BANK FOR INTERNATIONAL SETTLEMENTS

BIS Working Papers

No 903

Bargaining power and the Phillips curve: a micro-macro analysis

by Marco J Lombardi, Marianna Riggi and Eliana Viviano

Monetary and Economic Department

November 2020

JEL classification: E31, E32, J23, J60.

Keywords: Low inflation, bargaining power, Phillips curve.

This publication is available on the BIS website (www.bis.org).

ISSN 1020-0959 (print)
ISSN 1682-7678 (online)

Bargaining power and the Phillips curve: a micro-macro analysis*

Marco J. Lombardi — BIS

Marianna Riggi — Bank of Italy

Eliana Viviano — Bank of Italy

November 2, 2020

Abstract

We use a general equilibrium model to show that a decrease in workers' bargaining power amplifies the relative contribution to the output gap of adjustments along the extensive margin of labour utilization. This mechanism reduces the cyclical movements of marginal cost (and inflation) relative to those of the output gap. We show that the relationship between bargaining power and adjustments along the extensive margin (relative to the intensive margin) is supported by microdata. Our analysis relies on panel data from the Italian survey of industrial firms. The Bayesian estimation of the model using euro-area aggregate data covering the 1970-1990 and 1991-2016 samples confirms that the decline in workers' bargaining power has weakened the inflation-output gap relationship.

JEL Classification: E31, E32, J23, J60.

Keywords: Low inflation, Bargaining power, Phillips curve.

*We thank Olivier J. Blanchard, Flora Budianto, Federico Cingano, Jeffrey Fuhrer, Benoit Mojon, Stefano Neri, Athanasios Orphanides, Luiz Pereira, Mario Pietrunti, Paolo Sestito, Frank Smets, Roberto Torrini, Egon Zakrajsek and Roberta Zizza for helpful comments and discussions. This project was conceived when Marco J. Lombardi was visiting Banca d'Italia. Part of this project was completed while Marianna Riggi was visiting the Massachussets Institute of Technology. Their hospitality is gratefully acknowledged. The views expressed here do not necessarily reflect those of Banca d'Italia or of the BIS.

1 Introduction

The relationship between inflation and economic activity – the so-called Phillips curve – is one of the cornerstones of macroeconomics. Yet in recent decades our understanding of the Phillips curve has been repeatedly called into question, as in most advanced economies inflation dynamics have remained muted in spite of wide swings in output and unemployment.

Most researchers would agree that the empirical relationship between output and inflation has become elusive since the Great Moderation (Blanchard 2016). Figure 1 reports rolling estimates (based on 20-years windows) of the slope of the Phillips curve, based on a panel of six advanced economies (France, Germany, Italy, Japan, United Kingdom, United States). More specifically, we estimate the equation $\pi_{i,t}= \pi^*_{i,t}+\beta\widetilde{y}_{i,t}+u_{i,t}$, where $\pi_{i,t}$ is core inflation, $\pi^*_{i,t}$ is a measure of trend inflation[1] and $\widetilde{y}_{i,t}$ is either the output (left-hand panel) or the unemployment gap (right-hand panel). The correlation has substantially declined since the mid-1980s.

In this paper we relate the vanishing relationship between inflation and the output gap to the erosion of workers' bargaining power. We argue that the allocation of bargaining power affects the cyclical relationship between price dynamics and measures of slack, through its impact on the relative importance of the extensive and the intensive margin of labour adjustment.

In a nutshell, our argument is that a given change in the output gap may give rise to very different inflation reactions depending on the relative contribution of the number of workers (the extensive margin) and hours per employee (the intensive margin) in the cyclical adjustment of labour input. Following a given shock that causes a certain variation in the output gap, the larger is the contribution of employment relative to hours per worker, the smaller the response of unit labor cost and, hence, that of inflation. The reason is that the marginal wage (i.e. the derivative of the real wage relative to hours per employee), which is the main driver of unit labour costs, increases with hours per worker.[2] We argue that the long-standing weakening in workers' bargaining power has induced firms to react to shocks by resorting more to changes in the extensive rather than in the intensive margin of labour, this being a key factor behind the observed flattening of the Phillips curve.

[1] Trend inflation is computed as the four-quarter moving average of past core inflation. This measure was shown to be a good proxy for inflation expectations in the setting of reduced-form Phillips curves by Atkeson and Ohanian (2001).

[2] This holds provided that the elasticity of hours supply is finite.

As labour markets and the wage setting mechanism are key ingredients of the relationship between economic activity and inflation, the idea that workers' bargaining power might be a relevant driver of inflation may appear natural. In a cost-push view of inflation, under tight labour markets workers securing higher wages will lead to higher production costs and eventually higher consumer prices. Yet, while this pertains to the level of inflation, the role of bargaining power for the relationship between price dynamics and slack (the slope of the Phillips curve) is not straightforward. In order to explore this channel from both a micro and a macro perspective, we proceed in three steps.

We first use a general equilibrium model with search and matching frictions in the labour market and infrequent price adjustment, based on Thomas (2011). In general equilibrium, firms would adjust their demand for labour based on the amount of the surplus they can extract from the employment relationship. If firms are able to adjust the number of hours of their workers, the allocation of bargaining power may affect firms' incentive to vary hours per employee (i.e. the intensive margin of labour) rather than the number of workers to hire/fire (i.e. the extensive one). We show that in an economy where workers only get a small part of the surplus, the contribution of employment relative to hours per worker to the adjustment of labour input is larger compared to a regime characterized by higher workers' bargaining power. The reason is that when a shock hits, firms' marginal benefit from changing the number of employees instead of hours per worker increases with the share of the surplus firms would accrue from new employment relationship. Hence, as the marginal wage increases in hours per employee, in a regime characterized by low workers' bargaining power, the cyclical movements of inflation associated with any given output gap variation turn out smaller relative to the ones that would emerge if workers bargaining power was high. We then interpret the decline in bargaining power registered since the mid-eighties as a possible cause of the flattening of the Phillips curve.

Moving to a micro perspective, we then check whether the key mechanism of our theoretical model – i.e. the relationship between bargaining power and firms' (relative) propensity to adjust along the extensive margin – can be detected in microdata. We use firm-level data drawn from a survey (conducted yearly by the Bank of Italy) of Italian non-financial firms with at least 20 employees (INVIND). Firms are asked to report the share of workers who are members of unions - a measure of firm-level union density that we use as a proxy for workers' bargaining power.[3] We find that in firms with a higher degree of unionization, the reaction of the extensive margin to shocks is smaller and the

[3] To limit the impact of endogeneity of firms' adjustments and workers'unionization we take the level of unionisation registered in 2010 and look at adjustments in the following years.

one of the intensive margin is larger. We also find that, for given demand shock, firms' price changes are smaller when workers are less unionized, as suggested by the theoretical model.[4]

Finally, we estimate the general equilibrium model with euro-area data over two samples, 1970-1990 and 1990-2017. Our estimates point to a large decline in the bargaining power of workers, who achieved more than half of the joint surplus in the first period while being paid their reservation salary in the average of the more recent years. Together with a decline in the frequency of price adjustment, this has strongly reduced the inflation-output gap multiplier by means of an increase in the contribution of the extensive margin of labour relative to the intensive one, in driving output gap fluctuations.

The literature on the apparent flattening of the Phillips curve is huge, ranging from the role of better monetary policy as obfuscating factors (McLeay and Tenreyro 2020) to the idea of hidden slack (see Lane 2019 and references therein) or more cyclical explanations, like the role of financial frictions (Gilchrist et al 2017). Some commentators have argued for the death of the Phillips curve and the need to seek for alternative theories of inflation (see Farmer and Nicolò 2018). In this large context, our paper speaks to the contributions trying to identify secular trends that may have weakened the relationship between inflation and economic activity. Such trends range from demographics (Daly, Hobijn, and Pyle 2016, Mojon and Ragot 2019, Juselius and Takats 2018) to innovation and globalization (Auer, Borio, Filardo 2017). The increase in competitive pressures following the ICT revolution and globalization has led to an increase in strategic complementarities in price settings, which has flattened the Phillips curve (Riggi and Santoro 2015). Besides, the secular decline in trend inflation lowers the inflation-output gap trade off (Riggi and Santoro 2015)[5] and may induce firms to change prices less often, another factor which lowers the inflation-output gap multiplier (Ball et al 1988).[6] More recently, Stansbury and

[4] We obtained qualitatively similar results by using a cross section of firms in different European countries, drawn from the so-called WDN survey. We show these results in the Appendix.

[5] Riggi and Santoro (2015) show that the well-known result of the trend inflation literature, according to which the slope of the Phillips curve is decreasing with the level of trend inflation is valid only in a Dixit-Stiglitz world. Whereas in a Dixit-Stiglitz world the slope of the new Keynesian Phillips curve becomes steeper under lower trend inflation (Ascari, 2004), in the more general case of variable demand elasticity, the presence of strategic complementarities inverts the sign of the derivative and the Phillips curve flattens as trend inflation rate declines.

[6] Setting aside secular trends, there are also "cyclical" explanations. Among them, for instance, financial frictions (Gilchrist et al 2017, Duca et al 2017) and the persistence of the business cycle phase (Conti, Guglielminetti and Riggi 2019) reduce the reaction of prices to slack. Moreover, the low price dynamics observed in recent years might also reflect the inadequacy of standard measures to fully capture economic slack. On this respect, among various measures of slack, those related to the labour market, e.g. relying on different definitions of unemployment and the pool of potential workers, have gained a

Summers (2020) provide evidence of the decline of workers bargaining power in the US and, like ourselves, argue that the lower bargaining power can be seen as an explanation for the flattening of the Phillips curve. With respect to their paper, we propose a theoretical model in which the link between bargaining power and the flattening of Phillips curve emerges explicitly.

Our paper speaks also to the analysis in Bulligan, Guglielminetti and Viviano (2019), who show that the wage Phillips curve depends not only on the unemployment gap but also on the gap of hours per worker. Bulligan, et al. (2019) use a partial equilibrium model with firm adjustment costs and workers' disutility from work and show that the sign of the correlation between wages and hours per-worker depends on two factors: workers' disutility of work and the costs for firms to adjust the extensive vs. the intensive margin. The authors also argue that differences in the sensitivity of wages to the hours gap depend on the structural features of the labour market that affect the adjustment cost of one margin relative to the other. In our paper we argue that the relative importance of the two margins has changed over time due to the erosion in workers' bargaining power and we show that this change was a key driver of the flattening of the Phillips curve[7]

The paper is organized as follows. In the next section we present some descriptive evidence which motivates our analysis. Section 3 lays out the theoretical model and derives its predictions on the role of bargaining power for the relative movement of inflation and output gap. Section 4 uses micro data in order to verify that the key mechanism is at play at the firm level. Section 5 estimates the model with euro-area data. Section 6 concludes.

2 Motivating evidence

Labour markets in advanced economies have been subject to considerable structural changes over the past decades. Among (and related to) these long-standing changes there is the erosion of workers' bargaining power, i.e. workers' ability to successfully enforce their wage requests. This refers not only to the ability of ensuring protection of their purchasing power against expected inflation, but, most importantly, to their ability to extract (part of) the benefits of productivity gains (Krueger 2018). This erosion may stem from many factors that may have made workers more vulnerable to job loss and obsolescence of their skills –declining unionization, less favorable employment protection laws,

certain prominence to explain the muted inflation pressures (see Yellen 2014).

[7] We then make explicit the role of structural characteristics of the labour market and their impact on the output gap and price dynamics.

or even globalization and the associated delocalization threats, just to name a few. The decline in bargaining power, defined in a broad sense, is well visible in different descriptive indicators. To show the extent and the dynamics of this phenomenon, we select four of such indicators taken from the OECD dataset, each related to different facets of the wage bargaining process: union density and coverage (respectively, the percentage of workers who are members of a trade union and those in jobs where a trade union is present), employment protection legislation and the coverage of collective bargaining agreements. We then construct, for the same set of countries considered for the estimates shown in Figure 1, a summary measure of bargaining power by taking the first principal component of the four indicators. Results (Figure 2) point to a substantial and broad-based weakening of workers' bargaining power.

Our approach rests on the hypothesis that such weakening has magnified the role of the extensive margin of labour utilization in the adjustment of labour input.

Figure 3 shows the contribution to variation in total hours worked of the number of workers relative to hours per employee in the euro for two samples: 1970-1990 and 1991-2016.[8] The former subsample covers a period where workers' bargaining power was arguably higher than in the latter, consistently with Figure 2. The increase in the contribution of the extensive margin would be really striking if one limited the second sample to 2008, as the share of fluctuations in total labour input due to the number of workers went from an average 56 per cent between 1970 and 1990 to 90 per cent between 1990 and 2008. Including the years after 2008 downsizes this increase, mostly due to Germany, where short-time work was used to an exceptional extent in order to secure jobs in the aftermath of the Great Financial Crisis.[9] Still, even including these years, the share of fluctuations in the total labour input due to the extensive margin has strongly increased, averaging 80 per cent between 1990 and 2016.

As a first descriptive inspection of the connection between this change and the erosion in workers bargaining power, we check whether changes in the index of bargaining power presented in Figure 2 are associated with different responses of the extensive relative to the intensive margin. Figure 4 shows the ratio between the percentage change in employment

[8]Following Kudoh et al (2018) and Bulligan et al (2019), in Figure 3 we measure the relative contribution to variation in total hours worked from variations in the extensive margin and the intensive margin as $\alpha_n = \frac{cov(th,n)}{var(n)}$ and $\alpha_h = \frac{cov(th,h)}{var(h)}$, respectively, where th denotes the Hodrick–Prescott filter of log total hours, n is the Hodrick–Prescott filter of the log number of workers and h the Hodrick–Prescott filter of log hours per employee. Data are taken from Ohanian and Raffo (2012) dataset. Results are robust to the use of different filters.

[9]On the so called "German employment miracle" see Burda and Hunt (2011) among many others.

relative to changes in the intensive margin (net of changes in value added)[10] and our broad measure of bargaining power. In line with our intuition, the relationship is negative and statistically significant.

To sum up, a sizable increase in the relevance of the extensive margin of labour relative to the intensive one went hand-in-hand with the erosion of workers bargaining power. In what follows, we use a general equilibrium theoretical model and provide micro and macro evidence to point out why these two macroeconomic facts are connected and have been an important driver of the flattening of the Phillips curve.

3 The macroeconomic perspective

In what follows, we use the model developed in Thomas (2011), whose novelty stems from the assumption that price setters are subject both to infrequent price adjustments and search frictions in the labour market[11].

The key mechanism that we want to highlight is that the bargaining power of contracting parties in wage setting does not affect the cyclical relationship between inflation and marginal cost (which is usually called the "slope" of the New Keynesian Phillips curve). Yet by influencing the relative movement of the intensive and the extensive margins of labour, the bargaining power affects the cyclical relationship between marginal costs and the output gap[12] and, through this channel, the relative movement over the cycle between inflation and the output gap – i.e. what is commonly taken as the "slope" of a reduced-form Phillips curve. The reason is as follows.

The fact that price setters cannot adjust employment instantaneously makes their marginal cost depend on the cost of increasing production along the intensive margin of labour, which we call the marginal wage. As long as hours' supply is not infinitely elastic (i.e. the disutility of work is convex in hours worked), firm's marginal wage turns out to be upward sloping, i.e. increasing in average hours per employee[13]. In this case, workers' bargaining power affects the optimal relationship between the use of the intensive

[10] We use national account data for Germany, France and Italy (private sector only).

