors) before the estimation. We calibrate some parameters to match long-run features of Italian data and to avoid identification issues.

The discount factor β is fixed to 0.9926 to achieve the quarterly real interest rate of 4 to 5% (Bokan et al., 2018). The share of capital in production α is equal to 0.33 (Annicchiarico et al., 2013). The quarterly depreciation rate of capital δ is set to 0.025 (Orsi et al., 2014). We choose a conventional value of 0.33 for the time allocation to working activities $h^{\star}$[12] (Cheron et al., 2004). Due to the lack of microeconomic evidence on the value of job search effort e, we parameterize it to be 1/2 of time devoted to working activities as in Cheron et al. (2004). The weights of labour supply for employed workers ψ_1 and unemployed workers ψ_2 are backed out from steady-state conditions.

Regarding the labour market, we target an unemployment rate of 9 percent (Elsby et al., 2013). This value, together with an exogenous job separation rate s of 6 percent implies that the job finding rate $f(\theta^{\star})$ is equal to 0.61. Hence, the unemployment spell duration is 1.64 years, a value consistent with what Schubert and Turnovsky (2016) found on Italian data. The probability of filling up vacancies $q^{\star}$ is fixed to 0.71 (Van Ours and Ridder, 1992). The matching elasticity γ is chosen to be 0.5 (Petrongolo and Pissarides, 2001; Cardullo and Guerrazzi, 2013). Vacancy posting costs (ω) are calibrated so that hiring costs $\Phi^{\star}$ represent one percent of output. The steady-state value of output is fixed to one. The government consumption-to-output ratio is equal to 0.2 to match its long-run average. The fraction of private consumption-to-output is obtained as a residual. We summarize our agnostic priors in Table 3 in the appendix B.

We estimate the remaining parameters with Bayesian techniques. The posterior distribution is simulated using the Random Walk Metropolis Hastings Algorithm (RWMH) for which we generate 300,000 draws and we target an acceptance ratio of 0.3. We discard the first 150,000 draws. We choose conventional priors used in the literature (Smets and Wouters, 2007; Gertler et al., 2008; Justiniano et al., 2010; Furlanetto and Groshenny, 2016a). For persistence parameters, we choose a prior Beta distribution with mean 0.5 and standard deviation 0.2. For shocks processes, we

[12] $\star$ denotes variables in steady-state.

use a prior inverse Gamma distribution with mean 0.01 and standard deviation 0.3. For remaining parameters, we use either a prior Beta or a prior Gamma distribution (Faccini et al., 2013 Albertini et al., 2012).

5.3 Estimation results

Before running the estimation, we conduct a Dynare identification test (Iskrev, 2010; Ratto and Iskrev, 2011b; Ratto and Iskrev, 2011a)[13]. All our structural parameters are locally identified (Ratto and Iskrev, 2011a). Columns 4-5 of Table 1 report the posterior mean of estimated parameters with 90 percent probability intervals[14]. The inverse Frisch elasticity of labour supply ι has a posterior mean of 2.36, a value substantially higher than its prior but consistent with the estimate of Smets and Wouters (2007) for the US. This suggests that employment volatility is much higher at the extensive rather than the intensive margin.

Table 1: Priors and Posteriors Distributions of Structural Parameters and Shocks

Structural parameters	Symbol	Prior density	Posterior mean	Confidence interval
Inverse Frisch elasticity	ι	Gamma (1, 0.2)	2.36	[2.08, 2.63]
Bargaining power	ξ	Beta (0.5, 0.2)	0.79	[0.63, 0.96]
Wage adjustment	ρ_w	Beta (0.75, 0.1)	0.98	[0.97, 0.99]
Autoregressive parameters				
Technology	ρ_a	Beta (0.5, 0.2)	0.74	[0.63, 0.85]
Matching	ρ_ς	Beta (0.5, 0.2)	0.81	[0.68, 0.96]
Government	ρ_g	Beta (0.5, 0.2)	0.62	[0.48, 0.78]
Wage Barg	ρ_ξ	Beta (0.5, 0.2)	0.23	[0.09, 0.35]
Investment	ρ_i	Beta (0.5, 0.2)	0.57	[0.42, 0.72]
Preference	ρ_φ	Beta (0.5, 0.2)	0.61	[0.49, 0.73]
Labour supply	ρ_ϑ	Beta (0.5, 0.2)	0.90	[0.83, 0.96]
Shocks				
Technology	σ_a	InvGamma (0.01, 0.3)	0.01	[0.008, 0.012]
Matching	σ_ς	InvGamma (0.01, 0.3)	0.04	[0.040, 0.051]
Government	σ_g	InvGamma (0.01, 0.3)	0.01	[0.011, 0.015]
Wage Barg	σ_ξ	InvGamma (0.01, 0.3)	0.47	[0.179, 0.732]
Investment	σ_i	InvGamma (0.01, 0.3)	0.75	[0.560, 0.943]
Preference	σ_ϖ	InvGamma (0.01, 0.3)	0.01	[0.008, 0.017]
Labour supply	σ_ϑ	InvGamma (0.01, 0.3)	0.01	[0.004, 0.006]

The firm's bargaining power ξ is estimated between 0.63 and 0.96 and has a posterior mean

[13] The literature on identification issues in DSGE models includes among others Canova and Sala (2009); Qu and Tkachenko (2012); Koop et al. (2013); Qu and Tkachenko (2017).

[14] In Figures 11-12 in the appendix D, we plot the prior and the posterior distributions of structural parameters and shocks processes.

of 0.79. This is consistent with the estimates of Faccini et al. (2013) for the UK and Gertler et al. (2008) for the US and aligns with Hagedorn and Manovskii (2008) who suggest a lower bargaining power value for workers. Wage persistence ρ_w has a posterior mean of 0.98 which is substantial higher than its prior of 0.75. This estimate suggests that real wages are very rigid in Italy. Regarding persistence parameters, the neutral technology shock, the matching efficiency shock and the labour supply shock are highly persistent. The government consumption shock, the investment-specific technology shock and the time preference shock are moderately persistent. The wage persistence shock has a posterior mean estimate below its prior of 0.5. In terms of variances, the wage bargaining shock and the investment-specific technology shock have the most volatile shock estimates.

Finally, we have done a sensitivity analysis on the wage persistence parameter in order to evaluate how wage rigidities affect labour market dynamics. The simulated impulse responses are shown in Figures 14-19 in the appendix E. Our impulse responses show that accounting for wage rigidities drastically affects labour market dynamics and improves the relevance of shocks in explaining the volatility in labour market dynamics. Table 8 in the appendix compares the second-order moments from the estimated model with those emerging from the data.

The estimated model is able to replicate the stylized facts of Italian data. In the data, vacancies and real wages have procyclical co-movement with output. Unemployment exhibits a countercyclical co-movement with output. Unemployment and vacancies are more volatile than output. Real wages are less volatile than output. We find a negative co-movement of unemployment with vacancies both in the data (-0.76) and in the estimated model (-0.88). However, Furlanetto and Groshenny (2016b) point out that the correlation between unemployment and vacancies depends greatly on the degree of nominal rigidities (i.e. price stickiness) and on the persistence of the matching efficiency shock. Overall, our estimated model fits the data well as it replicates the relative volatilities of unemployment and vacancies and the strong persistence of labour market dynamics.

6 Sources of Fluctuations

In this section, we examine the short-run macroeconomic dynamics in the estimated model through the lens of impulse responses, variance decomposition and historical decomposition.

6.1 Impulse Responses

Figure 2-7 present the impulse responses to six structural shocks[15]. The horizontal axis represents the time horizon in quarters and the vertical axis denotes the deviation from the steady-state in percent.

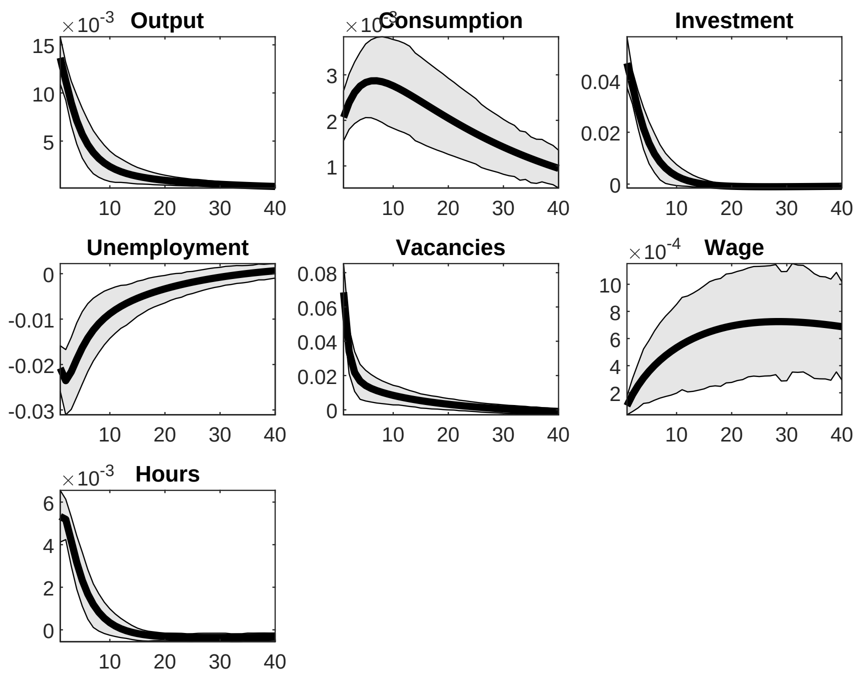

Figure 2: Responses to a neutral technology shock. The black line shows the posterior mean at each horizon. The shaded grey area indicates the 90 percent confidence intervals.

Figure 2 shows the responses to a one standard deviation positive neutral technology shock. A positive neutral technology shock improves the economy as whole and especially labour market conditions. Consumption and output expand on impact. This raises the productive capacity of firms and incites the latter to invest in additional capital and open up additional vacant positions in the labour market. As a result, investment and total hours rise sharply while unemployment plunges substantially over many quarters. The improvement in the MPL pushes up real wages on impact. The surge in real wages is initially slow due to wage rigidities but it is protracted.

Figure 3 presents the impulse responses to a one standard deviation positive matching efficiency shock. A positive matching efficiency shock enhances the efficiency of matching unfilled vacant positions with unemployed workers in the labour market. An expansionary matching efficiency

[15] Based on the findings of the unconditional variance decomposition, we do not report the responses to a government consumption shock since its role is only marginal.

shock leads to an improvement in labour market conditions and as a result the amount of unfilled vacant positions posted in the labour market goes up on impact. The response of vacancies is rather short-lived.

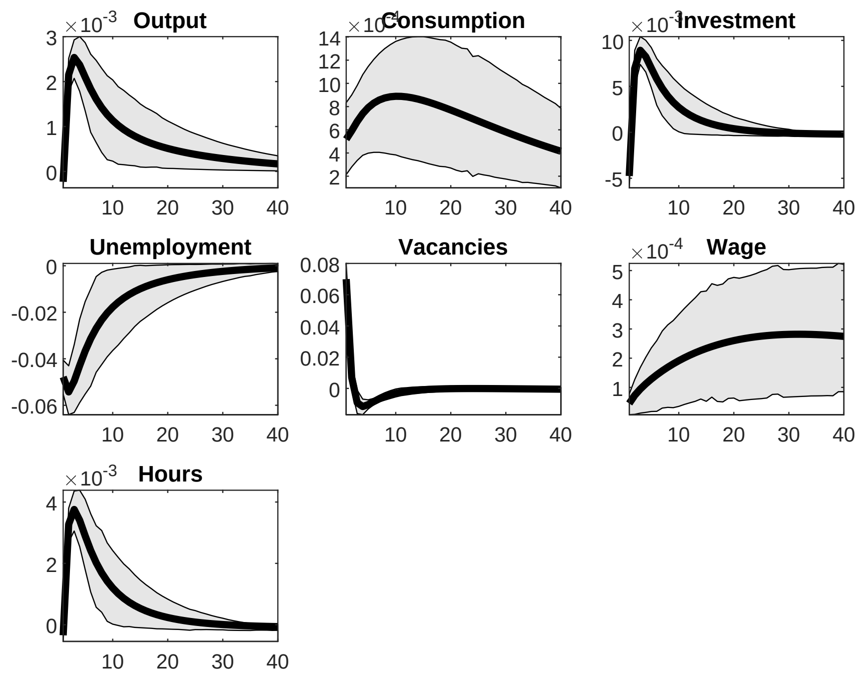

Figure 3: Responses to a matching efficiency shock. The black line shows the posterior mean at each horizon. The shaded grey area indicates the 90 percent confidence intervals.

The shock expands the economy's capacity to produce more goods, thereby increasing output and consumption on impact while unemployment plummets. The rise in output is statistically insignificant on impact but turns out significant after the first quarter. The increase in total hours generates a rise in output of the same magnitude. Investment drops on impact as firms do not find it profitable to expand capital facilities. The permanent increase in real wages is triggered by the improvement in MPL as labour market conditions tighten.

Figure 4 exhibits the impulse responses to a one standard deviation positive time preference shock. A time preference shock acts as a demand shock in our model and induces a rise in the degree of patience of households (i.e. a high degree of consumption smoothing). A positive time preference shock generates an increase in investment and a decrease in consumption on impact. The decline in consumption indicates that households are more patient and choose to trade off high investment for less consumption today.

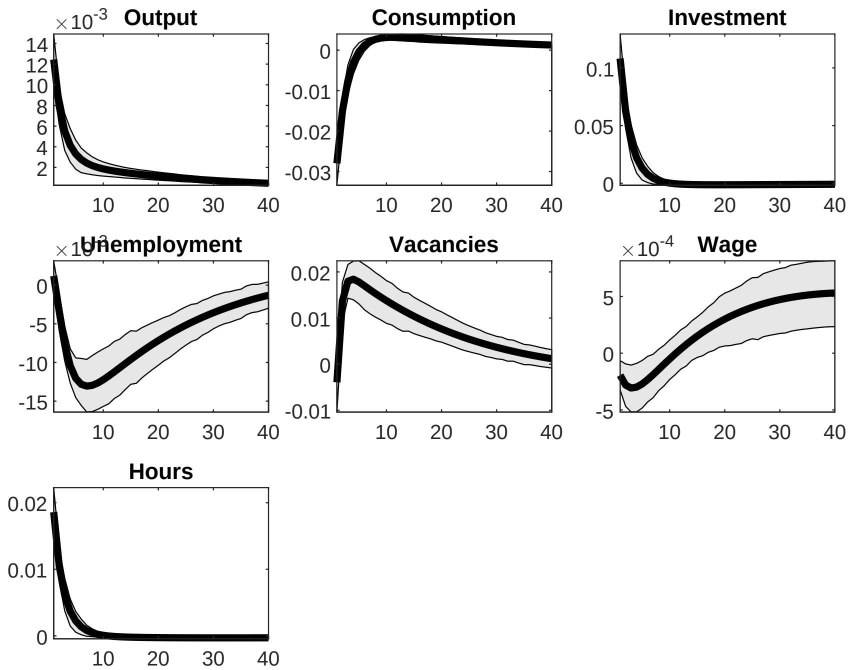

Figure 4: Responses to a time preference shock. The black line shows the posterior mean at each horizon. The shaded grey area indicates the 90 percent confidence intervals.

The increase in total hours triggers a rise in output on impact. The booming in output encourages firms to open up more vacant positions in the labour market. Firms hire additional workers and as a result, unemployment goes down. The decline in unemployment is hump-shaped and extended over several quarters. The shock generates a prolonged and hump-shaped fall in real wages. Investment raises up shortly as firms expand production capacities.

Figure 5 displays the impulse responses to a one standard deviation positive labour disutility shock. A positive labour disutility shock raises up the trade-off between leisure and labour. Consequently, this triggers a persistent drop in total hours. Unemployment goes up persistently as workers substitute leisure for labour. Real wages increase permanently due to a reduction in competition among unemployed workers in the labour market. The labour market tightens as firms post more unfilled positions for only few searching unemployed workers. The rise in vacancies is also permanent. The decline in total hours triggers a permanent decrease in consumption and investment.

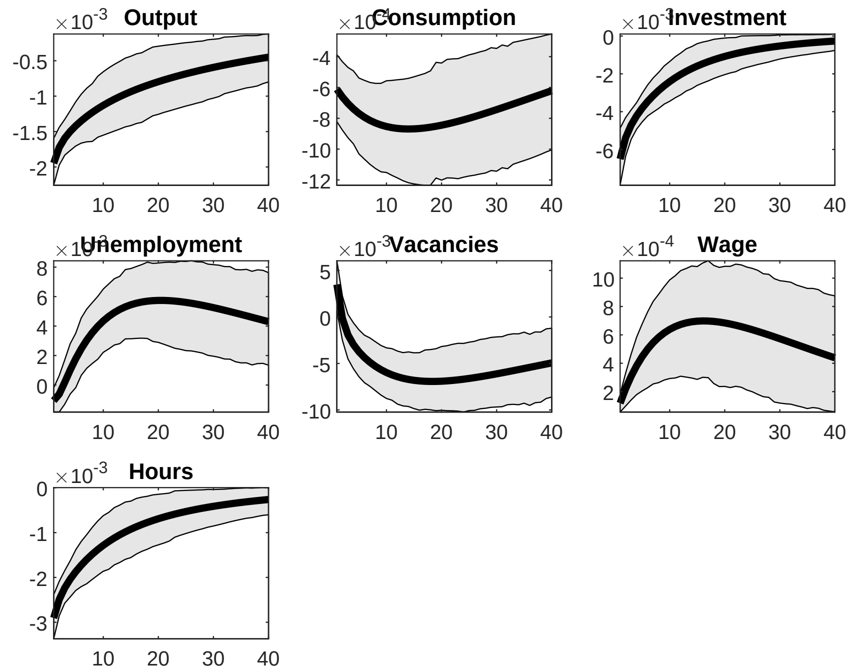

Figure 5: Responses to a labour disutility shock. The black line shows the posterior mean at each horizon. Thee shaded grey area indicates the 90 percent confidence intervals.

Figure 6 shows the impulse responses to a one standard deviation positive investment-specific technology shock. A positive investment-specific technology shock makes investment more productive. As investment becomes more productive for the desired capital stock, less investment is needed in the economy. Hence, consumption increases while investment drops on impact. This is consistent with the results of Faccini et al. (2013) for the UK. The decline in total hours triggers a decrease in output on impact. As output expands timidly in the short-run, vacancies and real wages increase permanently while unemployment plunges persistently. The decrease in unemployment is hump-shaped.

Figure 7 displays the impulse responses to a one standard deviation positive wage bargaining shock. An expansionary wage bargaining shock improves the firm's bargaining power in wage negotiations and incites the latter to expand production capacities. The labour market tightens but real wages drop as firms reap a great share of the surplus of the employment relationship. Firms post more vacant positions and hire additional unemployed workers searching in the labour market, thereby dropping unemployment permanently. The rise in total hours generates an increase in output.

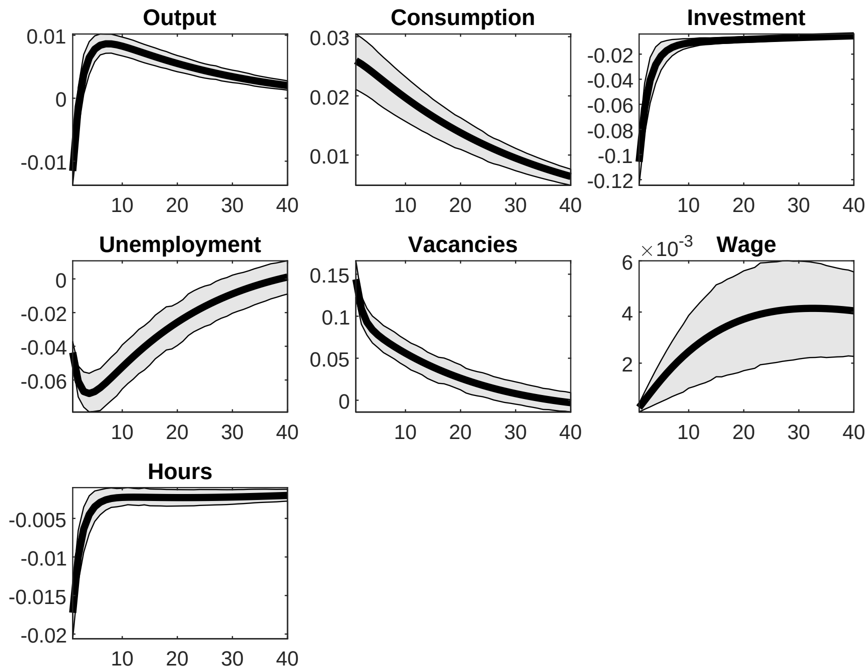

Figure 6: Responses to an investment-specific technology shock. The black line shows the posterior mean at each horizon. The shaded grey area indicates the 90 percent confidence intervals.