[11] The literature on new Keynesian models with search frictions in the labour market commonly avoids interactions between staggered price setting and wage bargaining at the firm level by separating between intermediate firms, which hire workers facing search and matching frictions and operate in a competitive market in relation to the goods they produce, and retailers, who are monopolistically competitive and set prices in a staggered fashion.

[12] In what follows we define the output gap as the wedge between the actual level of GDP and the level of gdp that would be observed if prices had always been flexible.

[13] In the New Keynesian search and matching frictions with a producer-retailer structure, each retailer's marginal cost is independent of its own output.

and the extensive margins of labour by influencing the relationship between the expected benefit of hiring and the expected path of hours per employee. Hence, it also affects the volatility of the marginal cost (and hence inflation) relative to GDP. A drop in workers' bargaining power amplifies the cyclical movements of employment relative to hours per worker; this reduces the cyclical movements of marginal cost relative to those of the output gap, leading, for any given shock, to a smaller inflation-output gap multiplier.

3.1 A theoretical model

We modify the model by Thomas (2011) with the aim of bringing it to the data, while keeping it as simple as possible in order to shed light on the key mechanisms at stake. First, while Thomas (2011) uses the cash-in-advance specification for aggregate demand, we consider a cashless environment in which the central bank directly sets the nominal interest rate. Second, the stochastic dynamics is driven by four orthogonal structural shocks in order to avoid stochastic singularity and achieve an exact identification of the model: a technology (total factor productivity) shock, two preference shocks (an intertemporal disturbance to consumers' impatience and an intratemporal disturbance to labour disutility) and a monetary policy shock. We assume a stochastic trend component in technology, so that data do not need to be detrended before estimation and the dynamics of the model is evaluated with respect to a balanced growth path.

3.1.1 The matching function

A matching function $m(v_t, u_t)$, where v_t is the total number of vacancies and u_t is the total number of unemployed workers, represents search frictions in the labour market. The function m is strictly increasing and strictly concave in both arguments. Labour force is normalized to 1, hence u_t also represents the unemployment rate. We define the labour market tightness as $\theta_t \equiv \frac{v_t}{u_t}$. Given the assumption of constant returns to scale in the matching function (Petrongolo and Pissarides, 2001), the job finding probability $p_t \equiv \frac{m_t(v_t,u_t)}{u_t} = m_t(\theta_t, 1)$ (i.e. the matching probability for unemployed workers) and the probability that any open vacancy is matched with a searching worker $q_t \equiv \frac{m_t(v_t,u_t)}{v_t} = m_t\left(1, \frac{1}{\theta_t}\right)$ are functions of the labour market tightness.

3.1.2 Households

We assume a large representative household, where a fraction n_t of its members are employed in a measure-one continuum of firms, while the remaining fraction $u_t = 1 -$

n_t search for jobs. In the presence of unemployment risk, differences in consumption levels between employed and unemployed workers might emerge. We avoid this issue by assuming a full income insurance scheme where the household shares consumption risk within the family by pooling members' income and assigning equal consumption to all members. Household welfare is given by:

$$\mathcal{HW}_t = \Omega_t \left\{ u(c_t) - \left[bn_t + \int_0^1 n_{it} \frac{h_{it}^{1+\eta}}{1+\eta} di \right] \mathfrak{u}_t \right\} + \beta \mathbb{E}_t \mathcal{HW}_{t+1} \tag{1}$$

where n_{it} and h_{it} denote the number of workers and hours per worker in firm $i \in [0,1]$, b is labour disutility unrelated to h_{it} and c_t is a CES function over a continuum of goods with elasticity of substitution $\gamma > 1$. Denoting with P_{it} is the price of good i, cost minimization implies $\int_0^1 P_{it} c_{it} di = P_t c_t$, where $P_t \equiv \left(\int_0^1 P_{it}^{1-\gamma} di \right)^{\frac{1}{1-\gamma}}$ is the price index. $\Omega_t = \Omega_{t-1}^{\rho_\Omega} e^{\varepsilon_{\Omega t}}$ and $\mathfrak{u}_t = \Upsilon_{t-1}^{\rho_\Upsilon} e^{\varepsilon_{\Upsilon t}}$ are an intertemporal and intratemporal preference disturbance terms, respectively, with mean unity, which follow a stationary first order autoregressive process. The period budget constraint takes the form:

$$\int_0^1 P_{it} c_{it} di + Q_t B_t \leq B_{t-1} + \int_0^1 n_{it} w_{n,it}(h_{it}) di + \Pi_t \tag{2}$$

where B_t represents purchases of one-period bonds at price Q_t, $w_{n,it}(h_{it})$ is the nominal wage income earned by workers in firm i as a function of hours worked, $\Pi_t = \int_0^1 \Pi_{it} di$ is a lump-sum component of income (which may include, among other items, dividends from ownership of firms). The optimal consumption/savings decisions is given by the following Euler equation:

$$Q_t = \beta \mathbb{E}_t \left\{ \frac{c_t}{\Omega_t} \frac{\Omega_{t+1}}{c_{t+1}} \frac{P_t}{P_{t+1}} \right\} \tag{3}$$

Denoting with λ the exogenous separation rate, the household's employment rate evolves according to

$$n_{t+1} = (1-\lambda)\, n_t + p(\theta_t)(1-n_t) \tag{4}$$

3.1.3 Firms

The value of firm $i \in [0,1]$ in period t is given by

$$V_{it} = \frac{P_{it}}{P_t} y_{it}^d - w_{it}(h_{it}) n_{it} - \frac{\chi}{u'(c_t)\Omega_t} v_{it} + \mathbb{E}_t \beta_{t,t+1} V_{it+1}$$

where P_{it} and y_{it}^d are the firm's nominal price and real sales, respectively, v_{it} are vacancies posted in period t, χ is the utility cost of posting a vacancy and $\beta_{t,T} \equiv \beta^{T-t} \frac{u'(c_T)\Omega_T}{u'(c_t)\Omega_t}$ is the stochastic discount factor between periods t and $T \geq t$. All firms face an identical isoelastic demand schedule, given by $y_{it}^d = \left(\frac{P_{it}}{P_t}\right)^{-\gamma} y_t$, and take the aggregate price level P_t and aggregate demand $y_t = c_t$ as given. The production function is:

$$y_{it}^s = A_t n_{it} h_{it} \tag{5}$$

where A_t is an exogenous labour productivity process, which we assume to have a unit root, thus being nonstationary in levels, so that a technology shock affects productivity in the long-run: $\log \frac{A_t}{A_{t-1}} = (1 - \rho_a)\tau_a + \rho_a \log \frac{A_{t-1}}{A_{t-2}} + \varepsilon_{At}$ where τ_a defines the constant growth rate and ε_{At} is the i.i.d. technology shock. Once a firm has chosen a price, it commits to supplying whatever amount is demanded at that price $y_{it}^s = y_{it}^d$. This requires the following condition to hold at all times:

$$\left(\frac{P_{it}}{P_t}\right)^{-\gamma} y_t = A_t n_{it} h_{it} \tag{6}$$

In each period each firm posts a number v_{it} of vacancies. Assuming that firms are large, λ and $q(\theta_t)$ are the fraction of workers that separate from the firm and the fraction of vacancies that the firm fills, respectively. New hires become productive in the following period. Hence, the firm's workforce n_{it} is given at the start of the period. The law of motion of the firm's employment stock is given by

$$n_{it+1} = (1 - \lambda) n_{it} + q(\theta_t) v_{it} \tag{7}$$

We denote with mc_{it} and ϕ_{it} the Lagrangian multipliers with respect to constraints (6) and (7), respectively, meaning that mc_{it} represents the real marginal cost of production. The firm chooses the state contingent path $\{h_{it}, v_{it}, n_{it+1}\}_{t=0}^{\infty}$ that maximizes

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_{0,t} \left\{ \begin{array}{c} \frac{P_{it}}{P_t} y_{it}^d - w_{it}(h_{it}) n_{it} - \frac{\chi}{u'(c_t)\Omega_t} v_{it} + \\ + mc_{it} \left[A_t n_{it} h_{it} - \left(\frac{P_{it}}{P_t}\right)^{-\gamma} y_t \right] + \\ + \phi_{it} \left[(1 - \lambda) n_{it} + q(\theta_t) v_{it} - n_{it+1} \right] \end{array} \right\} \tag{8}$$

The first order conditions are the following.

$$mc_{it} = \frac{w'_{it}(h_{it})}{A_t} \tag{9}$$

$$\frac{\chi}{u'\left(c_t\right)\Omega_t} = \phi_{it} q\left(\theta_t\right) \tag{10}$$

$$\phi_{it} = \beta \mathbb{E}_t \frac{u'\left(c_{t+1}\right)\Omega_{t+1}}{u'\left(c_t\right)\Omega_t}\left[mc_{it+1}A_{t+1}h_{it+1} - w_{it+1}(h_{it+1}) + \phi_{it+1}(1-\lambda)\right] \tag{11}$$

The real marginal cost (9) is given by the ratio between the real marginal wage and the marginal product of labour. Since employment is predetermined, the firm needs to raise hours per worker in order to increase production. This comes at a marginal cost of $w'_{it}(h_{it})$ per employee. Equation (10) states that the marginal cost of posting a vacancy must equal the probability that the vacancy is filled times the expected value of an additional worker in the next period. According to (11), the expected value of an additional worker in the next period is given by the expected marginal reduction in the firm's cost, minus the expected wage to be paid to the new hire, plus her continuation value for the firm.

3.1.4 Wage bargaining

Labour market frictions generate a surplus associated with an established employment relationship and the wage determines how that surplus is split between workers and firms. We assume Nash bargaining between the firm and each individual worker, where they receive a fraction of the joint match surplus (which is the sum of firm and worker surplus).

The worker's surplus in consumption units is $S^w_{it} \equiv \frac{(\partial H_t/\partial n_{it})}{u'(c_t)\Omega_t}$. Hence, considering equations (1), (2), and (4), together with $n_t = \int_0^1 n_{it}di$, it is given by:

$$\begin{aligned} S^w_{it} = w_{it}(h_{it}) - \tfrac{b\mathrm{u}_t}{u'(c_t)} - \tfrac{h_{it}^{1+\eta}}{1+\eta}\tfrac{\mathrm{u}_t}{u'(c_t)} + \\ +\beta\left(1-\lambda\right)\tfrac{u'(c_{t+1})\Omega_{t+1}}{u'(c_t)\Omega_t}\mathbb{E}_t S^w_{it+1} + \\ -p(\theta_t)\int_0^1 \tfrac{v_{jt}}{v_t}\mathbb{E}_t\beta\tfrac{u'(c_{t+1})\Omega_{t+1}}{u'(c_t)\Omega_t}S^w_{jt+1}dj \end{aligned} \tag{12}$$

where $p(\theta_t)\frac{v_{jt}}{v_t}$ is the probability that an unemployed member is matched to firm $j \in [0,1]$ and $w_{it}(h_{it})$ is the real wage income earned by workers in firm i as a function of hours worked. On the firm side, the surplus obtained from the marginal worker is given by:

$$S^f_{it} = mc_{it}A_t h_{it} - w_{it}(h_{it}) + (1-\lambda)\mathbb{E}_t\beta\frac{u'(c_{t+1})\Omega_{t+1}}{u'(c_t)\Omega_t}S^f_{it+1} \tag{13}$$

As highlighted by Thomas (2011), the term $mc_{it}A_t h_{it}$ is the marginal increase in costs that the firm would have to incur if the employee walked away from the job. Since the firm is demand constrained, it would have to make up for the lost production $A_t h_{it}$ by raising working hours for all the other employees, which comes at the cost of $mc_{it}A_t h_{it}$. The contribution of the marginal worker to flow profits is not the marginal revenue product of the worker (as in standard real business cycle models), but rather the marginal reduction in the wage bill.

We denote with ζ the workers' bargaining power. The Nash bargain must satisfy:

$$\zeta S_{it}^f = (1-\zeta) S_{it}^w \tag{14}$$

This implies:

$$w_{it}(h_{it}) = \zeta mc_{it}A_t h_{it} + (1-\zeta)\left[\frac{b\mathfrak{u}_t}{u'(c_t)} + \frac{h_{it}^{1+\eta}}{1+\eta}\frac{\mathfrak{u}_t}{u'(c_t)} + p(\theta_t)\int_0^1 \frac{v_{jt}}{v_t}\mathbb{E}_t\beta\frac{u'(c_{t+1})\Omega_{t+1}}{u'(c_t)\Omega_t}S_{jt+1}^w dj\right] \tag{15}$$

The worker receives a weighted average of her contribution to cost reduction and the opportunity cost of holding the job (which is the sum of labour disutility and outside options). From (11) and (13), one gets $\phi_{it} = \mathbb{E}_t\beta\frac{u'(c_{t+1})\Omega_{t+1}}{u'(c_t)\Omega_t}S_{it+1}^f$. Combining this together with (10) and (14), we get:

$$w_{it}(h_{it}) = \zeta\left[mc_{it}A_t h_{it} + \theta_t\frac{\chi}{u'(c_t)\,\Omega_t}\right] + (1-\zeta)\frac{\mathfrak{u}_t}{u'(c_t)}\left(b + \frac{h_{it}^{1+\eta}}{1+\eta}\right) \tag{16}$$

3.1.5 Vacancy posting

The vacancy-posting policy can be obtained by combining the first order conditions (10) and (11) the real wage schedule (16):

$$\frac{\chi}{q(\theta_t)} = \beta\left\{\begin{array}{c} (1-\zeta)\left[\mathbb{E}_t u'\left(c_{t+1}\right) mc_{it+1}A_{t+1}h_{it+1}\Omega_{t+1} - \mathbb{E}_t\Omega_{t+1}\mathfrak{u}_{t+1}\left(b + \frac{h_{it+1}^{1+\eta}}{1+\eta}\right)\right] + \\ -\zeta\mathbb{E}_t\theta_{t+1}\chi + \mathbb{E}_t\frac{\chi}{q(\theta_{t+1})}(1-\lambda) \end{array}\right\} \tag{17}$$

The real marginal wage is:

$$w_{it}'(h_{it}) \equiv \frac{\partial w_{it}(h_{it})}{\partial h_{it}} = \zeta mc_{it}A_t + (1-\zeta)\mathfrak{u}_t\frac{h_{it}^{\eta}}{u'(c_t)} \tag{18}$$

Using this to substitute for $w'_{it}(h_{it})$ in (9), we have:

$$mc_{it} = \frac{\mathfrak{u}_t}{A_t} \frac{h_{it}^{\eta}}{u'(c_t)} \tag{19}$$

Using this in equation (17) leads to

$$\frac{\chi}{q(\theta_t)} = \beta \mathbb{E}_t \left\{ (1-\zeta)\mathfrak{u}_{t+1}\Omega_{t+1} \left[\eta \frac{h_{it+1}^{1+\eta}}{1+\eta} - b \right] - \zeta\chi\theta_{t+1} + (1-\lambda)\frac{\chi}{q(\theta_{t+1})} \right\} \tag{20}$$

According (20) the firm's incentives to hire are driven by fluctuations in the expected path of hours per employee: if the firm expects hours to be higher in the future, it also expects larger reductions in its wage bill from having additional workers. This leads to post more vacancies today up to the point in which the expected marginal benefit of hiring equals its marginal cost $\frac{\chi}{q(\theta_t)}$.