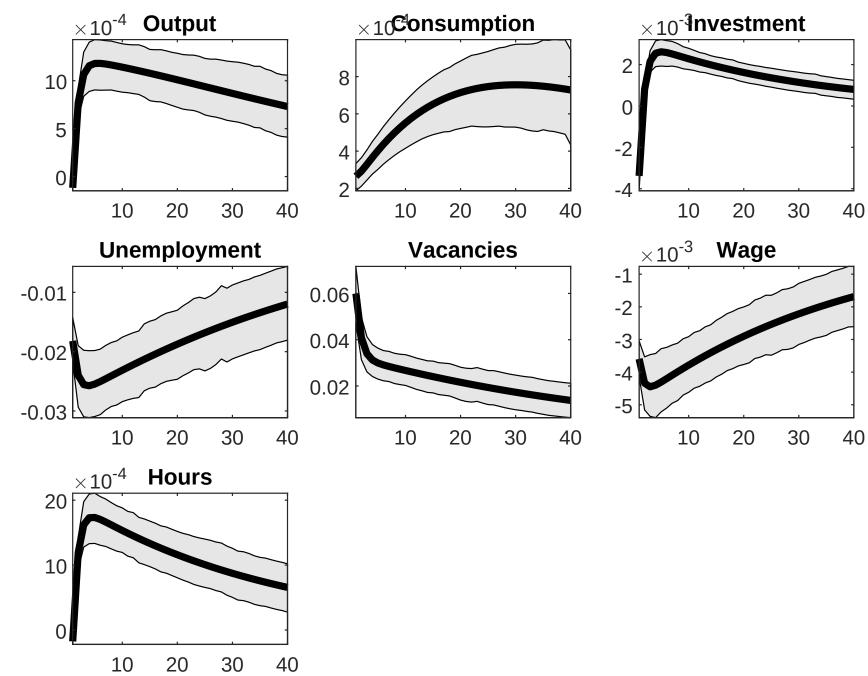

Figure 7: Responses to a wage bargaining shock. The black line shows the posterior mean at each horizon. The shaded grey area indicates the 90 percent confidence intervals.

6.2 Variance decomposition

Table 2 presents the forecast error variance decomposition of selected structural shocks at the infinite horizon based on the posterior mean. In Tables 4-7 in the appendix D, we report the forecast error variance decompositions at selected horizons[16] for selected variables.

Table 2: Variance decomposition

	Technology	Matching	Wage Barg	Investment	Labour Supply	Preference
Output	23	2	2	57	2	14
Consumption	2	0	0	86	0	11
Investment	13	1	0	47	1	40
Real Wage	2	1	31	64	2	1
Unemployment	3	17	18	59	2	3
Vacancies	5	4	19	68	2	3
Total Hours	7	5	5	47	4	33

The neutral technology shock and the investment-specific technology shock explain a great share (80 percent) of economic fluctuations in output. This is consistent with previous findings of Justiniano et al. (2010) and Gertler et al. (2008) for the US and Faccini et al. (2013) for the UK. The investment-specific technology shock accounts for most of economic volatility throughout horizons. The relevance of the matching efficiency and the wage bargaining shocks in explaining unemployment and vacancies fluctuations is quite substantial and it is consistent with Furlanetto and Groshenny (2016a).

The contribution of the matching efficiency shock in explaining output fluctuations is very limited in our model. This is consistent with Furlanetto and Groshenny (2016a) who find similar results for the US. Furlanetto and Groshenny (2016a) further show that the propagation of the matching efficiency shock depends on the presence of nominal rigidities and on the form of hiring costs (pre-match vs post-match). The importance of the time preference shock in driving macroeconomic dynamics is significant. The labour disutility shock only plays a marginal role in explaining economic fluctuations.

As for the variance decomposition at selected horizons, the neutral technology, the investment-specific technology and the time preference shocks account for a great share of economic fluctuations across horizons. The matching efficiency, the investment-specific technology and the wage bargaining shocks are the largest contributors to unemployment and vacancies fluctuations both at short and

[16]The forecast error variance decomposition shows the contribution of each shock in explaining economic fluctuations of a given variable in the short-run, the middle-run and the long-run.

long horizons. Finally, most of total hours fluctuations are driven by the time preference and the investment-specific technology shocks.

6.3 Historical decomposition

Figures 8-10 exhibit the historical decomposition of structural shocks for selected variables. The historical decomposition computes the contribution of structural shocks to the deviation of the variable (in level) from its forecasted path. In other words, it shows how much of the deviation of each variable from its predicted path is explained by structural shocks. The black line denotes the log deviation of each variable from its predicted forecast. The coloured bars show the share of each shock to the deviation of the variable of interest from its predicted path. Initial values refer to the part of the deviations not explained by shocks, but rather by unknown conditions.

Figure 8 shows the historical decomposition of output from 2004Q1 to 2018Q2. Our findings confirm the primacy of the neutral technology, the investment-specific technology and the time preference shocks in explaining business cycle fluctuations over time. The investment-specific technology and the time preference shocks contribute a lot in expanding output over time. The neutral technology shock has not been effective in boosting output during this period. Figure 9, presents the historical decomposition of unemployment. Both technology shocks, the matching efficiency shock, and the wage bargaining shock are responsible for the increase in unemployment over time. In contrast, the time preference and the investment-specific technology shocks have driven the reduction in unemployment during this period.

Figure 10 plots the historical decomposition of vacancies. The time preference and the investment-specific technology shocks are the main drivers of the rise in vacancies during this period. In contrast, the neutral technology shock, the investment-specific technology shock, and the wage bargaining shock have contributed to the reduction in vacancies over this period.

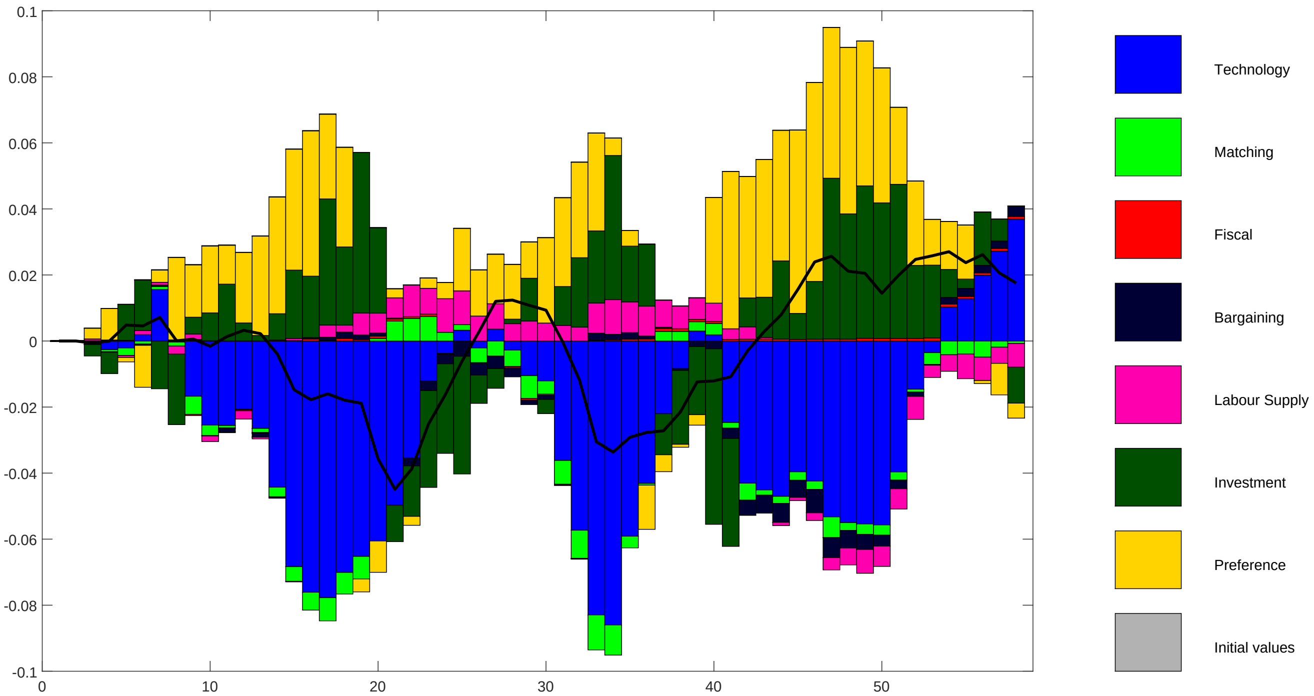

Figure 8: Historical Decomposition for Output

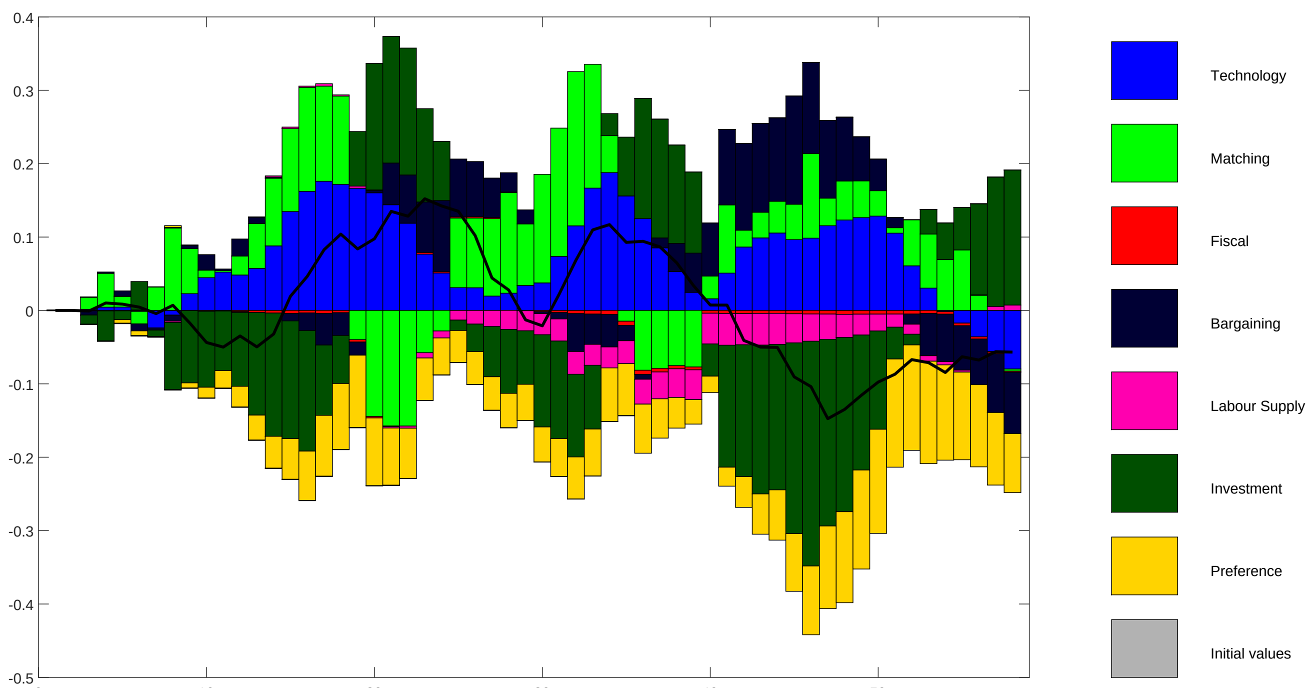

Figure 9: Historical Decomposition for Unemployment.

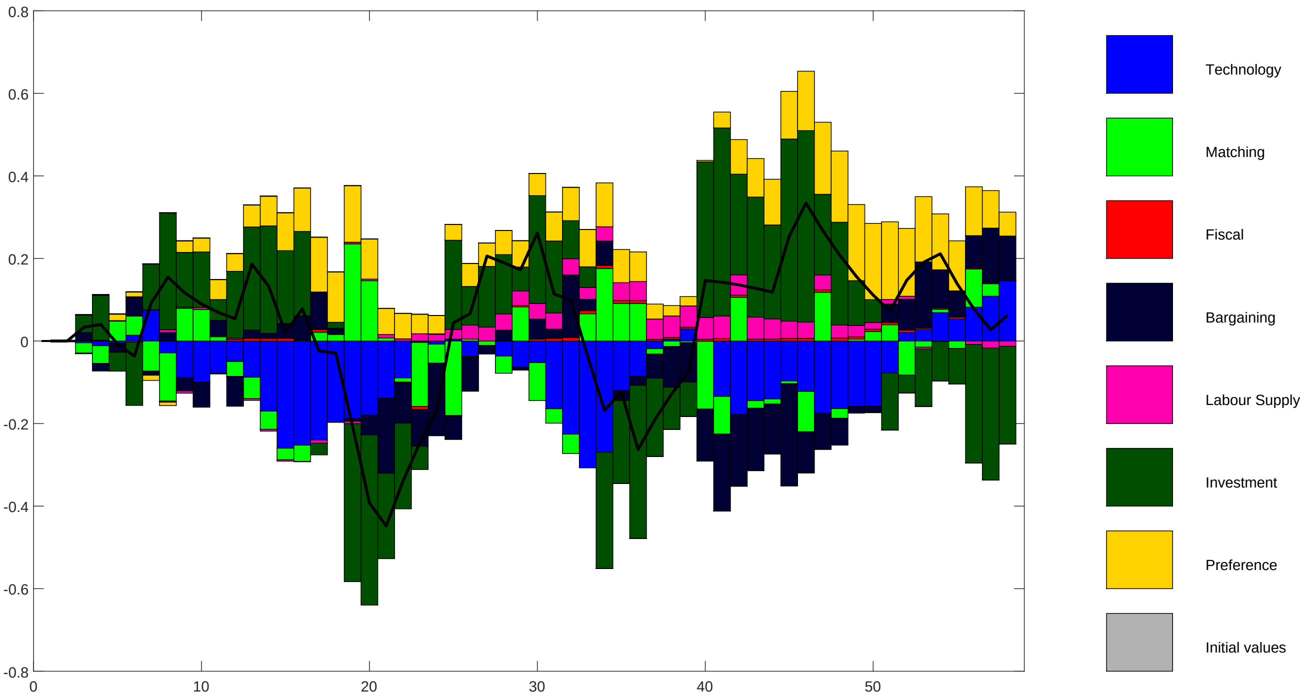

Figure 10: Historical Decomposition for Vacancies.

7 Conclusion

In this paper, we evaluate how Italian labour market institutions influence business cycle fluctuations. Regarding structural features of the Italian labour market, we document a reduction in employment protection legislation through a matching efficiency shock that enhances the efficiency at which vacant positions are matched with unemployed workers in the aggregate labour market.

We account for a weakening in firing costs via a disturbance that increases firms' bargaining power during wage negotiations. We introduce real wage rigidities via collective wage bargaining mechanism and (ii) the existence of sticky real wages.

We embed these labour market rigidities in a neoclassical DSGE model and estimate the latter on Italy data using Bayesian techniques in order to examine the macroeconomic effects of demand, supply, and labour market shocks on the macroeconomy and to quantify their significance for economic fluctuations.

Our results can be summarized as follows. Results that emerge from our forecast error variance decomposition show that both technology shocks, the time preference shock and the wage bargaining shock are among the greatest sources of economic fluctuations across horizons. Moreover, labour market shocks (i.e. the matching efficiency shock and the wage bargaining shock) explain a significant share of unemployment and vacancies fluctuations but their role is marginal for output fluctuations.

Our historical decomposition findings support that productivity-enhancing and investment supply-side policies together with consumption demand-side policies contributed to output and vacancies expansion and unemployment reduction during the sample period. Conversely, productivity-enhancing supply-side policies have not been very effective in decreasing unemployment.

We also discover that labour market relaxation policies have only marginally contributed to the reduction in unemployment throughout the sample period. In light of these results, our main message to policymakers is that they should (i) encourage additional changes in the labour market institutions, (ii) improve productivity-enhancing supply-side policies, and (iii) reinforce investment supply-side policies.

Eventually, in order to assess to what extent accounting for wage rigidities in the model influences labour market dynamics, we simulate short-run macroeconomic dynamics in the presence and in the absence of wage rigidities. Our results show that allowing for wage rigidities has an amplifying effect on labour market dynamics and helps the model fit the data well.

As future avenues, researchers may try to incorporate real rigidities (e.g. habit formation, investment adjustment costs, capital utilization), nominal rigidities (e.g. price stickiness) and additional labour market rigidities such as dual labour markets, endogenous firing costs, endogenous separation and evaluate how accounting for these rigidities influence labour market dynamics.

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Appendix

A Model Solution

A.1 Households

There is a continuum of identically and infinitely-lived agents who perfectly insure each other against labour market risks (Andolfatto, 1996). A share of employed households n_t works while the remaining share $1 - n_t$ searches for vacant positions in the labour market. The state space of the household $S_t^H = (k_t, n_t)$. The recursive problem of the representative household as follow:

$$W(S_t^H) = \max_{c_t^n, c_t^u, k_{t+1}} \left\{ [n_t U^n(c_t^n, \ell_t^n) + (1 - n_t) U^u(c_t^u, \ell_t^u)] + \beta \varphi_t E_t[W(S_{t+1}^H)] \right\} \tag{36a}$$

s.t

$$n_t c_t^n + (1 - n_t) c_t^u + k_{t+1} = (1 - \delta + r_t) k_t + w_t h_t n_t + \Pi_t - t_t \tag{36b}$$

$$n_{t+1} = (1 - s) n_t + f(\theta_t)(1 - n_t) \tag{36c}$$

Using the Lagrangian approach, the household's problem can be written as follows:

$$\begin{aligned} \mathcal{L} = & \left\{ [n_t U^n(c_t^n, \ell_t^n) + (1 - n_t) U^u(c_t^u, \ell_t^u)] + \beta \varphi_t E_t[W(S_{t+1}^H)] \right\} \\ & + \lambda_t \left[(1 - \delta + r_t) k_t + w_t h_t n_t + \Pi_t - t_t - n_t c_t^n - (1 - n_t) c_t^u - k_{t+1} \right] \\ & + \phi_t \left[(1 - s) n_t + f(\theta_t)(1 - n_t) - n_{t+1} \right] \end{aligned}$$