3.1.6 Pricing decision and monetary policy

Following the formalism proposed in Calvo (1983), each firm may reset its price only with probability $1-\delta$ in any given period, independently of the time elapsed since the last adjustment. A firm reoptimizing in period t will choose the price P_{it} that maximizes the current market value of the profits generated while that price remains effective:

$$\max \mathbb{E}_t \sum_{T=t}^{\infty} \delta^{T-t} \beta_{t,T} \left\{ \left(\frac{P_{it}}{P_T}\right)^{1-\gamma} y_T - mc_{iT/t} \left(\frac{P_{it}}{P_T}\right)^{-\gamma} y_T \right\} \tag{21}$$

where the subscript T/t denotes period T values conditional on the firm not having reset its price since period t. Therefore $mc_{iT/t}$ is the firm's real marginal cost in period T conditional on the price P_{it} being still in place. The first order condition is

$$\mathbb{E}_t \sum_{T=t}^{\infty} \delta^{T-t} \beta_{t,T} P_T^{\gamma} y_T \left\{ \frac{P_{it}^*}{P_T} - \frac{\gamma}{\gamma - 1} mc_{iT/t} \right\} = 0 \tag{22}$$

Using (19) and the fact that hours must adjust in order to meet demand $h_{it} = \frac{y_{it}}{A_t n_{it}}$, we can express $mc_{iT/t}$ as a function of the firm's output in period T

$$mc_{iT/t} = \left(\frac{y_{iT/t}}{A_t n_{iT/t}}\right)^{\eta} \frac{\mathfrak{u}_T}{A_T u'(c_T)} \tag{23}$$

where $y_{iT/t} = \left(\frac{P_{it}^*}{P_T}\right)^{-\gamma} y_T$. Equation (23) implies that, under the assumption of convex labour disutility (i.e. $\eta > 0$) the firm's marginal cost curve is an increasing function of its own output level.

The monetary authority sets the nominal interest rate according to the following Taylor rule:

$$\frac{R_t}{\overline{R}} = \mathbb{E}_t \left[\frac{P_{t+1}}{P_t}\right]^{\phi_\pi} \left(\frac{y_t}{y_{n,t}}\right)^{\phi_y} \mu_t$$

where $R_t = \frac{1}{Q_t}$ and $\overline{R}$ is the steady state nominal gross rate, $y_{n,t}$ denotes the natural level of output, i.e. the level of economic activity that would emerge under flexible prices and μ_t is a monetary policy shock, which is assumed to follow the stationary AR(1) process $\mu_t = \mu_{t-1}^{\rho_\mu} e^{\varepsilon_{\mu t}}$.

3.2 On the role of bargaining power

We now use the model presented above to shed light on the effects that changes in workers bargaining power might have on the cyclical behavior of inflation. In what follows, we assume a log-utility (to be consistent with a balanced growth path) $u(c_t) = \log c_t$ and the following functional form for the matching function $m_t(v_t, u_t) = \varsigma v_t^{\varepsilon} u_t^{1-\varepsilon}$, with $\varsigma > 0$ and $\varepsilon \in (0, 1)$.

We show that the interaction between the bargaining power of contracting parties in wage setting and the elasticity of labour supply is key in shaping the relative movement of macroeconomic variables. Therefore, before discussing the channels at stake, let us clarify the role played by the labour supply elasticity.

In the model, η is the inverse of the Frisch elasticity of labour supply[14]: the larger is η, the lower the elasticity of labour supply, the smaller the changes in hours worked due to changes in wages. When $\eta = 0$, labour supply is infinitely elastic as the marginal disutility of labour does not depend on hours worked. In other words, η measures the convexity of labour disutility (see equation 1).

Once the firm sets its price, its output is demand-determined and the firm commits to supplying whatever amount is requested at that price by varying hours per worker. Indeed, as employment is predetermined, the firm needs to raise hours per employee in order to increase production. This comes at the marginal cost of $w'_{it}(h_{it}) \equiv \frac{\partial w_{it}(h_{it})}{\partial h_{it}}$ per employee, which is upward sloping (i.e. increasing in average hours per employee), to the extent labour disutility is convex in hours worked ($\eta > 0$). In this context, if $\eta > 0$,

[14]The Frisch elasticity of labour supply measures the percentage change in hours worked due to the percentage change in wages, holding constant the marginal utility of wealth.

hiring decisions are driven by the expected path of hours per employee: when firms expect hours per employee to be higher in the future they have an incentive to create more jobs, because having more workers will allow to satisfy demand with less hours per employee, thereby reducing the marginal cost of production ($mc_{it} = \frac{w'_{it}(h_{it})}{A_t} = \frac{\frac{\partial w_{it}(h_{it})}{\partial h_{it}}}{A_t}$). The latter depends indeed on the cost of increasing production along the intensive margin of labour and is increasing with hours per employee to the extent that $\eta > 0$.

To describe the relative movement of macro-variables, and how the latter is affected by changes in bargaining power of contracting parties, we resort to the definition of shock-dependent cumulative multiplier in the spirit of Forbes, Hjortsoe, and Nenova (2018) and Ramey and Zubairy (2018). Accordingly, we define the $Y - X$ multiplier as the ratio between the cumulated impulse response functions of two variables of interest at a horizon h. Hence, let $IRF_Y(h)$ denote the impulse response coefficient of the Y variable, h periods after impact. We characterize the Y-X trade-off as:

$$k_h = \frac{\sum_{i=0}^{h} IRF_Y(i)}{\sum_{i=0}^{h} IRF_X(i)} \tag{24}$$

The latter gives a measure of the relative volatility of the two variables conditional on the shock at stake. In order to illustrate the main mechanisms at play, we focus on the expansionary intertemporal preference shock. However, the same results and intuitions would hold for any demand side disturbance.

3.2.1 Bargaining power and the relative movement of the extensive and the intensive margin

To the extent labour disutility is realistically convex in hours worked ($\eta > 0$), the lower is workers' bargaining power, the larger the movement of employment relative to hours per worker (Figure 5A).

Intuitively, the marginal benefit of hiring decreases with workers' bargaining power (ζ), as the larger is workers' bargaining power the lower is the share of the joint surplus generated from the employment relationship which goes to firms.

The employment-hours trade-off is instead unaffected by workers' bargaining power when labour supply is infinitely elastic ($\eta = 0$; Figure 5B), because in this case job creation decisions do no longer depend on expected hours per employee. In this case the marginal cost of production (the cost of increasing production along the intensive margin of labour) is no longer increasing with hours per employee.

To see this analytically, consider the vacancy posting condition (20), where the expected marginal benefit of hiring EBH_t is:

$$EBH_t = \beta \mathbb{E}_t \left\{ (1-\zeta) \left[\eta \frac{h_{it+1}^{1+\eta}}{1+\eta} - b \right] \mathfrak{u}_{t+1} \Omega_{t+1} - \zeta \chi \theta_{t+1} + (1-\lambda) \frac{\chi}{q(\theta_{t+1})} \right\} = \frac{\chi}{q(\theta_t)}$$

Note that the relation between the expected benefit of hiring and the expected path of hours per employee ($\frac{\partial EBH_t}{\partial h_{t+1}}$) depends on the product between firms bargaining power $(1-\zeta)$ and the convexity of labour supply η.

3.2.2 Bargaining power and the relative movement of inflation and the output gap

Provided labour disutility is realistically convex in hours worked ($\eta > 0$), a lower workers' bargaining power is associated with a lower marginal cost-output gap multiplier and, accordingly, a lower inflation-output gap multiplier (Figure 6A). The allocation of bargaining power does not affect these trade-offs only if labour supply is infinitely elastic ($\eta = 0$; Figures 6B).

Intuitively, regardless of η, changes in the relative bargaining power between parties do not affect the response of the output gap to shocks (see Figure 7). However, by affecting the incentive of firms to move the extensive relative to the intensive margin of labour, changes in bargaining power affect the marginal cost of production, through the changes in workers' marginal disutility of labour (with elasticity η).

To see this analytically, we log-linearize the model around the stationarized steady state[15], to write the Phillips curve as:

$$\widehat{\pi}_t = \beta \mathbb{E}_t \pi_{t+1} + k \widehat{mc}_t \tag{25}$$

where $\widehat{\pi}_t$ is inflation and k is a convolution of deep parameters not including ζ (the allocation of bargaining power does not affect the relationship between inflation and marginal cost)[16]. Considering equation (19), together with technology (5) and the aggregate resource constraint, the marginal cost can be written as:

[15] In what follows lower case letters with "hats" denote proportional deviations from steady state and "tildes" indicate that the variable has been rescaled by the level of technology, to obtain the stationary representation, before being log-linearized around the balanced growth steady state.

[16] As shown by Thomas (2011) $k = \frac{(1-\delta)(1-\delta\beta)}{\delta} \frac{1}{1+\eta\gamma-\delta\beta\eta\tau^n}$ where $\tau^n = \frac{\gamma\delta}{1-\gamma(1-\delta)\tau^*}$ and $\tau^* = \frac{(1-\delta\beta)\eta}{1+\eta\gamma-\delta\beta\eta\tau^n}$.

$$\widehat{mc}_t = \begin{aligned} &(1+\eta)\underbrace{\left(\widehat{\widetilde{y}}_t - \widehat{\widetilde{y}}_{n,t}\right)}_{\text{output gap}} - \eta\underbrace{\left(\widehat{n}_t - \widehat{n}_{n,t}\right)}_{\text{employment gap}} = \\ &= \underbrace{\left(\widehat{\widetilde{y}}_t - \widehat{\widetilde{y}}_{n,t}\right)}_{\text{output gap}} + \eta\underbrace{\left(\widehat{h}_t - \widehat{h}_{n,t}\right)}_{\text{hours gap}} \end{aligned} \tag{26}$$

where $\widehat{\widetilde{y}}_{n,t}$ and $\widehat{n}_{n,t}$ denote the natural level of GDP and employment, respectively, that is the level of GDP and employment that would be observed if prices had always been flexible. We can therefore write:

$$\widehat{\pi}_t = \beta \mathbb{E}_t \widehat{\pi}_{t+1} + k(1+\eta)\underbrace{\left(\widehat{\widetilde{y}}_t - \widehat{\widetilde{y}}_{n,t}\right)}_{\text{output gap}} - \eta k \underbrace{\left(\widehat{n}_t - \widehat{n}_{n,t}\right)}_{\text{employment gap}} \tag{27}$$

or, alternatively,

$$\widehat{\pi}_t = \beta \mathbb{E}_t \widehat{\pi}_{t+1} + k\underbrace{\left(\widehat{\widetilde{y}}_t - \widehat{\widetilde{y}}_{n,t}\right)}_{\text{output gap}} + k\eta\underbrace{\left(\widehat{h}_t - \widehat{h}_{n,t}\right)}_{\text{hours gap}} \tag{28}$$

where $\widehat{h}_{n,t}$ denotes the natural level of hours per worker.

A drop in workers bargaining power does not affect the response of the output gap to shocks, but it affects the relative contribution to variation in total hours worked of the intensive and the extensive margin of labour, as firms' incentive to hire depends on the share of the surplus firms can secure. Hence, when workers bargaining power is lower, the same variation of the output gap is driven more by the extensive margin than by the intensive one, relatively to the case of higher workers' bargaining power. Following a shock, for the same variation in economic activity, a smaller contribution of hours per employee implies a smaller response of the marginal cost (see eq. 26) and hence of inflation (see eq. 28). This happens because the marginal wage is increasing with hours per employee (see eq. 19), at least as long as hours supply is not infinitely elastic (i.e. if $\eta > 0$).

This explains why in the more recent past large variations of economic activity were associated with more muted reaction of inflation compared to the 1970s-1980s. It also implies that econometric estimates of the slope of a reduced form Phillips curve in which the hours gap is omitted are subject to a downward bias, as the cyclicality of hours per worker has shrunk over time.

4 The microeconomic perspective

In this section we use microdata to investigate the relationship (if any) between workers' bargaining power and the propensity of firms to adjust the extensive relative to the intensive margin - the key mechanism of our model. We rely on Italian panel data from INVIND, a survey on firms conducted yearly by the Bank of Italy. Sample descriptive statistics are reported in the Appendix.

We obtain qualitatively similar results by using microdata from the Wage Dynamics Network survey (WDN), a European System of Central Banks (ESCB) initiative aimed at collecting (cross-sectional) information on how firms in European countries responded to shocks during the period 2010-2013. Although compared to the analysis that can be carried out using INVIND data, the one based on the WDN is rather partial, additional micro evidence on a bunch of different countries can offer some additional support to our main findings and we report it in the Appendix.

4.1 Data and descriptive statistics

INVIND is a survey on industrial and non-financial service firms with at least 20 employees. The survey, which is stratified according to firms' branch of activity, size class and geographical areas, is conducted since 1984 on a yearly basis and collects data on many relevant variables like sales, investments, export. More importantly for our purposes, firms are asked to report output prices (average yearly change), the number of employees, total hours worked, the total value of sales they expect for the next year, and, only in the 2010 vintage, the share of workers who are members of a union.[17]

By exploiting the panel structure of the data we can infer by how much firms adjusted the extensive margin (percentage change in employment), the intensive margin (percentage change in hours per worker), the percentage change in average producer prices, and, based on firms' expectations, the percentage difference between expected sales (at time $t-1$) and realized sales (at time t), which we use as a proxy for a demand shock[18]. Following the literature (e.g. Stansbury and Summers 2020) we take the share of workers who are members of a union as a proxy for workers' bargaining power.[19]

We use data from 2011 to 2014. Even though we could use data until 2018, we limit

[17]Data on the share of workers members of a union was also collected in 2013 and 2014 but only for half of the sample. We do not use this information in this paper.

[18]Since our model does not distinguish between positive and negative shocks, in our preferred specification we take the absolute value of this difference.

[19]By controlling for fixed effect we can also control for unobserved time invariant characteristics.

our time span because in 2015 the Italian labour market underwent a deep reform to induce firms to hire workers after a period of prolonged recession. The reform lowered firing costs in large firms (which are typically more unionized) and introduced new rules for firms applying to public wage supplementation schemes in the case of a reduction of hours worked. These reforms may have affected the relative reaction of the extensive vs. the intensive margin and may have caused a structural break in firms behaviour. In the Appendix we report the main characteristics of the sample and the distribution of the main variables.