The optimal conditions of the household's problem are:

$$[c_t^n] : \lambda_t = U_1^n(c_t^n, \ell_t^n) \tag{37}$$

$$[c_t^u] : \lambda_t = U_1^u(c_t^u, \ell_t^u) \tag{38}$$

$$[k_{t+1}] : \lambda_t = \beta \varphi_t E_t[W_1(k_{t+1}, n_{t+1})] \tag{39}$$

Equations (37) and (38) state that the Lagrangian multiplier equals the marginal utility of consumption. Due to complete markets assumption, it follows that $c_t^n = c_t^u = c_t$. Plugging this new condition into (38) implies that $\lambda_t = \dfrac{1}{c_t}$. Equation (39) is the standard Euler condition. Applying the envelope theorem and taking the derivative of the value function with respect to k_t, it results that:

$$W_1(k_t, n_t) = (1 - \delta + r_t) \tag{40}$$

Iterating one period ahead, we have:

$$W_1(k_{t+1}, n_{t+1}) = (1 - \delta + r_{t+1}) \tag{41}$$

Therefore, the Euler condition follows that:

$$\lambda_t = \beta\varphi_t[\lambda_{t+1}(1 - \delta + r_{t+1})] \tag{42}$$

A.2 Firms

The representative firm produces output using a Cobb-Douglas technology with capital and labour inputs. Moreover, she takes the probability of filling a vacant position $q(\theta_t)$ and the wage bill $w_t h_t$ as given. The state space of the firm $S_t^F = (k_t, n_t)$. The recursive problem of the firm is formally presented as follows:

$$\Upsilon(S_t^F) = \max_{k_t, v_t, n_{t+1}} \left\{ a_t k_t^{\alpha}(n_t h_t)^{1-\alpha} - w_t h_t n_t - \omega v_t + \beta E_t[(\lambda_{t+1}/\lambda_t)\Upsilon(S_{t+1}^F)] \right\} \tag{43}$$

s.t

$$n_{t+1} = (1 - s)n_t + q(\theta_t)v_t \tag{44}$$

Using the Lagrangian approach, the firm's problem can be written as follows:

$$\begin{aligned} \mathcal{L} = &\left\{ a_t k_t^{\alpha}(n_t h_t)^{1-\alpha} - w_t h_t n_t - \omega v_t + \beta\varphi_t E_t[(\lambda_{t+1}/\lambda_t)\Upsilon(S_{t+1}^F)] \right\} \\ &+ \mu_t \left[(1 - s)n_t + q(\theta_t)v_t - n_{t+1}\right] \end{aligned}$$

The optimal conditions of the firm's problem are:

$$[k_t] : r_t = \alpha \frac{y_t}{k_t} \tag{45}$$

$$[n_{t+1}] : \mu_t = \beta \varphi_t E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \Upsilon_2(S^F_{t+1}) \right] \tag{46}$$

$$[v_t] : \omega = q(\theta_t)\mu_t \tag{47}$$

Applying the envelope condition and taking the derivative of the firm's value function with respect to n_t, it follows that:

$$\Upsilon_2(S^F_t) = \left((1-\alpha)\frac{y_t}{n_t} - w_t h_t + (1-s)\mu_t \right) \tag{48}$$

Iterating one period ahead, we obtain the following condition:

$$\Upsilon_2(S^F_{t+1}) = \left((1-\alpha)\frac{y_{t+1}}{n_{t+1}} - w_{t+1} h_{t+1} + (1-s)\mu_{t+1} \right) \tag{49}$$

Replacing(47) and (49) into (46), we obtain the following the job creation condition (JCC) of the firm:

$$\frac{\omega}{q(\theta_t)} = \beta \varphi_t E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \left((1-\alpha)\frac{y_{t+1}}{n_{t+1}} - w_{t+1} h_{t+1} + (1-s)\frac{\omega}{q(\theta_{t+1})} \right) \right] \tag{50}$$

A.3 Derivation of Nash Bargaining Wage and Hours

The marginal value of employment for the worker is given by:

$$\begin{aligned} W_2(k_t, n_t) = & \left\{ \lambda_t \left(w_t h_t + c^u_t - c^n_t \right) + (1-s)\beta\varphi_t E_t[W_2(S^H_{t+1})] \right\} \\ & - \left\{ (U^u(c^u_t, \ell^u_t) - U^n(c^n_t, \ell^n_t)) + f(\theta_t)\beta\varphi_t E_t[W_2(S^H_{t+1})] \right\} \end{aligned} \tag{51}$$

The marginal value of employment for the firm is:

$$\Upsilon_2(k_t, n_t) = \left\{ (1-\alpha)\frac{y_t}{n_t} - w_t h_t + (1-s)\beta\varphi_t E_t[(\lambda_{t+1}/\lambda_t)\Upsilon_2(S^F_{t+1})] \right\} \tag{52}$$

The Nash bargaining wage determination problem is given by:

$$w^{NB}_t h_t = \underset{w_t h_t}{\operatorname{argmax}} \left(W_2(S^H_t)/\lambda_t \right)^{1-\xi_t} \left(\Upsilon_2(S^F_t) \right)^{\xi_t} \tag{53}$$

The FOC with respect to $[w_t^{NB} h_t]$ is:

$$(1-\xi_t)\Upsilon_2(S_t^F) = \xi_t \left(W_2(S_t^H)/\lambda_t \right) \tag{54}$$

From the firm's side, we have the following optimal condition:

$$\beta\varphi_t E_t[(\lambda_{t+1}/\lambda_t)\Upsilon_2(S_{t+1}^F) = \frac{\omega}{q(\theta_t)} \tag{55}$$

Using condition (54) and replacing $W_2(S_t^H)/\lambda_t$ by:

$$\begin{aligned} W_2(S_t^H)/\lambda_t = &\left\{ \xi_t \left(w_t h_t + c_t^u - c_t^n \right) + (1-s-f(\theta_t))\xi_t \beta\varphi_t E_t \left[\frac{W_2(S_{t+1}^H)}{\lambda_t} \right] \right\} \\ &- \xi_t \left\{ \frac{(U^u(c_t^u, \ell_t^u) - U^n(c_t^n, \ell_t^n))}{\lambda_t} \right\} \end{aligned} \tag{56}$$

Replacing in (56) the fact that:

$$\xi_t \beta\varphi_t E_t \left(W_2(S_{t+1}^H)/\lambda_t \right) = (1-\xi_t)\beta\varphi_t E_t \left[(\lambda_{t+1}/\lambda_t)\Upsilon_2(S_t^F) \right] = \frac{\omega}{q(\theta_t)} \tag{57}$$

Using the FOC (54), it follows that :

$$(1-\xi_t)\left\{ (1-\alpha)\frac{y_t}{n_t} - w_t h_t + (1-s)\frac{\omega}{q(\theta_t} \right\} \quad = \left\{ \xi_t w_t h_t + (1-s-f(\theta_t))(1-\xi_t)\frac{\omega}{q(\theta_t)} \right\} - \xi_t \frac{U_t^u - U_t^n}{\lambda_t} \tag{58}$$

Using the fact that $f(\theta_t) = \theta_t q(\theta_t)$, the resulting Nash bargaining real wage is:

$$w_t^{NB} h_t = (1-\xi)\left[(1-\alpha)\frac{y_t}{n_t} \right] + \xi \left[\frac{U_t^u - U_t^n}{\lambda_t} + \frac{1-\xi}{\xi}\frac{\omega v_t}{1-n_t} \right]$$

Given the marginal values of employment for the household and the firm, the total surplus S_t of the two parties can be written as a sum of their surpluses:

$$S_t = \left(W_2(S_t^H)/\lambda_t \right) + \left(\Upsilon_2(S_t^F) \right)$$

Hours is perfectly determined in this economy, hence taking the MPL $F_{2,t} = \alpha \frac{y_t}{n_t h_t}$ as given and deriving the mutual surplus with respect to hours h_t, it follows that:

$$\frac{1}{\lambda_t} \frac{\psi_1 \vartheta_t}{(1-h_t)^\eta} = (1-\alpha) \frac{y_t}{n_t h_t}$$

A.4 Equilibrium conditions

$$m_t = \varsigma_t v_t^\gamma (e(1-n_t))^{1-\gamma} \tag{59}$$

$$u_t = 1 - n_t \tag{60}$$

$$q(\theta_t) = \frac{m_t}{v_t} \tag{61}$$

$$f(\theta_t) = \frac{m_t}{u_t} \tag{62}$$

$$\theta_t = \frac{v_t}{u_t} \tag{63}$$

$$n_{t+1} = (1-s)n_t + m_t \tag{64}$$

$$k_{t+1} = (1-\delta)k_t + \delta_t i_t \tag{65}$$

$$y_t = a_t \zeta k_t^\alpha (n_t h_t)_t^{1-\alpha} \tag{66}$$

$$h_t + \ell_t = 1 \tag{67}$$

$$n_t + h_t = th_t \tag{68}$$

$$R_t = \alpha \frac{y_t}{k_t} + 1 - \delta \tag{69}$$

$$1 = \beta \varphi_t E_t[\frac{c_t}{c_{t+1}} R_{t+1}] \tag{70}$$

$$\frac{\omega}{q(\theta_t)} = \beta \varphi_t E_t \left[\frac{c_t}{c_{t+1}} \left((1-\alpha) \frac{y_{t+1}}{n_{t+1}} - w_{t+1} h_{t+1} + (1-s) \frac{\omega}{q(\theta_{t+1})} \right) \right] \tag{71}$$

$$w_t^{NB} h_t = (1-\xi_t) \left[(1-\alpha) \frac{y_t}{n_t} + \frac{\omega v_t}{1-n_t} \right] + \xi_t c_t \left[U_t^u - U_t^n \right] \tag{72}$$

$$\psi_1 \vartheta_t (1-h_t)^{-\eta} c_t = (1-\alpha) \frac{y_t}{n_t h_t} \tag{73}$$

$$w_t = \rho_w w_{t-1} + (1-\rho_w) w_t^{NB} \tag{74}$$

$$y_t = c_t + i_t + g_t + \omega v_t \tag{75}$$

$$\ln a_t = (1-\rho_a) \ln \bar{a} + \rho_a \ln a_{t-1} + \epsilon_t^a \tag{76}$$

$$\ln \varsigma_t = (1-\rho_\varsigma) \ln \bar{\varsigma} + \rho_\varsigma \ln \varsigma_{t-1} + \epsilon_t^\varsigma \tag{77}$$

$$\ln \vartheta_t = (1-\rho_\vartheta) \ln \bar{\vartheta} + \rho_\vartheta \ln \vartheta_{t-1} + \epsilon_t^\vartheta \tag{78}$$

$$\ln \varpi_t = (1-\rho_\varpi) \ln \bar{\varpi} + \rho_\varpi \ln \varpi_{t-1} + \epsilon_t^\varpi \tag{79}$$

$$\ln \varepsilon_{i,t} = (1-\rho_{\varepsilon_i}) \ln \bar{\varepsilon_i} + \rho_{\varepsilon_i} \ln \varepsilon_{i,t-1} + \epsilon_t^i \tag{80}$$

$$\ln \varphi_t = (1 - \rho_\varphi) \ln \bar{\varphi} + \rho_\varphi \ln \varphi_{t-1} + \epsilon_t^\varphi \tag{81}$$

$$\ln \epsilon_{g_t} = (1 - \rho_g) \ln \epsilon_g + \rho_g \ln \epsilon_{g_{t-1}} + \nu_t^g \tag{82}$$