4.2 Estimated models and results

We can use INVIND to get some insight on the key mechanism of our model at the firm level. In particular, we check whether in firms with high workers' bargaining power, the reaction of the extensive margin to unexpected changes in demand is smaller than in other firms whereas the reaction of the intensive margin is larger (for given size of the shock). We indicate the annual variation in the number of workers (extensive margin) with ΔEM and the percentage change in average hours worked by each worker (the intensive margin) with ΔIM. We then estimate the following two-equation model, by the use of a SURE estimator:

$$\begin{cases} \Delta EM_{f,t} = \gamma_1 shock_{f,t} + \gamma_2 shock_{f,t} * WBP_f + \gamma_3 X_{f,t} + \gamma_t + \nu_{f,t} \\ \Delta IM_{f,t} = \theta_1 shock_{f,t} + \theta_2 shock_{f,t} * WBP_f + \theta_3 X_{f,t} + \gamma_t + \epsilon_{f,t} \end{cases} \tag{29}$$

where f denotes the firm and t the year. As mentioned before, the variable WBP_f is our proxy for workers' bargaining power, equal to the share of unionized workers in total firm f employment in 2010, i.e. before the changes observed in both the extensive and the intensive margin. By doing so, we control for the endogeneity arising from firms potentially adjusting their labour input to affect the share of unionized workers. On average, the percentage of unionised workers is about 34% in our sample. This is very close to the average union density for Italy as a whole, as per the OECD data underlying Figure 2. Firm-specific shocks are captured by $shock_{f,t}$; $X_{f,t}$ are time-varying controls, i.e. the share of foreign sales in total firms' sales, to proxy for market structure, the percentage change in investments, to control for changes in the stock of capital, sector (Nace 1-digit) and geographical area dummies. The variable γ_t represents time dummies. The results are reported in Table 1. The coefficients confirm that both $\Delta EM_{f,t}$ and $\Delta IM_{f,t}$ positively correlate with the unexpected change in sales. Given the characteristics of our model, we are particularly interested in the coefficients γ_2 and θ_2 relative to the interaction term $shock_{f,t} * WBP$ (cols. 2 and 3). We find that γ_2 is negative and θ_2 is positive, suggesting that higher workers' bargaining power reduces the elasticity of the extensive margin to shocks and increases the elasticity of the intensive margin to the same shock. For example, if union density was to revert to 50% as it was in the early 80s, the elasticity of the extensive margin to demand shock would drop by about 30%. Last, in column 4 we re-run equation (29) on de-meaned variables to control for firm-level time-invariant unobserved characteristics. The coefficients γ_2 and θ_2 remain unchanged. All this evidence is clearly consistent with our theoretical model.

Second, we conduct some exercises aimed at showing that, following a shock, the reaction of price changes is larger the higher is the bargaining power of workers. To do so, we estimate:

$$\Delta Price^{abs}_{f,t} = \delta_1 WBP_f * shock^{abs}_{f,t} + \gamma_f + \gamma_t + \eta_{f,t} \tag{30}$$

where $\Delta Price^{abs}_{f,t}$ is the yearly percentage change in the average prices of firm f's products in absolute value and $shock^{abs}_{f,t}$ is the absolute value of the unexpected change in sales. We look at absolute values because our model is symmetric with respect to the sign of the shock. Higher workers' bargaining power, by increasing the reaction of the intensive margin relative to the extensive one, implies a stronger reaction to shocks both if the shock is positive and if the shock is negative. Moreover, since the movement of the extensive margin relative to the intensive one is driven by WBP, equation (30) can be interpreted as a reduced form including a pre-determined variable (WBP_f) and an exogenous ($shock^{abs}_{f,t}$). This specification is preferable to directly include $\Delta EM_{f,t}$ and $\Delta IM_{f,t}$, possibly interacted with WBP.

Results are reported in Table 2. The absolute value of the shock is not significantly correlated with the absolute value of price changes (col.1). The sign of its interaction with workers' bargaining power is instead positive and statistically significant in line with the results of our model. One may argue that WBP is capturing other market forces, relevant for price determination, e.g. firms' monopoly power in the product market. To partially rule out this critique, in column 3 we include the share of foreign sales in total sales as a proxy for the degree of competition in product market, under the assumption that exporters are subject to higher competition than firms that operate only in the domestic market. Additionally, in column 4 equation (30) is estimated on the sub-sample of firms with positive foreign sales. All in all, even if none of the estimates presented in this section can be interpreted as causal, we believe that the correlations that we find constitute new evidence in line with the predictions of our theoretical macro model.

5 Bayesian estimation

To confirm that the changes in workers' bargaining power are correctly represented by our model and to quantify their role in explaining the changes observed in the relative volatility of macroeconomic variables, we bring the model to euro-area data. We estimate the model with Bayesian methods, where restrictions on estimated parameters are defined in terms of probability distributions. The posterior distribution for the model parameters $\xi \in \Xi$ combines the formalized prior distribution and the likelihood of the data.

Formally, denoting with $P(\xi, M)$ the prior beliefs on parameters ξ given model M and with $P(Y_T/\xi, M)$, $Y_T = \{y_t\}_{t=1}^{T}$ the conditional distribution (likelihood), according to the Bayes rule the posterior density $P(\xi/Y_T, M)$ can be written as:

$$P(\xi/Y_T, M) = \frac{P(Y_T/\xi, M)P(\xi, M)}{P(Y_T, M)} \tag{31}$$

Following the literature, we get the Bayesian posterior estimates by using the Kalman filter to form the likelihood function and the Metropolis-Hastings algorithm for Monte Carlo integration (three chains of 500,000 draws) to optimize the posterior density function.

5.1 Data, measurement equations and prior distributions

To estimate the model we use euro-area quarterly data over two sample periods: 1970Q1-1990Q4 and 1991Q1-2016Q4. The choice of the break in 1990 is consistent with the visual evidence reported in figures 1 and 2: the first subsample corresponds to a period where workers' bargaining power was arguably higher than in the second. However, to further check the rationale of this choice we also estimate the model over shorter windows of ten-years. As discussed in the next Section, results support our assumption of a break in the 1990s.

We consider four time series: the log-first-difference of real compensation per employee $\left(\triangle \log\left(\frac{w_{n,t}}{P_t}\right)\right)$, the log-first-difference of hours per worker ($\triangle \log h_t$), the log-first-difference of GDP deflator ($\triangle \log P_t$) as a measure of inflation and the first difference of the employment rate ($\triangle(1 - u_t)$). Compensation per employee, GDP deflator and the employment rate are taken from the Area Wide Model (AWM) dataset by Fagan, Henry and Mestre (2005), while hours per worker are obtained from the Ohanian and Raffo (2012) dataset.

In the theoretical model, the nonstationary productivity shock gives rise to a common stochastic trend in GDP, consumption and wages. Since the model displays balanced growth, long-run stationary ratios emerge among these variables and between each variable and productivity. Hence, a stationary representation of the model can be obtained by using the following transformations: $X_t = \widetilde{X}_t A_t$, where X_t is the generic nonstationary variable and $\widetilde{X}_t$ its corresponding stationary ratio. The stationary representation of the model is then log-linearized around the balanced growth steady state.

The resulting measurement equations linking the model variables to observables are the following:

$$\begin{bmatrix} \triangle \log \left(\frac{w_{n,t}}{P_t} \right) \\ \triangle \log h_t \\ \triangle \log P_t \\ \triangle (1 - u_t) \end{bmatrix} = \begin{bmatrix} \widehat{\widetilde{w}}_t - \widehat{\widetilde{w}}_{t-1} + \log \frac{A_t}{A_{t-1}} \\ \widehat{h}_t - \widehat{h}_{t-1} \\ \widehat{p}_t - \widehat{p}_{t-1} + \log \overline{\pi} \\ \widehat{n}_t - \widehat{n}_{t-1} \end{bmatrix}$$

where lower case letters with "hats" denote proportional deviations from steady state and "tildes" indicate that the variable has been rescaled by the level of technology, to obtain the stationary representation, before being log-linearized around the balanced growth steady state. Also, $\overline{\pi}$ denotes the steady-state inflation rate. Note that the term $\log \frac{A_t}{A_{t-1}}$ comes from having expressed the model in log deviations around the stochastic growth path[20].

In order to improve the identification of the key structural parameters, the following parameters are calibrated. The discount factor β is fixed at 0.99, a standard calibration for macroeconomic models. As in Woodford (2005) and Thomas (2011), we set the elasticity of substitution across differentiated goods γ at 7.67, so as to yield a steady state markup of around 15 per cent. Following the standard practice in the search and matching literature (see the seminal contribution by Blanchard and Diamond, 1989), the elasticity of the matching function with respect to vacancies ε is set to 0.6. We calibrate the steady

[20] More precisely, as regards the data from the AWM dataset, $w_{n,t}$ is wage per head (series code WRN), calculated as the ratio of compensation of employees (series code WIN; millions of euros, current prices, calendar and seasonally adjusted data) and total employment (series code LNN; thousands of persons, calendar and seasonally adjusted data). P_t is the GDP deflator (series code YED); u_t is the unemployment rate (series code URX; percentage of civilian work force, total all ages, total male and female, seasonally adjusted, but not working day adjusted data).

state job finding probability $\overline{p} = 0.250$, as together with our prior for the separation rate (see below), it implies a steady state unemployment rate of around 9 per cent, which is consistent with the euro-area labour market. The vacancy posting cost parameter χ is calibrated by targeting a steady-state ratio of vacancy-posting costs to GDP of 1%, as in Andolfatto (1996), Gertler and Trigari (2009), Blanchard and Galì (2010) and Thomas (2011). Finally, our sample data indicate an average quarterly growth rate of almost 0.7% in both sample periods, and average quarterly GDP deflator inflation of 1.97% and 0.48% in the first and second period, respectively. We use these information to calibrate τ_a and $\overline{\pi}$.

All remaining parameters are estimated. The prior distributions are the same in the two subsamples; they are reported in Tables 3A and 3B. We choose the shape of the prior distributions with the following criteria: a beta distribution is adopted for parameters theoretically defined in the $[0 - 1]$ range, whereas a normal distribution is assumed for priors on parameters theoretically defined over the $\mathbb{R}$ range. As for the structural shocks, the reference distribution is the inverted gamma which is defined over the $\mathbb{R}^+$ range.

We set the prior mean of the parameter defining workers' bargaining power, ζ, at 0.5, the middle of the distribution's support. Also, by setting the prior standard deviation at 0.2, we assume a very weakly informative prior: given the centrality of this parameter for our analysis, we let the data speak as much as possible. A very diffuse prior, centered on a mean value of 2 with prior standard deviation 0.5, is also assumed for the inverse of Frisch elasticity η, reflecting both the very imprecise opinion about the dimensionality of labour supply elasticity as well as, again, the effort to increase the weight of the likelihood of the data relative to that of the prior non-sample information in the posterior estimates, given the importance of this parameter for the slope of the Phillips curve. The prior distribution for the Calvo parameter δ is assumed to follow a beta distribution centered at 0.85 with standard deviation equal to 0.1. This informative prior is in line with the estimates provided by Smets and Wouters (2007), for the average of a long sample covering the years between 1980 and 1999. For the parameter measuring the steady state labour market tightness θ we adopt a tight prior defined by a beta distribution centered on 0.7 with standard deviation equal to 0.05. This prior mean is consistent with the steady state value suggested in Thomas (2011). For the separation rate λ, we assume a prior centered on 0.03 with a standard error of 0.005 which is in line with the value suggested in Blanchard and Gali (2010) and yields, together with the calibrated value for the job finding rate, a steady state unemployment rate of 9 per cent, which is consistent with euro-area data. The parameters describing monetary policy are based on a standard Taylor rule: the prior means of the Taylor coefficient on expected inflation ϕ_π and the output gap ϕ_y are set at 1.5 and 0.5, with a standard deviation of 0.350 and 0.1, respectively, so as to guarantee a unique solution path when solving the model.

The priors on the stochastic processes (Table 4B) are harmonized and weakly informative, reflecting the very imprecise opinion about the dimensionality and the persistence of shocks (see Table 2). The standard errors of the innovations have a prior mean of 0.08 with two degrees of freedom. All shocks are assumed to be serially correlated with autoregressive coefficient having a prior mean of 0.5 and a prior standard deviation of 0.1.

5.2 Results

Summary statistics of the posterior distributions are reported in Tables 3A and 3B. Macroeconomic data, read through the lenses of this general equilibrium model, point to three significant changes, all of which affect the trade off between inflation, wages and the output gap.

First, workers' bargaining power has dramatically decreased. While in the first subsample, workers achieved more than half of the joint surplus ($\zeta = 0.6336$), they are paid their reservation wage in the average of the more recent years ($\zeta = 0.0197$). Second, labour supply has become more elastic: the inverse of Frisch elasticity falls from $\eta = 1.8124$ to $\eta = 0.8044$. Third, price stickiness has strongly increased (with the Calvo parameter δ going from 0.1008 to 0.6926). This is consistent with the common wisdom that as inflation has decreased over time, one would expect price setters to change prices less often, as prices' adjustment costs may induce firms to vary prices less frequently when inflation is lower (Ball, Mankiw, and Romer 1988 and Klenow and Malin 2010).

Note that the posterior mean of the Calvo parameter is somewhat smaller than values typically used to calibrate macroeconomic models, especially in the first subsample. It is, however, more in line with microeconometric estimates: in 2005 the Inflation Persistence Network of the ECB estimated an average duration of prices in the euro area of one year (see Altissimo, Ehrmann and Smets, 2006). The estimate of the Calvo parameter for the second subsample (0.6926) is almost perfectly aligned with this evidence, as it implies an average duration of prices of three quarters and a half. If one buys the story that price stickiness has strongly increased over time, then the figure of 0.1008 for the average of 1970-1990 period looks plausible as well, as it implies that prices lasted on average slightly more than one quarter. The reason why the Calvo parameter is lower than in other macroeconometric estimates is that real rigidities in price settings (i.e. the fact the price setters have an incentive to keep their prices in line with the overall price level) allow the model to match inflation dynamics without the need of assuming unrealistically long price contracts.[21]

Figure 8 shows the prior and posterior distributions of the three parameters at stake.

Consider again the Phillips curve:

$$\widehat{\pi}_t = \beta \mathbb{E}_t \widehat{\pi}_{t+1} + k \underbrace{\left[(1+\eta) \underbrace{\left(\widehat{\widehat{y}}_t - \widehat{\widehat{y}}_{n,t} \right)}_{\text{output gap}} - \eta \underbrace{\left(\widehat{n}_t - \widehat{n}_{n,t} \right)}_{\text{employment gap}} \right]}_{\widehat{mc}_t} \tag{32}$$

where k is a convolution of deep parameters not including ζ, which decreases with the calvo parameter δ and with the inverse of the Frisch elasticity η[22]. The inflation-output gap multiplier depends on the relationship between inflation and marginal cost and on the relationship between marginal cost and the output gap.

Figure 9 shows these three multipliers, conditional on the intertemporal demand shock, estimated in the two subsamples. According to our estimates the collapse of the inflation output gap multiplier (panel A) mirrors:

- a decline in inflation-marginal cost multiplier (panel B), driven by higher price stickiness, as the average duration of prices is estimated to have increased by almost two quarters. A longer average duration of prices is consistent with the idea put forward by Ball et al. (1988) that the presence of costs associated with adjusting nominal prices induces firms to vary prices less frequently when inflation is lower. Micro and cross-country evidence confirms that inflation correlates positively with the frequency of price adjustments (e.g., see Nakamura and Steinsson, 2008; Wulfsberg, 2009; Klenow and Malin 2010).

- a downfall in the marginal cost - output gap multiplier (panel C), caused by plunging workers' bargaining power. The latter increases the contribution of the employment gap to the output gap movements, relative to the contribution of the intensive

[21] Real rigidities in price setting arise from the fact that price setters are subject both to infrequent price adjustments as well as to search and matching frictions in the labour market, with employment being a firm-specific endogenous state variable, together with the assumption of convex labor disutility. See Thomas (2011) for a parallelism with the real rigiditity mechanism arising in models of firm-specific capital (Sveen and Weinke 2005, Woodford 2005, Altig et al. 2011)

[22] As shown by Thomas (2011) $k = \frac{(1-\delta)(1-\delta\beta)}{\delta} \frac{1}{1+\eta\gamma-\delta\beta\eta\tau^n}$ where $\tau^n = \frac{\gamma\delta}{1-\gamma(1-\delta)\tau^*}$ and $\tau^* = \frac{(1-\delta\beta)\eta}{1+\eta\gamma-\delta\beta\eta\tau^n}$.

margin. This increase in the relative importance of the extensive margin of labour relative to hours per employee dampens the movement of the marginal cost, for any given movement of the output gap, as it reduces the fluctuations of the marginal wage ($w'_{it}(h_{it}) \equiv \frac{\partial w_{it}(h_{it})}{\partial h_{it}}$).

The implications of the fall in the frequency of price adjustments and in workers bargaining power on the inflation-output gap multiplier are only to a minimum extent counterbalanced by the increase in labour supply elasticity (η falls from 1.8124 to 0.8044). The drop in η, which measures the elasticity of the marginal wage to hours' worked, has two effects. First, it increases the sensitivity of inflation to marginal cost (as measured by k), because it reduces the real rigidity in price setting (i.e. the fact that firms' pricing decisions have an effect on their own marginal cost). Also, as explained in Section 2, it reduces the sensitivity of firms' marginal cost to the composition of the output gap between employment and hours, hence reducing the effect that workers bargaining power has on inflation-output gap multiplier.

It is interesting to observe that the data seems to point to a correlation pattern between workers' bargaining power and labour supply elasticity. This is not obvious, since the two parameters play quite different roles in the model – the former determines how the surplus is split in the bargaining process, while the latter is related to preferences towards work and leisure. Consequently, the prior distributions on these parameters were set as independent. Yet looking at the joint posterior distribution of ξ and η (Figure 10) reveals a marked correlation pattern. The direction of the correlation suggests that posterior draws with lower workers' bargaining power seem to go hand-in-hand with higher labour supply elasticity. Given that a higher labour supply elasticity also implies lower overtime compensation for workers, this may also suggest that another aspect of a generalized loss of workers' bargaining power is their inability to negotiate better overtime compensation packages. While this is suggestive, a framework in which labour supply elasticity is endogenously determined as a function of a broader workers' bargaining power concept is beyond the scope of this paper.

To make sure that our baseline estimates are not a spurious by-product of the Great recession, we also estimated the model over shorter ten-year windows. Figure 11 shows the results for ζ (the degree of workers bargaining power). Posterior means of ζ are roughly coincident in the 1970s and 1980s, around 0.6. They are very similar in the subsequent decades too, with workers paid approximately their reservation wage, with the minimum reached in the 1990s. While results over a shorter sample size should be taken with a pinch of salt, they also strengthen our assumption of a break in the 1990s: bargaining power of workers took a plunge between the end of 1980s and the beginning of 1990s, and did not recover thereafter.

6 Conclusions

Since the Great Moderation, the Phillips curve has become elusive, as the short-run inflation-output gap trade-off has substantially vanished. While this decline dates back to the mid-1980s, in recent years it has been at the center of the academic and policy debates, given the large swings observed in economic activity with inflation hardly responding[23].

Our paper contributes to this literature by studying the role that the progressive erosion of workers' bargaining power may have played for the cyclical relationship between price inflation and economic slack in the euro area. Unless the labour supply is infinitely elastic, dwindling workers bargaining power weakens the relationship between inflation and the output gap, by affecting the relative adjustment of the extensive and the intensive labour margins.

While the evaluation of specific policy prescriptions is outside the scope of this study, our analysis does entail potential implications for monetary policy. Our findings imply that in an environment of low workers' bargaining power, cyclical inflationary pressures coming from tight labour markets are likely to be muted. This can imply that central banks will have to provide more and more accommodation to stick to their targets. This is especially so under the so-called makeup strategies, which aim for a controlled overshooting of the inflation target during a cyclical upswing.

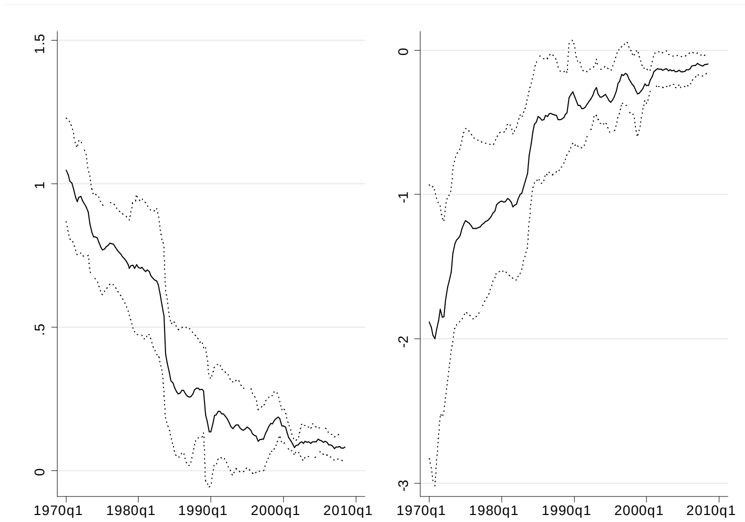
Our analysis strikes us as consistent with the remarks Alan Krueger gave at Jackson Hole in 2018. He argued that in setting monetary policy central bankers should take into account the structural shift against workers which has taken place in recent decades;[24] that, given the secular erosion in workers bargaining power, the price stability mandate would call, other things being equal, for a more accommodative monetary policy and that the central bank response to this long standing shift should depend on the elasticity of aggregate labour supply. The evaluation of these normative implications is beyond the scope of our work and is left for future research.

[23] This phenomenon is often referred to in the literature as the "twin puzzle": first, the missing disinflation between 2009 and 2011 and, second, the missing inflation starting from 2012.

[24] "*These considerations should be part of the conversation along with Central Banks' other weighty concerns, such as the effect of monetary policy on financial stability, the effect of tariffs and trade wars on inflation and output, and the effects of demographic shifts on potential output.*" Krueger (2018)

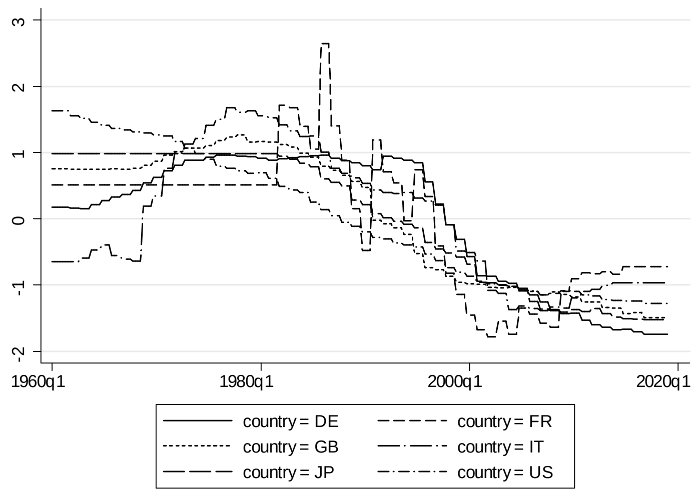
Figures and tables

Figure 1. Slope of the reduced form Phillips curve



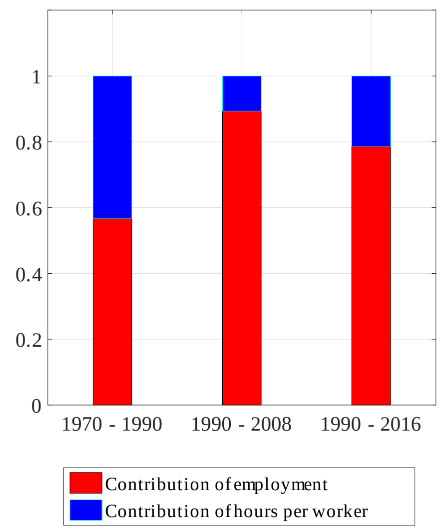
Notes. The y-axis displays rolling estimates (based on 20-years windows) of the slope β of the Phillips curve $\pi_{i,t}= \pi^*_{i,t}+\beta\widetilde{y}_{i,t}+u_{i,t}$, based on a panel of six advanced economies (France, Germany, Italy, Japan, United Kingdom, United States), where $\pi^*_{i,t}$ is a measure of trend inflation, computed as the four-quarter moving average of past core inflation and $\widetilde{y}_{i,t}$ is either the output (left-hand panel) or the unemployment gap (right-hand panel).

Figure 2. Workers bargaining power



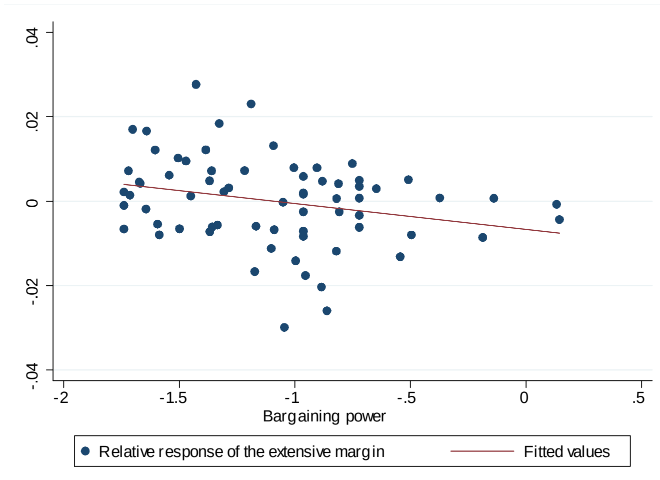
Notes. Each line is a synthetic measure of workers' bargaining power obtained by taking the first principal component of several indicators including union density and coverage, employment protection legislation and the coverage of collective bargaining agreements.

Figure 3. Relative contribution to variation in euro-area total hours worked from variations in the intensive margin and the extensive margin



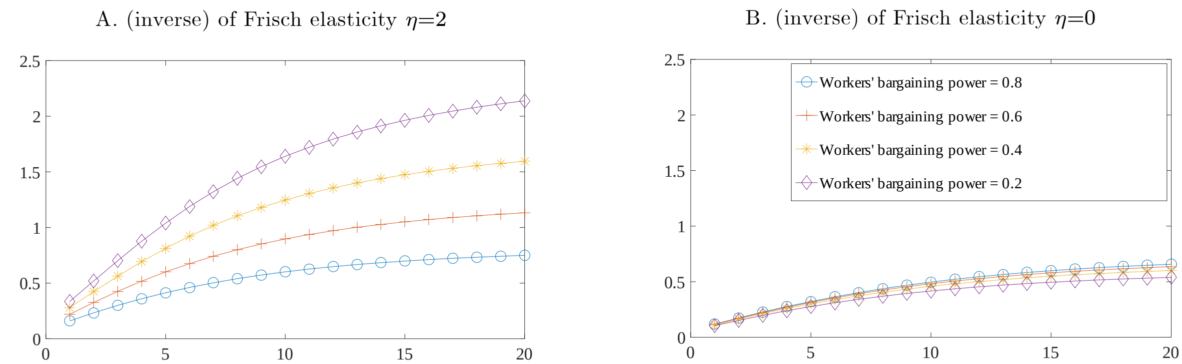
Notes: Denoting with th the Hodrick–Prescott filter of the log of total hours, with n the Hodrick–Prescott filter of the log of the number of workers and with h Hodrick–Prescott filter of the log of hours per employee, the contributions of employment and hours per worker to fluctuations in total hours worked is given by $\frac{cov(th,n)}{var(th)}$ and $\frac{cov(th,h)}{var(th)}$, respectively. Data are taken from the updated Ohanian and Raffo (2012) dataset.

Figure 4. Euro area: Correlation between the adjustment of the extensive margin relative to the intensive one and bargaining power



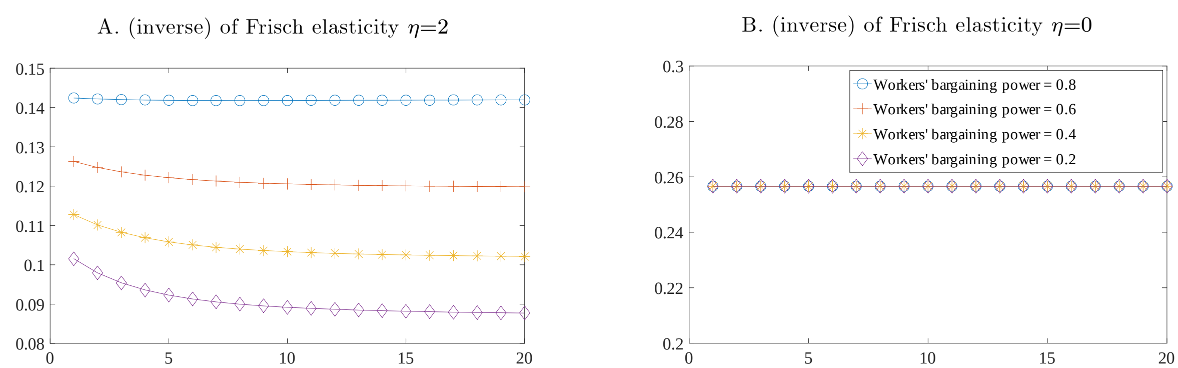
Notes: The figure displays the ratio between the percentage change in employment relative to changes in the intensive margin (net of changes in value added) and our measure of bargaining power. We use national account data for Germany, France and Italy (private sector only), over the sample 1996-2018.

Figure 5. Employment-hours per worker multiplier



Notes. The x-axis displays the time horizon h, while the y-axis displays the employment-hours per worker trade-off defined as the ratio between the cumulated impulse response functions to a 0.2% increase in Ω_t $k_h = \frac{\sum_{i=0}^{h} IRF_{\widehat{n}}(i)}{\sum_{i=0}^{h} IRF\widehat{h}(i)}$. Stochastic simulations are conducted by calibrating the parameters as in the prior distributions reported in table 3A and assuming $\rho_\Omega = 0.9$.

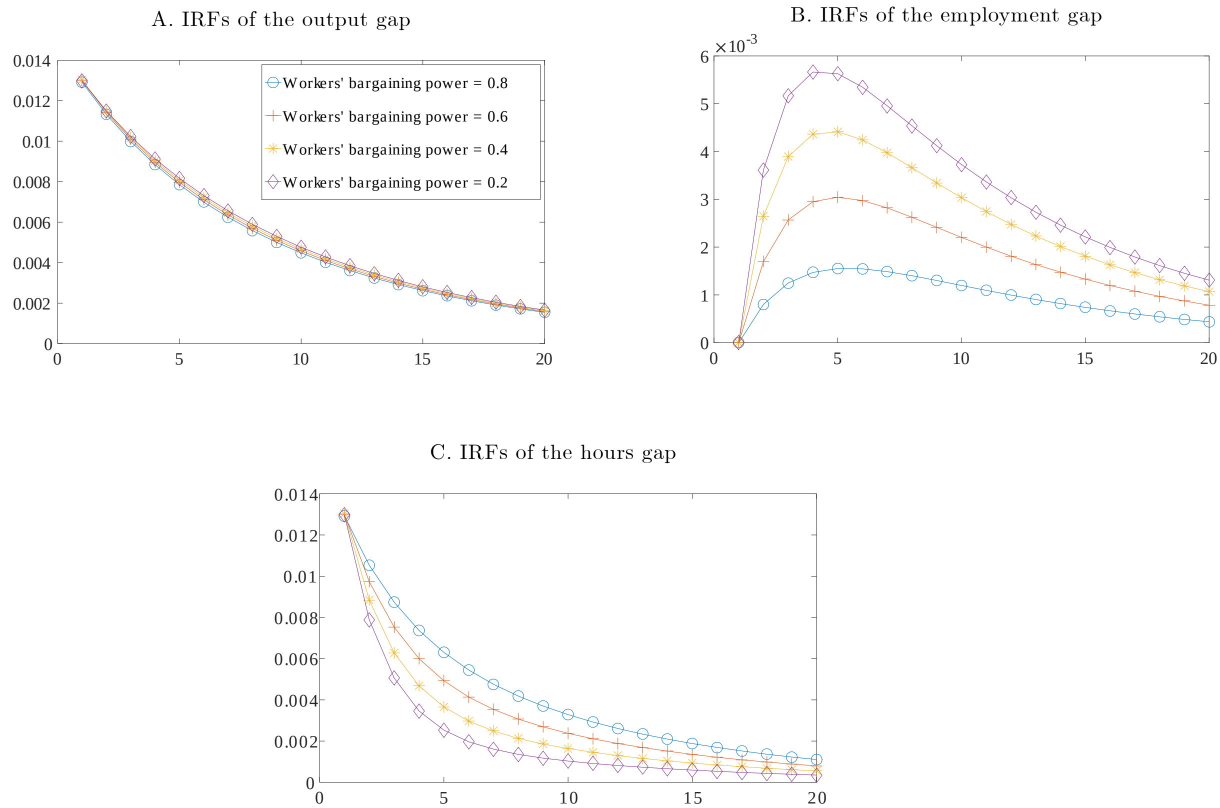
Figure 6. Inflation-output gap multiplier



Notes. The x-axis displays the time horizon h, while the y-axis displays the inflation-output gap trade-off defined as the ratio between the cumulated impulse response functions to a 0.2% increase in Ω_t $k_h = \frac{\sum_{i=0}^{h} IRF_{\widehat{\pi}}(i)}{\sum_{i=0}^{h} IRF\widehat{og}(i)}$. Stochastic simulations are conducted by calibrating the parameters as in the prior distributions reported in table 3A and assuming $\rho_\Omega = 0.9$.