A.5 Steady-state

$$m^\star = sn^\star \tag{83}$$

$$u^\star = 1 - n^\star \tag{84}$$

$$v = \frac{m^\star}{q^\star} \tag{85}$$

$$\theta^\star = \frac{v^\star}{u^\star} \tag{86}$$

$$i = \delta k^\star \tag{87}$$

$$y^\star = 1 \tag{88}$$

$$h^\star = 1/3 \tag{89}$$

$$\ell^\star = 1 - h^\star \tag{90}$$

$$th^\star = n^\star h^\star \tag{91}$$

$$R^\star = \frac{1}{\beta} \tag{92}$$

$$k^\star = \frac{(\alpha y^\star)}{R^\star + 1 - \delta} \tag{93}$$

$$1 = \beta R^\star \tag{94}$$

$$w^\star n^\star h^\star = (1-\alpha) - \left[\frac{1}{\beta} - (1-s)\right] \frac{\omega v^\star}{s} \tag{95}$$

$$w^\star = \frac{w^\star n^\star h^\star}{n^\star h^\star} \tag{96}$$

$$\psi_1 = (\ell^\star)^{-\eta}(1-\alpha)\frac{y^\star}{n^\star h^\star} \tag{97}$$

$$\psi_2 = \frac{\Upsilon^u (1-\eta)}{(1-e)^{1-\eta}} \tag{98}$$

$$c^\star = y^\star - \delta k^\star - g^\star - \Phi \tag{99}$$

$$\zeta = \frac{y^\star}{k^{\star\alpha}(n^\star h^\star)^{1-\alpha}} \tag{100}$$

$$a^\star = 1 \tag{101}$$

$$\varsigma^\star = 1 \tag{102}$$

$$\varphi^\star = 1 \tag{103}$$

$$\vartheta^\star = 1 \tag{104}$$

$$\varepsilon_i^\star = 1 \tag{105}$$

$$\varpi^\star = 1 \tag{106}$$

$$g^\star = (1 - \frac{1}{\epsilon_g^\star})y^\star \tag{107}$$

B Data

Data are extracted from three main sources: Eurostat, ISTAT and OECD databases. All data are in levels and in nominal values and the frequency is quarterly. Nominal data are converted into real values by dividing by the GDP deflator. Real wage is found by diving nominal wages by the harmonized CPI. Real data are then transformed into per capita terms by dividing by a measure of population. All data are seasonally adjusted and expressed in natural logs.

Nominal GDP: This series is extracted from the Eurostat database on August 05, 2018 ($nama_1 0_g dp$)[17] and excludes the external sector. Real GDP is obtained by dividing the nominal GDP by the GDP deflator index from OECD database (2015Q3=1).

Private consumption: This series is defined as Household and NPISH final consumption expenditure nominal households in the Eurostat database. Real private consumption is obtained by dividing the series by the GDP deflator.

Private investment: This series is defined as gross fixed capital formation in the Eurostat database. Real private investment is obtained by dividing the series by the GDP deflator.

Nominal wage index: This series is defined as hourly earnings (MEI) index from the OECD database (2015Q3=100). The series is divided by the harmonized CPI index (from the OECD database) to obtain real wage index.

Unemployment rate: This series is defined as the ratio of unemployed people 15-64 years old to the total labour force (in percentage). Data on unemployed people and labour force are taken from ISTAT.

Vacancies: This series is defined as job vacancies-enterprises with employees from ISTAT. The series comes from the quarterly survey on job vacancies and hours worked (VELA) and is expressed

[17]The database includes data on GDP and its main components (output, expenditure and income).

in percent of the labour force.

Hours worked: This series is defined as the product of the average number of usual weekly hours of work in the main job ($lfsqewhuis$) from Eurostat and the number of employment people (measured in thousand) from ISTAT. The latter is defined as the difference between the labour force and the number of unemployed people.

Population: This series is defined as the labour force (15-64 years old) (measured in thousand) from ISTAT.

Table 3: Agnostic Priors

Parameters	Description	Values
β	Discount factor	0.9926
α	Capital share	0.33
δ	Capital depreciation rate	0.025
$g^{\star}$	Exogenous spending/output ratio	0.20
ω	Vacancy posting cost	0.13
Φ	Total hiring cost	0.01
e	Job search effort	0.17
$h^{\star}$	Share of time devoted to work	0.33
s	Exogenous separation rate	0.06
$u^{\star}$	Steady state unemployment rate	0.09
ψ_1	Leisure parameter for employed	1.33
ψ_2	Leisure parameter for unemployed	0.99
$q^{\star}$	Vacancy filling rate	0.71
γ	Matching elasticity	0.5

C Log-Linear Model

In what follows, we present the log-linearized version of our model used for the estimation. We also include observables.

$$\hat{m}_t = \hat{\varsigma}_t + \gamma\hat{v}_t + (1-\gamma)\hat{u}_t \tag{108}$$

$$n^{\star}\hat{n}_t + u^{\star}\hat{u}_t = 0 \tag{109}$$

$$\hat{q}_t = \hat{m}_t - \hat{v}_t \tag{110}$$

$$\hat{f}_t = \hat{m}_t - \hat{u}_t \tag{111}$$

$$\hat{\theta}_t = \hat{v}_t - \hat{u}_t \tag{112}$$

$$n^\star \widehat{n_{t+1}} = (1-s)n^\star \hat{n}_t + m^\star \hat{m}_t \tag{113}$$

$$k^\star \widehat{k_{t+1}} = (1-\delta)k^\star \hat{k}_t + i^\star \varrho^\star \hat{i}_t + i^\star \varrho^\star \hat{\varrho}_t \tag{114}$$

$$\hat{y}_t = \hat{a}_t + \alpha\hat{k}_t + (1-\alpha)[\hat{n}_t + \hat{h}_t] \tag{115}$$

$$h^\star \hat{h}_t + \ell^\star \hat{\ell}_t = 0 \tag{116}$$

$$th^\star = \hat{n}_t + \hat{h}_t \tag{117}$$

$$R^\star \hat{R}_t = \alpha \frac{y^\star}{k^\star}(\hat{y}_t - \hat{k}_t) \tag{118}$$

$$E_t[\varphi_t + \hat{c}_t - \widehat{c_{t+1}} + \widehat{r_{t+1}}] = 0 \tag{119}$$

$$\begin{aligned}\frac{\omega v^\star}{m^\star}[\hat{v}_t - \hat{m}_t] = \beta\varphi^\star E_t[&\left((1-\alpha)\frac{y^\star}{n^\star} - w^\star h^\star + (1-s)\frac{\omega v^\star}{m^\star}\right)\hat{\varphi}_t + \left((1-\alpha)\frac{y^\star}{n^\star} - w^\star h^\star + (1-s)\frac{\omega v^\star}{m^\star}\right)\hat{c}_t \\ &+ \left(w^\star h^\star - (1-\alpha)\frac{y^\star}{n^\star} - (1-s)\frac{\omega v^\star}{m^\star}\right)\widehat{c_{t+1}} + (1-\alpha)\frac{y^\star}{n^\star}[\widehat{y_{t+1}} - \widehat{n_{t+1}}] \\ &- w^\star h^\star(\widehat{w_{t+1}} + \widehat{h_{t+1}}) + (1-s)\frac{\omega v^\star}{m^\star}(\widehat{v_{t+1}} - \widehat{m_{t+1}})]\end{aligned} \tag{120}$$

$$
\begin{aligned}
w^\star h^\star[\hat{w_t^{NB}} + \hat{h_t}] = (1-\alpha)\frac{y^\star}{n^\star}[\hat{y_t} - \hat{n_t}] + \frac{\omega v^\star}{u^\star}\,[\hat{v_t} - \hat{u_t}] + \xi\varpi^\star(1-\alpha)\frac{y^\star}{n^\star}[\hat{n_t} - \hat{y_t} - \epsilon\hat{\varpi_t}] \\
+ \xi\varpi^\star\frac{\omega v^\star}{u^\star}[\hat{u_t} - \hat{v_t} - \hat{\varpi_t}] + \xi\varpi^\star c^\star\psi_2\frac{(1-e)^{1-\eta}}{1-\eta}[\hat{c_t} + \hat{\varpi_t}] \\
- \xi\varpi^\star c^\star\psi_1\vartheta^\star\frac{(\ell^\star)^{1-\eta}}{1-\eta}\left[\hat{c_t} + \hat{\vartheta_t} + \hat{\varpi_t} + (1-\eta)\hat{\ell_t}\right]
\end{aligned} \tag{121}
$$

$$
-\eta\hat{\ell_t} + \hat{c_t} + \hat{\vartheta_t} = \hat{y_t} - \hat{n_t} - \hat{h_t} \tag{122}
$$

$$
\hat{w_t} = \rho_w\hat{w_{t-1}} + (1-\rho_w)\hat{w_t^{NB}} \tag{123}
$$

$$
y^\star\hat{y_t} = c^\star\hat{c_t} + i^\star\hat{i_t} + g^\star\hat{g_t} + \omega v^\star\hat{v_t} \tag{124}
$$

$$
\hat{g_t} = \epsilon_t^g \tag{125}
$$

$$
a_t = \rho_a a_{t-1} + \epsilon_t^a \tag{126}
$$

$$
\varsigma_t = \rho_\varsigma\varsigma_{t-1} + \epsilon_t^\varsigma \tag{127}
$$

$$
\varepsilon_{i,t} = \rho_{\varepsilon_i}\varepsilon_{i,t-1} + \epsilon_t^i \tag{128}
$$

$$
\vartheta_t = \rho_\vartheta\vartheta_{t-1} + \epsilon_t^\vartheta \tag{129}
$$

$$
\varphi_t = \rho_\varphi\varphi_{t-1} + \epsilon_t^\varphi \tag{130}
$$

$$
\varpi_t = \rho_\varpi\varpi_{t-1} + \epsilon_t^\varpi \tag{131}
$$

$$\epsilon_t^g = \rho_g \epsilon_{t-1}^g + \nu_t^g \tag{132}$$

D Bayesian estimation

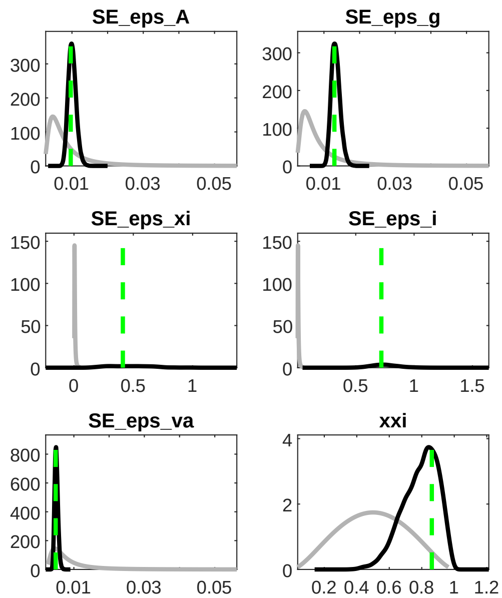

Figure 11: Prior and posterior distributions. The horizontal axis displays part of the support of the prior distribution, while the vertical axis shows the corresponding density. The grey line shows the prior density. The black line displays the density of the posterior distribution. The green horizontal line depicts the posterior mode.