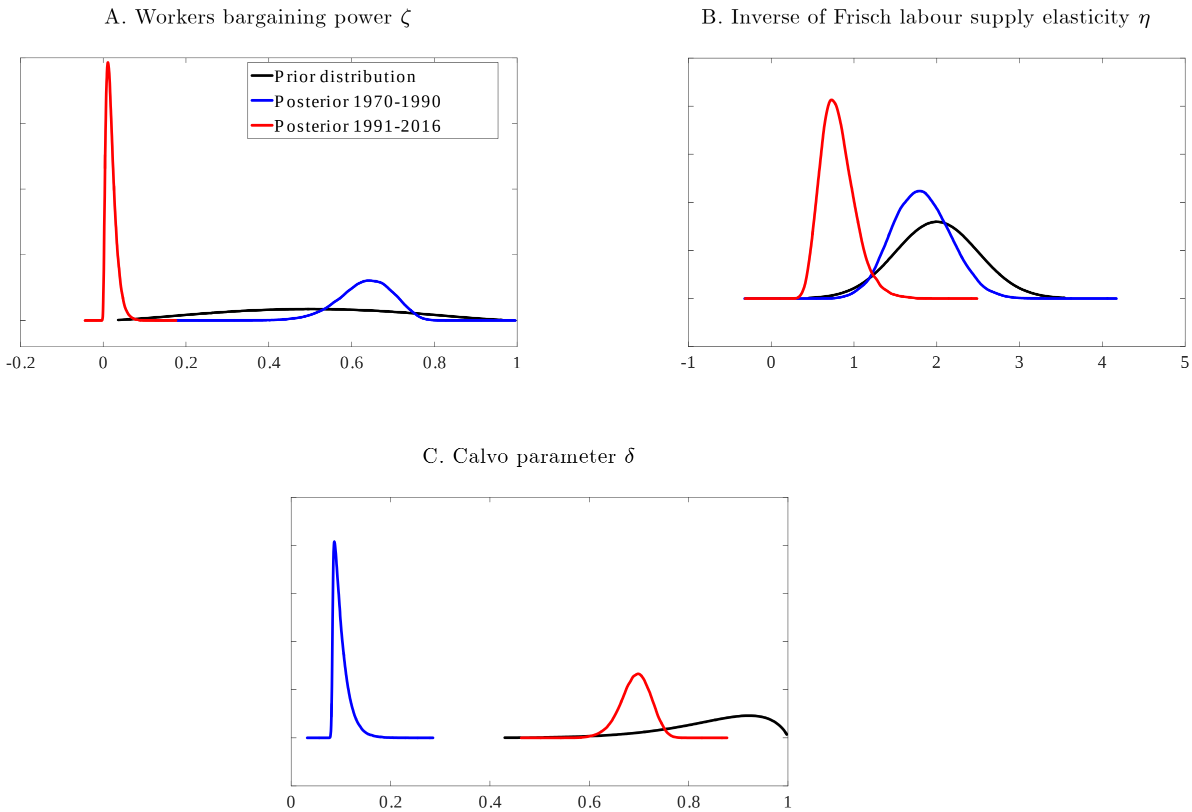
Figure 7. Impulse response functions of the output gap (A),employment gap (B) and hours gap (C), for different values of workers bargaining power

(inverse) of Frisch elasticity $\eta = 2$



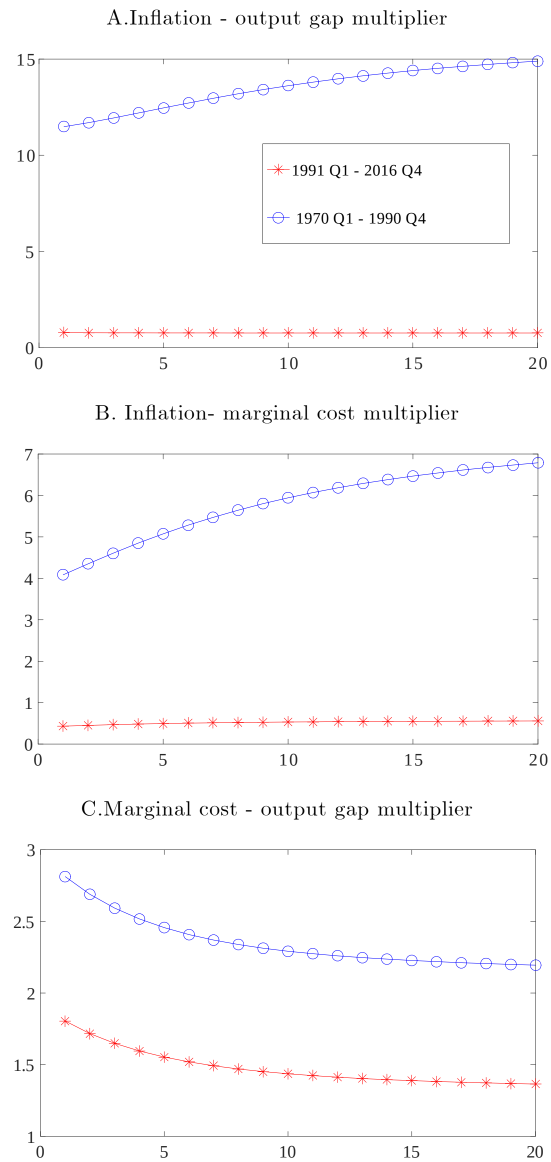
Notes. The x-axis displays the time horizon h, while the y-axis displays the impulse response function of the output gap (panel A), the employment gap (B) and the hours gap (C) to a 0.2% increase in Ω_t. Stochastic simulations are conducted by calibrating the parameters as in the prior distributions reported in table 3A and assuming $\rho_\Omega = 0.9$.

Figure 8. Prior and posterior distributions



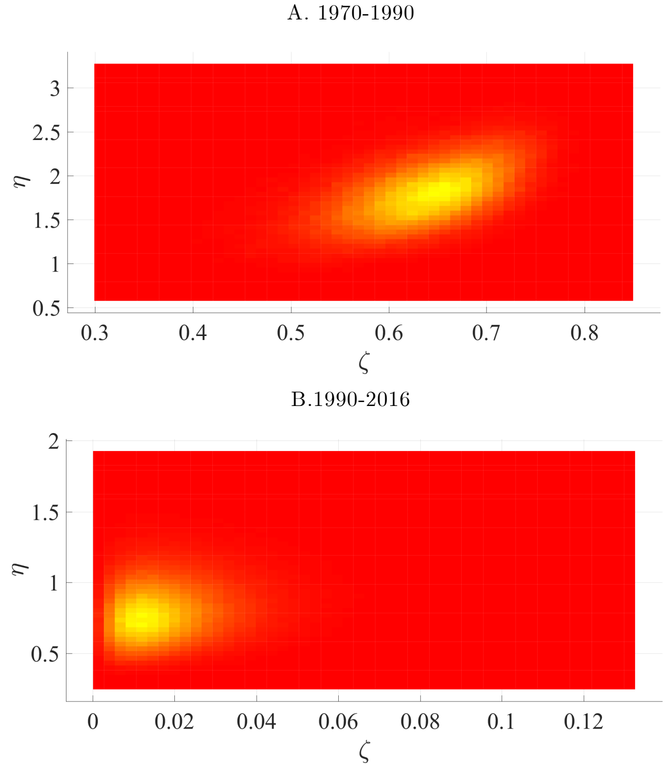
Notes. The x-axis displays the support of the distribution, while the y-axis the corresponding density. The black line refers to the prior distribution, while the blu and red ones refer to the posterior distribution over the sample 1970-1990 and 1991-2016, respectively.

Figure 9. Estimated multipliers conditional on the intertemporal demand shock



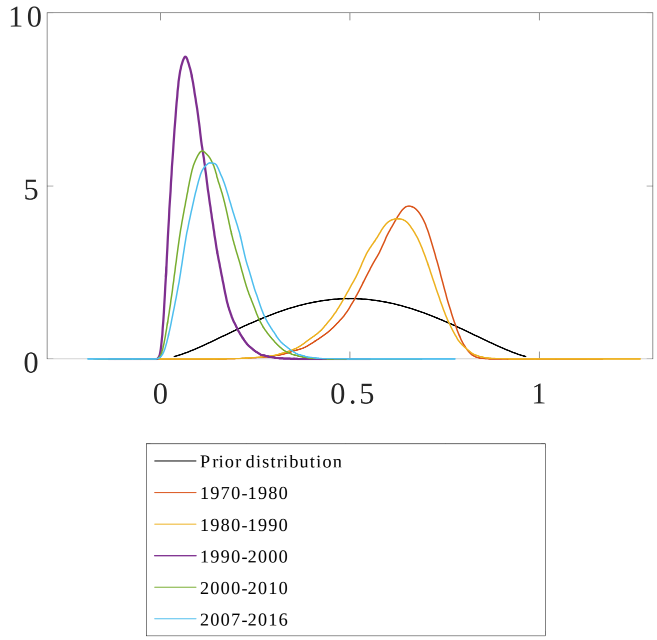
Notes. The x-axis displays the time horizon h, while the y-axis displays the trade-off between inflation and output gap (Panel A), marginal cost and output gap (Panel B), inflation and marginal cost (Panel C), defined as the ratio between the cumulated impulse response functions to a 0.2% increase in Ω_t $k_h = \frac{\sum_{i=0}^{h} IRF_Y(i)}{\sum_{i=0}^{h} IRF_X(i)}$, implied by the estimated parameters shown in Table 4A.

Figure 10. Joint posterior distributions of the inverse of Frisch labour supply elasticity η and workers' bargaining power ζ



Notes. Joint posterior distribution of η and ζ, obtained from the entire set of the joint draws of the parameters form the Metropolis-Hastings algorithm. The colour denotes probability density (low to high in red to yellow).

Figure 11. Prior and posterior distributions of workers' bargaining power ζ over different samples



Notes. The x-axis displays the support of the distribution, while the y-axis the corresponding density. The black line refers to the prior distribution, while the other ones report the posterior distribution over different time periods.

Table 1. Micro evidence: Labour adjustments and bargaining power - SURE model

	(1)	(2)	(3)	(4) *Demeaned variables*
			ΔEM	
shock	0.108*** (0.006)	0.134*** (0.010)	0.142*** (0.011)	0.097*** (0.011)
WBP		−0.000*** (0.000)	−0.000*** (0.000)	
shock*WBP		−0.001*** (0.000)	−0.001*** (0.000)	−0.001*** (0.000)
Controls	yes	no	yes	yes
Time dummies	yes	no	yes	yes
			ΔIM	
shock	0.086*** (0.008)	0.084*** (0.012)	0.067*** (0.013)	0.063*** (0.015)
WBP		0.000 (0.000)	0.000 (0.000)	
shock*WBP		0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)
Controls	yes	no	yes	yes
Time dummies	yes	no	yes	yes
R-squared - model 1	0.047	0.054	0.061	0.023
R-squared - model 2	0.024	0.029	0.027	0.016
Observations	6298	6298	6298	6298

Standard errors in parentheses *** p<0.1, ** p<0.05, * p<0.01. Estimates based on INVIND 2011-2014. In the two equation model the dependent variables the percentage change of yearly average employment (extensive margin, EM, model 1) and the percentage change of yearly hours worked per employee, respectively. Worker bargaining power (WBP) is proxied by the share of workers belonging to a union in 2010. The variable shock is the percentage difference between realized sales and sales expected at time t-1. Columns 1 and 3 include the following controls: the share of foreign sales in total firms' sales, to proxy for market structure, the percentage change in investments, to control for changes in the stock of capital, sector (Nace 1-digit) and geographical area dummies (4 areas). All the variables are de-meaned in column 4, to control for unobserved time invariant characteristics.

Table 2. Micro evidence: Price changes and bargaining power - Fixed effects.

	(1)	(2)	(3)	(4) *only export firms*
$shock_{abs}$	1.421 (1.177)	-1.623 (1.780)	-1.628 (1.780)	-0.443 (1.618)
$shock_{abs} * WBP$		0.109^{***} (0.050)	0.109^{***} (0.050)	0.107^{***} (0.065)
Firm fixed effects	yes	yes	yes	yes
Time dummies	yes	yes	yes	yes
Controls	no	no	yes	no
Observations	6519	6519	6519	6519
R-squared	0.476	0.478	0.478	0.521

Standard errors in parentheses *** p<0.1, ** p<0.05, * p<0.01. Clustered at the firm level. Estimates based on INVIND 2011-2014. The dependent variable is the absolute value of the percentage change in firm average product prices. Worker bargaining power (WBP) is proxied by the share of workers belonging to a union in 2010; shockabs is the percentage difference between realized sales and sales expected at time t-1 in absolute value. Column 3 includes the following controls: the share of foreign sales in total firms' sales, to proxy for market structure, the percentage change in investments, to control for changes in the stock of capital, sector (Nace 1-digit) and geographical area dummies (4 areas). Column 4 refers to the subsample of firms that have positive foreign sales.

Table 3A. Prior and Posterior distribution of structural parameters

	Prior Distribution		Posterior Distribution 1970Q1-1990Q4	Posterior Distribution 1991Q1-2016Q4
	Distr.	Mean (St. Dev)	Mean (5 perc; 95 perc)	Mean (5 perc; 95 perc)
ζ	$\mathcal{B}$	0.5 (0.200)	0.6336 (0.5324;0.7423)	0.0197 (0.0019;0.0374)
η	$\mathcal{N}$	2.0 (0.500)	1.8124 (1.2551;2.3998)	0.8044 (0.4756;1.1174)
δ	$\mathcal{B}$	0.85 (0.100)	0.1008 (0.0829;0.1224)	0.6926 (0.6445;0.7436)
θ	$\mathcal{B}$	0.7 (0.050)	0.6973 (0.6167;0.7756)	0.7021 (0.6218;0.7793)
λ	$\mathcal{B}$	0.03 (0.005)	0.0342 (0.0265;0.0417)	0.0229 (0.0179;0.0277)
ϕ_π	$\mathcal{N}$	1.5 (0.350)	3.4039 (3.1551;3.7265)	2.4865 (1.9605;3.0002)
ϕ_Y	$\mathcal{N}$	0.5 (0.100)	0.5431 (0.3823;0.7072)	0.7347 (0.5710;0.8833)

Note: The posterior distribution is obtained using the Metropolis-Hastings algorithm.

Table 3B. Prior and Posterior distribution of shock processes

	Prior Distribution		Posterior Distribution 1970Q1-1990Q4	Posterior Distribution 1991Q1-2016Q4
	Distr.	Mean (St. Dev.)	Mean (5 perc; 95 perc)	Mean (5 perc; 95 perc)
ρ_Ω	$\mathcal{B}$	0.5 (0.2)	0.9234 (0.89980.9497)	0.5857 (0.5188; 0.6570)
ρ_Υ	$\mathcal{B}$	0.5 (0.2)	0.9501 (0.94650.9529)	0.9477 (0.9412; 0.9529)
ρ_a	$\mathcal{B}$	0.5 (0.2)	0.6804 (0.57760.7894)	0.1491 (0.0819; 0.2126)
ρ_μ	$\mathcal{B}$	0.5 (0.2)	0.8000 (0.71930.8804)	0.8726 (0.8418; 0.9045)
σ_Ω	$\mathcal{IG}$	0.08	0.0566 (0.0420; 0.0704)	0.0681 (0.0562; 0.0797)
σ_Υ	$\mathcal{IG}$	0.08 (2)*	0.0174 (0.0139; 0.0208)	0.0125 (0.0106; 0.0143)
σ_a	$\mathcal{IG}$	0.08 (2)*	0.0101 (0.0094; 0.0109)	0.0155 (0.0134; 0.0176)
σ_μ	$\mathcal{IG}$	0.08 (2)*	0.0149 (0.0126; 0.0173)	0.0113 (0.0095; 0.0128)

: The posterior distribution is obtained using the Metropolis-Hastings algorithm.

*For the inverted gamma distributions degrees of freedom are indicated.

References

[1] Altig, David, Lawrence J. Christiano, Martin Eichenbaum, and Jesper Lind´e. (2011) "Firm-Specific Capital, Nominal Rigidities and the Business Cycle." *Review of Economic Dynamics*, 14, 225–47.

[2] Altissimo, Filippo Michael Ehrmann and Frank Smets (2006) "Inflation persistence and price-setting behaviour in the euro area. A summary of the IPN evidence," ECB Occasional Paper Series n. 46.

[3] Andolfatto, David. (1996) "Business Cycles and Labor-Market Search." *American Economic Review*, 86, 112–32.

[4] Ascari, G. (2004), "Staggered Prices and Trend Inflation: Some Nuisances", *Review of Economic Dynamics*, 7, 642-667.

[5] Atkeson Andrew and Lee E. Ohanian (2001) "Are Phillips Curves Useful for Forecasting Inflation", Quarterly Review, Federal Reserve Bank of Minneapolis, issue Win, pages 2-11.

[6] Auer Raphael, Claudio Borio and Andrew Filardo (2017) "The globalisation of inflation: the growing importance of global value chains" BIS Working Paper 602.

[7] Ball, L. M., G. Mankiw, and D. Romer. (1988). "The New Keynesian Economics and the Output-Inflation Tradeoff" Brookings Papers on Economic Activity 1, 1–82.

[8] Blanchard, Olivier J. (2016) "The Phillips Curve: Back to the '60s?", *American Economic Review: Papers & Proceedings* 2016, 106(5): 31–34

[9] Blanchard, Olivier J., and Peter Diamond. (1989) "The Beveridge Curve." *Brookings Papers on Economic Activity*, 1, 1–76.

[10] Blanchard, Olivier J., and Jordi Galì. (2010) "Labor Markets and Monetary Policy: A New Keynesian Model with Unemployment." *American Economic Journal: Macroeconomics*, 2, 1–30.

[11] Bulligan Guido, Elisa Guglielminetti and Eliana Viviano (2019) "Adjustments along the intensive margin and wages: Evidence from the euro area and the US", Bank of Italy, mimeo.

[12] Burda Michael C. and Jennifer Hunt (2011) "What Explains the German Labor Market Miracle in the Great Recession?" *Brookings Papers on Economic Activity*, pp. 273-335.

[13] Calvo, G. A. 1983. "Staggered Prices in a Utility-Maximizing Framework" *Journal of Monetary Economics* 12 (3): 383–98.

[14] Conti, Antonio M., Elisa Guglielminetti and Marianna Riggi (2019) "Labour productivity and the wageless recovery" Bank of Italy, mimeo.

[15] Daly, Mary C., Bart Hobijn, and Benjamin Pyle (2016). "What's up with wage growth?" In: FRBSF Economic Letter.

[16] Duca Ioana A., José M. Montero, Marianna Riggi and Roberta Zizza (2017) "I will survive. Pricing strategies of financially distressed firms" Temi di Discussione, Bank of Italy Working Paper, 1106.

[17] Fagan, Gabriel, Jerome Henry, and Ricardo Mestre (2005). "An area-wide model for the euro area". *Economic Modelling* 22(1), pp. 39-59.

[18] Farmer, Roger E.A. and Giovanni Nicolò (2018) "Keynesian Economics without the Phillips Curve", *Journal of Economic Dynamics and Control*, 89, 137-150.

[19] Forbes, Kristin, Ida Hjortsoe, and Tsvetelina Nenova (2018). "The shocks matter: Improving our estimates of exchange rate pass-through". In: *Journal of International Economics* 114, pp. 255-275.

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

[21] Gilchrist Simon, Raphael Schoenle, Jae Sim and Egon Zakrajšek (2017) "Inflation dynamics during the financial crisis" American Economic Review, 107 (3), 785-823.

[22] Juselius, Mikael and Elod Takats (2018) "The enduring link between demography and inflation," BIS Working Paper 722.

[23] Klenow, P. J., and B. A. Malin (2010), "Microeconomic Evidence on Price-Setting," NBER Working Paper No. 15826 (Cambridge, Massachusetts: National Bureau of Economic Research).

[24] Krueger, A. (2018), "Reflections on Dwindling Worker Bargaining Power and Monetary Policy" August 24, 2018 Luncheon Address at the Jackson Hole Economic Symposium.

[25] Kudoh, Noritaka, Hiroaki Miyamoto, and Masaru Sasaki (2018). "Employment and Hours over the Business Cycle in a Model with Search Frictions". *Review of Economic Dynamics* 27.

[26] Lane, Philip R. (2019) "The Phillips Curve at the ECB", speech at the 50 th Anniversary Conference of the Money, Macro & Finance Research Group London School of Economics 4 September.

[27] McLeay, M. and S. Tenreyro (2020): "Optimal inflation and the identification of the Phillips curve," NBER Macroeconomics Annual, 34, 199-255.

[28] Mojon Benoit and Xavier Ragot (2019) "Can an ageing workforce explain low inflation?" BIS Working paper 776.

[29] Nakamura, E. and J. Steinsson (2008), "Five Facts About Prices: A Reevaluation of Menu Cost Models", *The Quarterly Journal of Economics*, 123, 1415-1464.

[30] Ohanian, Lee E., and Andrea Raffo (2012). "Aggregate Hours Worked in OECD Countries: New Measurement and Implications for Business Cycles," *Journal of Monetary Economics*, vol. 59, no. 1, pp. 40-56.

[31] Petrongolo, Barbara, and Christopher A. Pissarides. (2001) "Looking into the Black Box: ASurvey of the Matching Function." *Journal of Economic Literature*, 39, 390–431.

[32] Ramey, Valerie A. and Sarah Zubairy (2018). "Government Spending Multipliers in Good Times and in Bad: Evidence from US Historical Data". *Journal of Political Economy* 126.2, pp. 850-901.

[33] Riggi Marianna and Sergio Santoro (2015) "On the slope and the persistence of the Italian Phillips curve" International Journal of Central Banking, 11(2), 157-197

[34] Smets, F. and R. Wouters (2007), "Shocks and Frictions in US Business Cycles: A Bayesian DGSE Approach", *American Economic Review* 97(3), 586-606.

[35] Stansbury, Anna, and Lawrence H. Summers. (2020) "The declining worker power hypothesis: An explanation for the recent evolution of the American economy." NBER Working paper 27193.

[36] Sveen, Tommy, and Lutz Weinke. (2005) "New Perspectives on Capital, Sticky Prices, and the Taylor Principle." *Journal of Economic Theory*, 123, 21–39.

[37] Thomas, Carlos (2011) "Search frictions, real rigidities and inflation dynamics", Journal of Money, Credit and Banking, 43(6), September 2011.

[38] Woodford, Michael. (2005) "Firm-Specific Capital and the New-Keynesian Phillips Curve." *International Journal of Central Banking*, 1, 1–46.

[39] Wulfsberg, F. (2009), "Price adjustments and inflation - evidence from Norwegian consumer price data 1975-2004", Norges Bank Working Paper No. 2009/11.

[40] Yellen, Janet L., (2014). "Labor Market Dynamics and Monetary Policy : a speech at the Federal Reserve Bank of Kansas City Economic Symposium, Jackson Hole, Wyoming, August 22, 2014," Speech 815, Board of Governors of the Federal Reserve System (U.S.).

Appendix

Descriptive statistics

In this Appendix we present the descriptive statistics of the sample used for the micro estimates based on INVIND (Table A1). Data refer to the period 2011-2014 and the sample is described in Table A1. It reports the average values of the variables used in the estimates discussed in Section 4 for each year of the panel-data sample.

Table A1, INVIND, sample characteristics.

	% change extensive margin	% change intensive margin	shock (unexpected change in sales)	% change in prices	Average share of unionized workers	Sample size
2010					0.293	2518
2011	-0.001	0.010	-0.003	0.025		2610
2012	-0.010	-0.012	-0.028	0.015		2263
2013	-0.011	0.001	-0.007	0.010		2123
2014	-0.008	0.012	-0.017	0.007		1999

Figure 1A. INVIND: Distribution of the percentage change in the number of employees

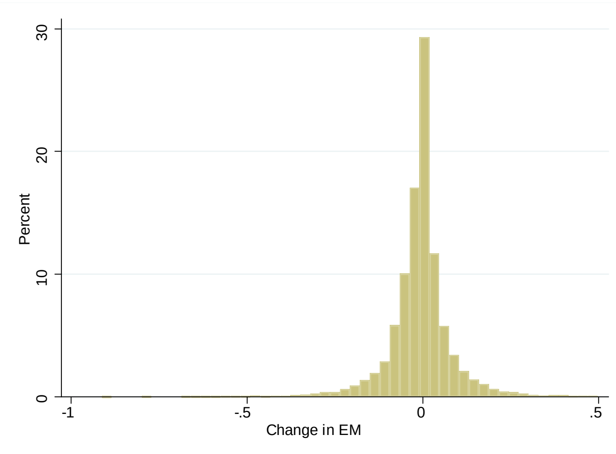


Figure 2A. INVIND: Distribution of the percentage change in the hours worked by employees

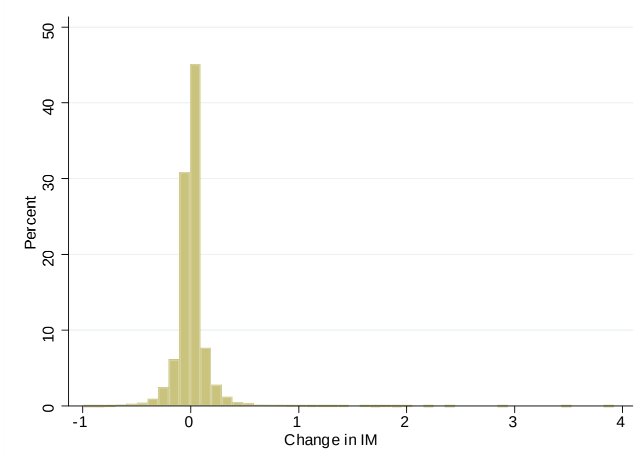


Figure 3A. INVIND: Distribution of the percentage difference between realized and expected demand

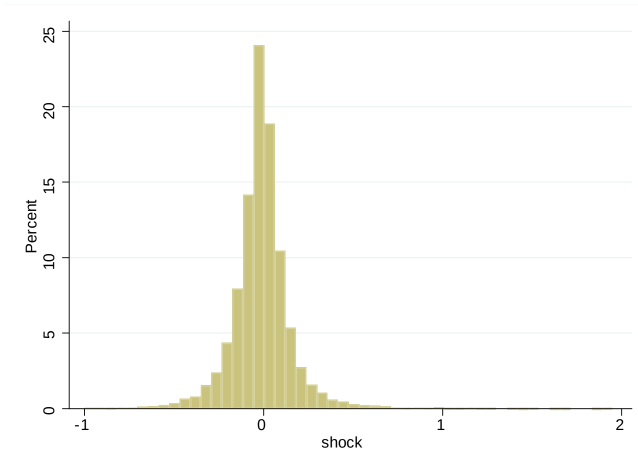


Figure 4A. INVIND: Distribution of the percentage change in product prices

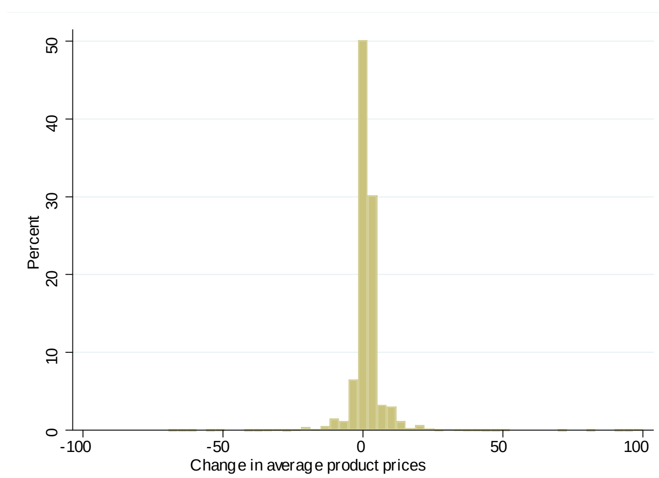
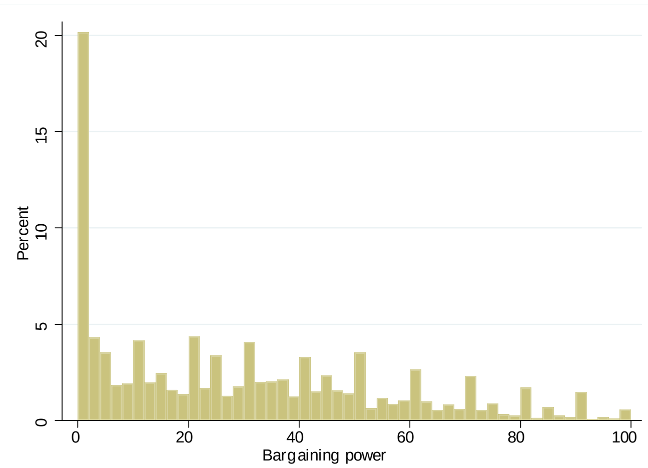


Figure 5A. INVIND: Distribution of the share of workers belonging to a union.