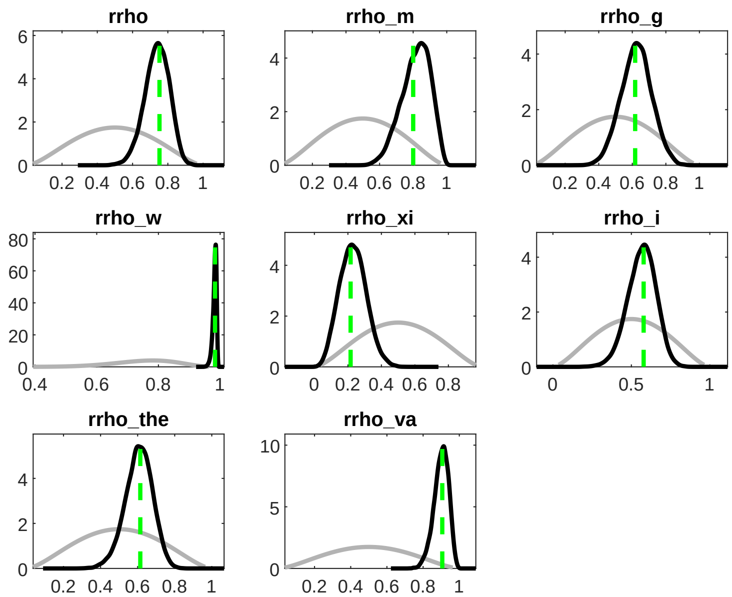

Figure 12: Prior and posterior distributions

.

Table 4: Output conditional variance decomposition

	On impact	4 year	9 year	Long-run
Technology	39	45	35	23
Matching	0	2	2	2
Wage Barg	0	0	1	0
Investment	28	25	41	57
Labour Supply	1	1	1	2
Preference	32	26	26	14

Table 5: Unemployment conditional variance decomposition

	On impact	4 year	9 year	Long-run
Technology	9	6	5	3
Matching	46	31	24	17
Wage Barg	7	8	10	18
Investment	39	54	60	59
Labour Supply	0	0	0	2
Preference	0	1	2	3

Table 6: Vacancies conditional variance decomposition

	On impact	4 year	9 year	Long-run
Technology	14	9	7	5
Matching	14	7	5	4
Wage Barg	11	11	12	19
Investment	61	71	73	68
Labour Supply	0	0	0	2
Preference	0	2	2	3

Table 7: Total hours conditional variance decomposition

	On impact	4 year	9 year	Long-run
Technology	5	8	8	7
Matching	0	4	6	5
Wage Barg	0	1	2	5
Investment	44	40	40	47
Labour Supply	1	3	3	4
Preference	50	44	42	33

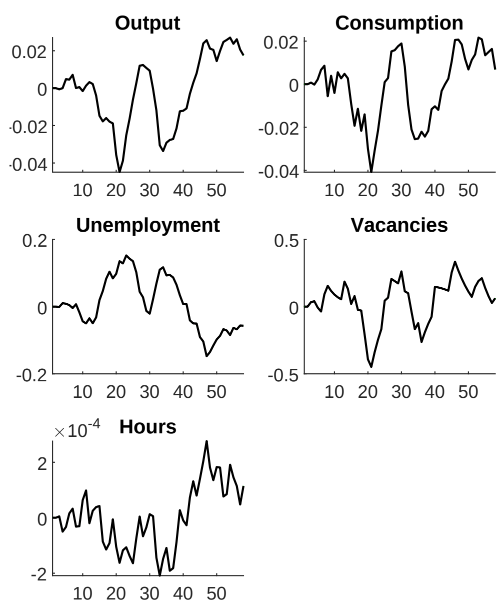

Figure 13: Smoothed variables estimated from the Kalman smoother.

E Sensitivity on wage rigidity parameter

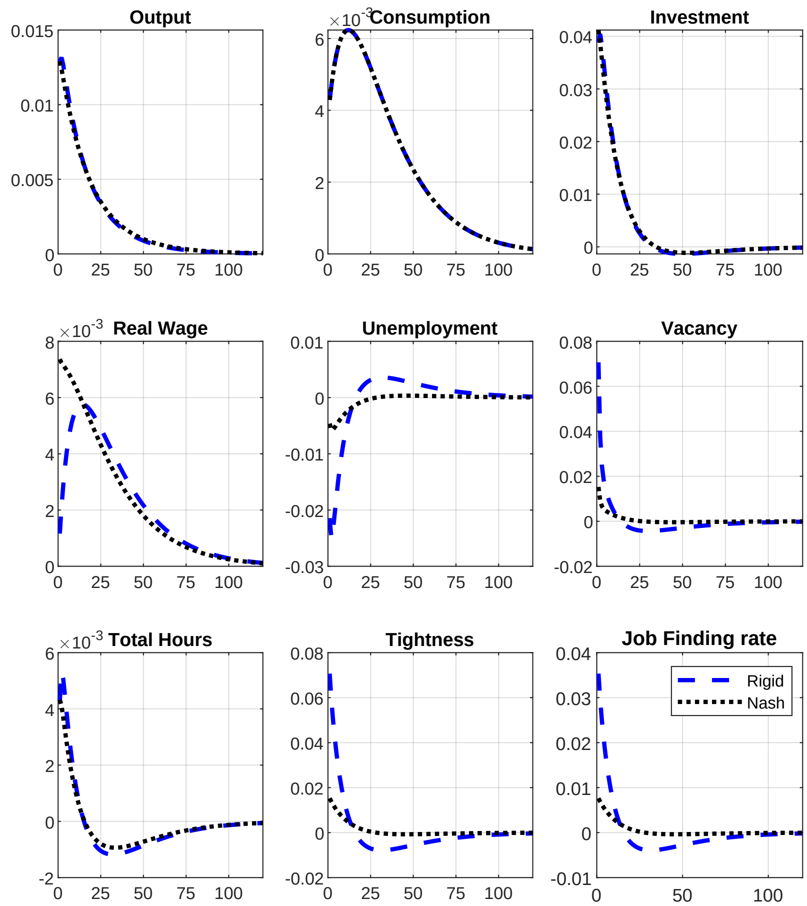

Figure 14: Impulse responses to a neutral technology shock. The dashed lines denote the presence of wage rigidities. The dotted lines denote the absence of wage rigidities.

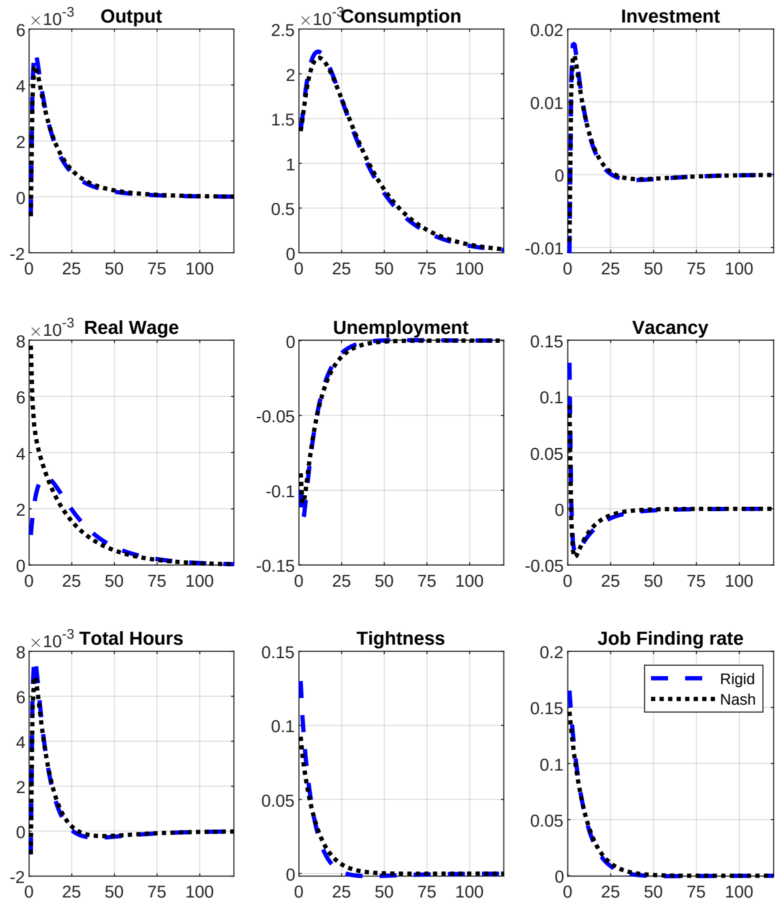

Figure 15: Impulse responses to a matching efficiency shock. The dashed lines denote the presence of wage rigidities. The dotted lines denote the absence of wage rigidities.

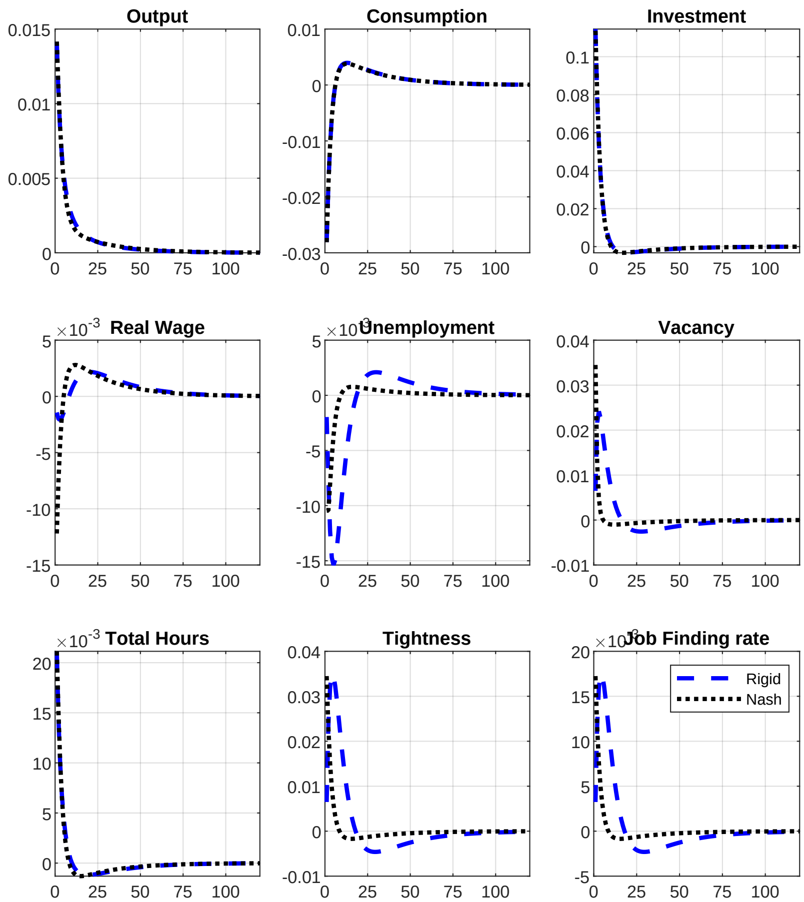

Figure 16: Impulse responses to a time preference shock. The dashed lines denote the presence of wage rigidities. The dotted lines denote the absence of wage rigidities.

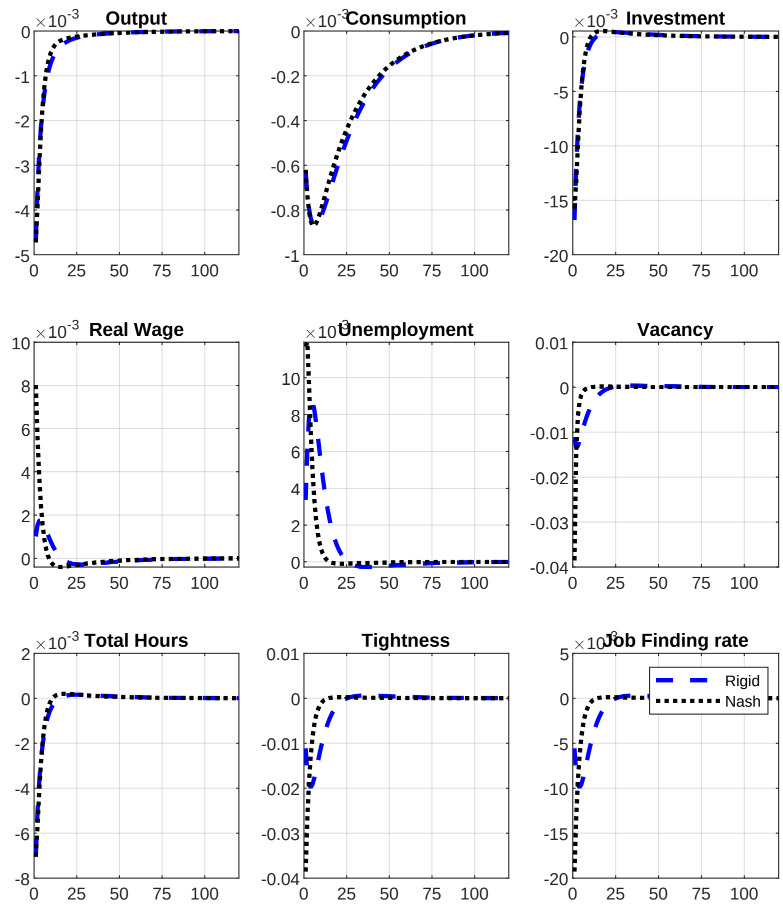

Figure 17: Impulse responses to a labour disutility shock. The dashed lines denote the presence of wage rigidities. The dotted lines denote the absence of wage rigidities.

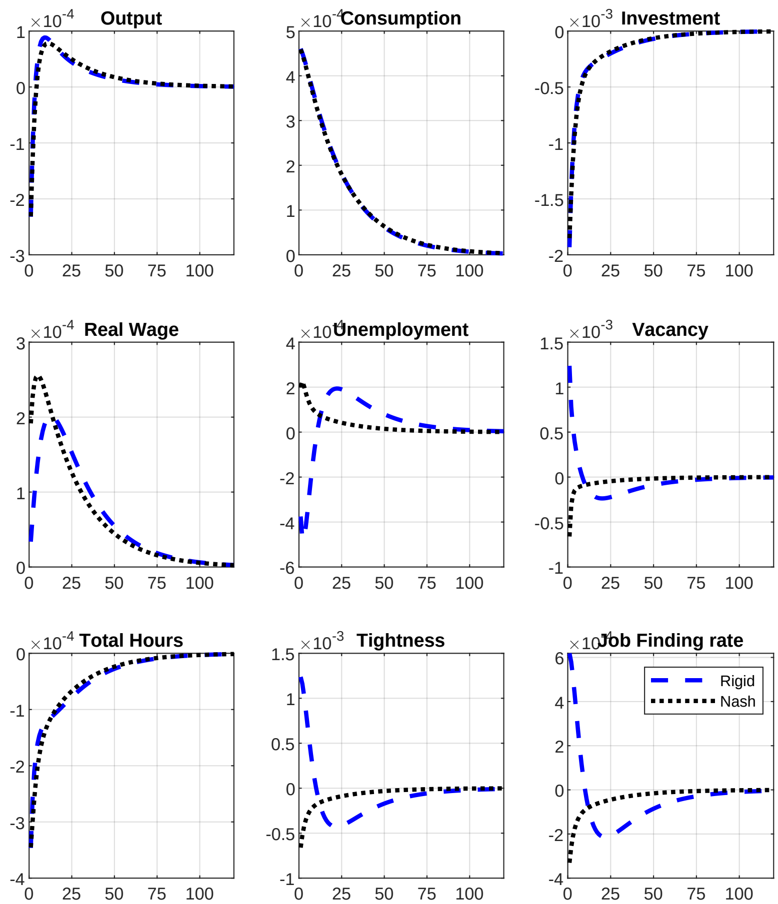

Figure 18: Impulse responses to an investment-specific technology shock. The dashed lines denote the presence of wage rigidities. The dotted lines denote the absence of wage rigidities.

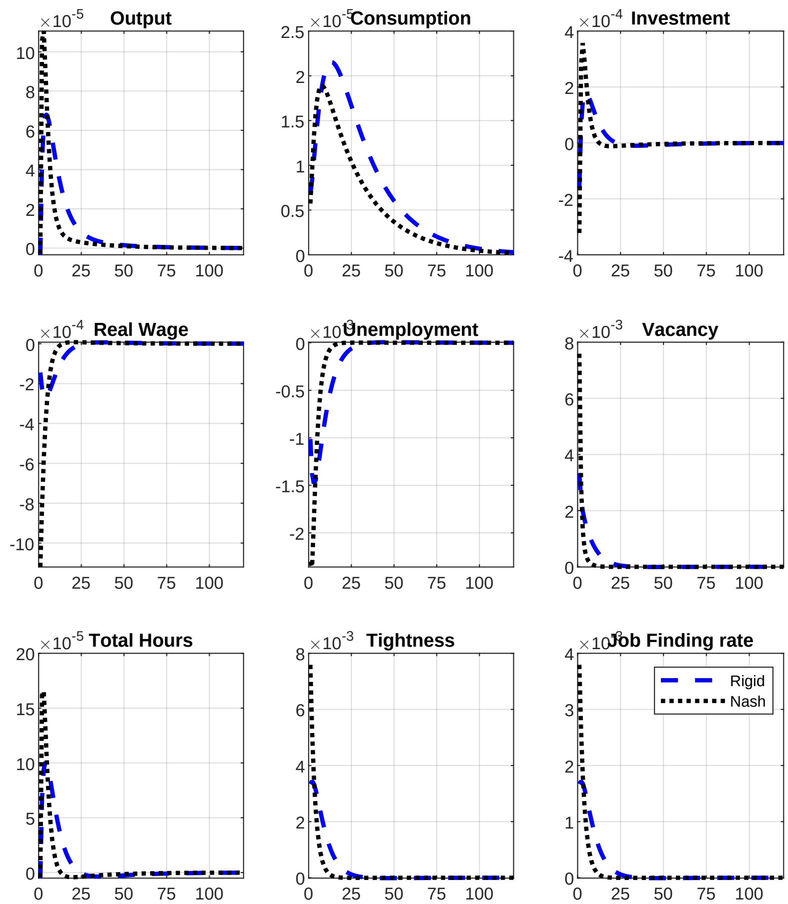

Figure 19: Impulse responses to a wage bargaining shock. The dashed lines denote the presence of wage rigidities. The dotted lines denote the absence of wage rigidities.

Table 8: Cyclical properties of data and estimated model

	Italy			Model		
	[1]	[2]	[3]	[1]	[2]	[3]
Real Wage	0.43	0.89	0.09	0.83	0.99	0.24
Unemployment	4.13	0.95	-0.86	6.57	0.97	-0.64
Vacancies	8.84	0.86	0.82	8.14	0.86	0.51

Notes: Column [1] is the relative standard deviation with respect to output. Column [2] denotes the persistence $Corr(x_t, x_{t-1})$. Column [3] denotes contemporaneous co-movement with output.