Results based on the WDN

The WDN survey was conducted by the ESCB between 2014 and 2015. The survey sampled about 25,000 firms in 25 European countries with the aim of assessing how firms adjusted wages and employment in response to the various shocks hitting the EU countries in the period 2010-13. The questionnaires are fully harmonized across countries. They are composed of two parts: a core questionnaire, collected by all the countries of the network, and a non-core one, conducted only in some countries.

The survey collects mainly qualitative information. Among other things, firms were asked if they needed to significantly adjust their labour input during the period 2010-13 by changing the number of employees, and/or hours per worker. Possible answers are: 1, "Strong decrease"; 2, "Moderate decrease";3, "No change"; 4, "Moderate increase"; 5 "Strong increase". We use these two questions to obtain two variables. First we take the ratio between the self-reported intensity in the use of the extensive margin and of the intensive margin, i. e. the ratio between the numeric values associated to each qualitative variable. Values lower than 1 signal that firms adjust more the extensive margin than the intensive one (and vice versa). We then derive a dummy variable equal to 1 if the ratio is lower than 1 and zero otherwise, i.e. the dummy variable is equal to one if the intensity of adjustment along the extensive margin is relatively higher. Second, we define a dummy equal to 1 if the firm adjusts only the extensive margin and zero if it changes both margins.

The survey also collects measures of self-perceived shocks. Here we rely on a question aimed at understanding whether firms' activity was affected by demand changes during the period 2010-13.[25] Possible answers are defined as above. For consistency with our theoretical model, we look at shocks independently on whether they were positive or negative and we define a dummy equal to zero in case of no change in product demand and 1 in case of any change. Workers' bargaining power is proxied by the proportion of employees covered by a collective agreement (either national/regional or at the firm level). Unfortunately, this information was included only in the non-core questionnaire and is available for few countries. In this paper we use the data of Belgium, France, Hungary, Lithuania, Luxembourg, Latvia, Poland, and Romania, for which larger sample size is available. We exclude Italy because in Italy virtually all workers are covered by a national (sector-level) collective agreement.

Table A2 reports the descriptive statistics of the sample used for the micro estimates

[25] The question is formulated as: *How did the level of demand for your products/services affect your firm's activity during 2010-2013*?

based on the WDN. The reference period of the WDN data is 2010-2013 (interviews conducted between 2014 and 2015). The data in Table A2 are averages for each of the countries used in the estimation (unweighted). The upper part of Table A2 refers to all firms, the lower part to those that regostered at least one demand shock (positive or negative) during the reference period.

Table A2. WDN, sample characteristics.

All	Intensity of adj. EM	Share firms adjusting EM	Share workers with collective agreement (WBP)	Share firms with a shock	Sample size
BE	1.134	58.7	93.0	79.0	388
FR	1.032	70.0	96.1	87.2	830
HU	0.948	77.4	86.5	60.2	334
LT	0.943	71.6	0.2	68.1	45
LU	0.953	68.0	80.4	71.5	89
LV	1.044	59.4	95.8	77.0	28
PL	0.922	62.7	93.4	74.5	64
RO	1.039	74.9	68.9	73.5	1820
Shock =1					
BE	1.145	57.5	92.6	1.0	305
FR	1.021	69.0	95.9	1.0	712
HU	0.937	73.3	86.7	1.0	216
LT	0.903	86.1	0.2	1.0	31
LU	0.950	60.3	76.0	1.0	60
LV	1.068	57.6	98.0	1.0	22
PL	0.978	50.2	91.7	1.0	48
RO	1.040	74.1	68.5	1.0	1301

Since the WDN is a qualitative survey, we simply run the regression of our two measures of relative change in the extensive margin on the share of workers in a union. We also control for country and sector dummies (manufacturing, energy). Results are reported in Table A3. The first two columns refer to the probability of a higher intensity in adjustments along the extensive margin (relative to the intensive one). The higher the ratio, the higher the intensity of the relative change in the extensive margin. The other two remaining columns report the probability of adjusting only the extensive margin, in the subset of firms that have adjusted at least one of the two margins. As before, regressions are conditional on having reported to have registered a demand shock (positive or negative). Results clearly show that when the share of workers covered by collective agreements increases, the use of the extensive margin (relative to the intensive one) is also less intense and it is less likely that firms adjust only the extensive margin.

Table A3: Micro evidence: Cross-country analysis. Probability of a more intense adjustment along the extensive margin in cols 1-2; probability to adjust only the extensive margin (instead of both margins) in cols. 3-4 . Conditional on having registered a demand shock.

	(1)	(2)	(3)	(4)
	Ratio	Ratio	Only the extensive	Only the extensive
WBP	-0.001^{*} (0.000)	-0.001^{*} (0.000)	-0.001^{*} (0.000)	-0.001^{*} (0.000)
Country dummies	yes	yes	yes	yes
Sector dummies	no	yes	no	yes
Observations	2695	2695	1982	1982
R-squared	0.009	0.020	0.016	0.019

Standard errors in parentheses *** p<0.1, ** p<0.05, * p<0.01. Estimates based on WDN, third survey. Sample of firms that received a shock between 2010 and 2013. In cols. 1 and 2 the dependent variable is equal to 1 if the ratio between the intensity of use in the extensive margin is higher than the intensity of use of the intensive 1. In cols. 3 and 4 the dependent variable is a dummy equal to one if the firm adjusts only the extensive margin, and 0 if it adjusts both the extensive and the intensive margin. Workers' bargaining power (WBP) is proxied by the share of workers belonging to a union.

Monte Carlo Markov Chains diagnostics

As specified in Section 4, for each sample we run three chains of 500,000 Metropolis-Hastings simulations. If the results are sensible, they should be similar within any of the 500,000 iterations of Metropolis-Hastings simulations and close across chains. We test for convergence using the Brooks and Gelman (1998) methodology.

Let ξ_{ij} be the i^{th} draw out of I, in the j^{th} sequence out of J. Let $\overline{\xi}_{\bullet j}$ be the mean of the j^{th} sequence and let $\overline{\xi}_{\bullet\bullet}$ be the mean across all available data. We denote with $\widehat{B} = \frac{1}{J-1}\sum_{j=1}^{J}\left(\overline{\xi}_{\bullet j} - \overline{\xi}_{\bullet\bullet}\right)^2$ the estimate of the "between" variance of the mean σ^2/I, and $B = \widehat{B}I$ an estimate of the variance. Also, we denote with $\widehat{W} = \frac{1}{J}\sum_{j=1}^{J}\frac{1}{I}\sum_{i=1}^{I}\left(\overline{\xi}_{ij} - \overline{\xi}_{\bullet j}\right)^2$ and with $W = \frac{1}{J}\sum_{j=1}^{J}\frac{1}{I-1}\sum_{i=1}^{I}\left(\overline{\xi}_{ij} - \overline{\xi}_{\bullet j}\right)^2$ two estimates of "within" variance.

To have sensible results one should have $\underset{I\to\infty}{lim}\widehat{B} \to 0$ and $\underset{I\to\infty}{lim}\widehat{W}$ $\to$constant. These can be done for any moments, not just the variance.

Figures 6A.a (for the 1970Q1-1990Q4) and 7A.a (for the 1991Q1- 2016Q4) report W (red line) and $\left(\widehat{W} + \widehat{B}\right)$ (blue line) of three measures of parameters moments: "m2", a measure of the variance, "m3" based on third moments and "interval", being constructed from 80% confidence interval around the parameter mean. In order to have reliable results these should be relatively constant and should converge. Figures 6A.b and 7A.b show an aggregate measure based on the eingenvalues of the variance-covariance matrix. The horizontal axis represents the number of Metropolis-Hastings iterations, whereas the vertical axis the measure of the parameter moments.

Diagnostics confirm convergence and stability in all measures of parameter moments.

Figure 6A.a Convergence diagnostic. Univariate analysis 1970Q1-1990Q4

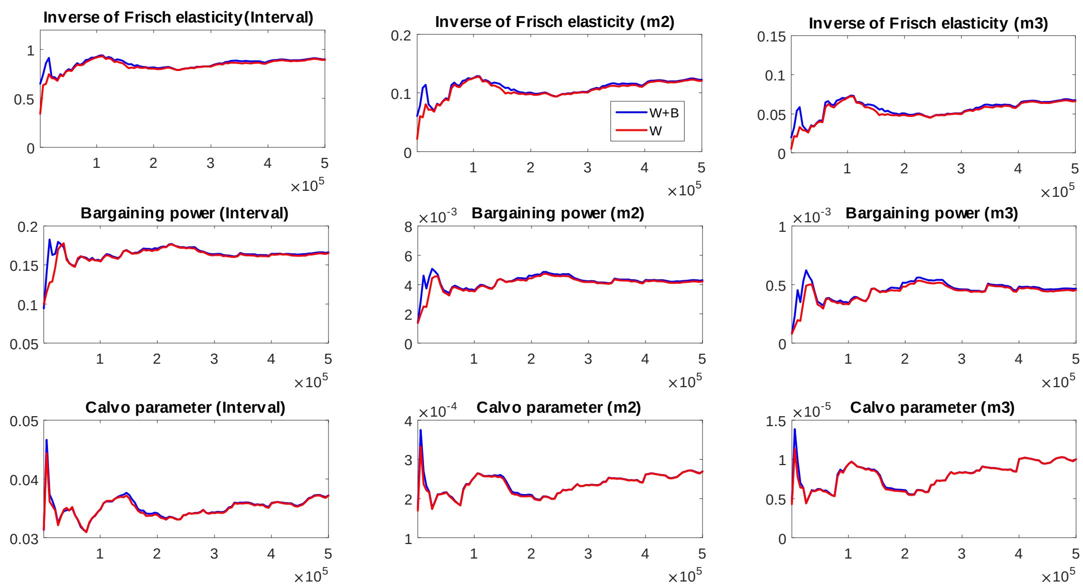


Figure 6A.b Convergence diagnostic. Multivariate analysis 1970Q1-1990Q4

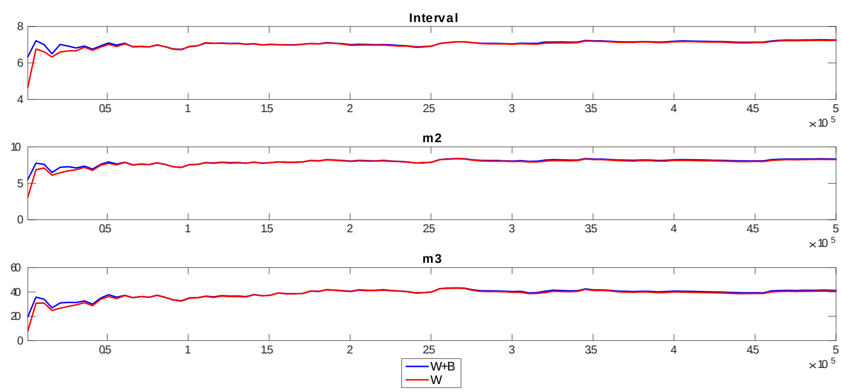


Figure 7A.a Univariate analysis 1991Q1- 2016Q4

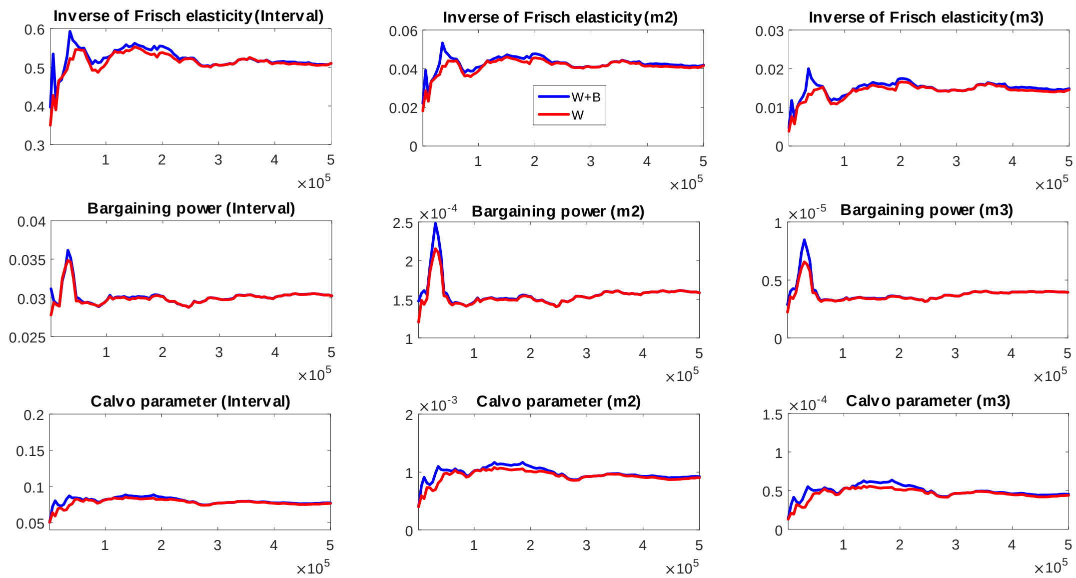
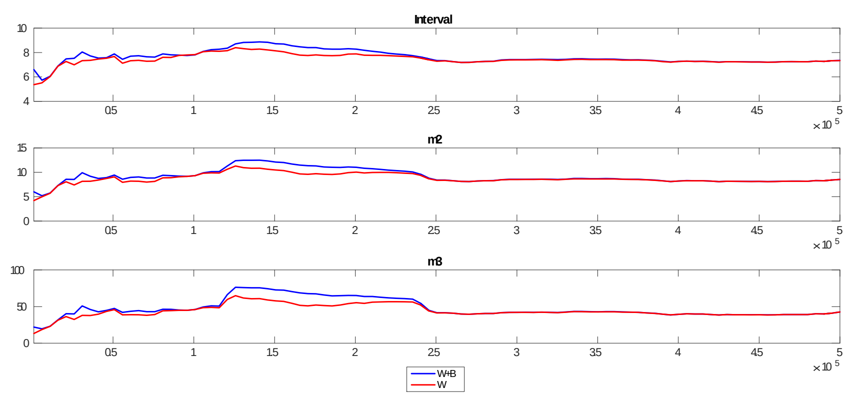


Figure 7A.b Convergence diagnostic. Multivariate analysis 1991Q1- 2016Q4



Previous volumes in this series

902 November 2020	An early stablecoin? The Bank of Amsterdam and the governance of money	Jon Frost, Hyun Song Shin and Peter Wierts
901 November 2020	Inside the regulatory sandbox: effects on fintech funding	Giulio Cornelli, Sebastian Doerr, Leonardo Gambacorta and Ouarda Merrouche
900 November 2020	What can commercial property performance reveal about bank valuations?	Emanuel Kohlscheen and Előd Takáts
899 November 2020	The macro-financial effects of international bank lending on emerging markets	Iñaki Aldasoro, Paula Beltrán, Federico Grinberg and Tommaso Mancini-Griffoli
898 November 2020	What comes next?	Daniel M Rees
897 October 2020	Non-US global banks and dollar (co-)dependence: how housing markets became internationally synchronized	Torsten Ehlers, Mathias Hoffmann and Alexander Raabe
896 October 2020	Have the driving forces of inflation changed in advanced and emerging market economies?	Güneş Kamber, Madhusudan Mohanty and James Morley
895 October 2020	Pass-through from short-horizon to long-horizon inflation expectations, and the anchoring of inflation expectations	James Yetman
894 October 2020	Effects of eligibility for central bank purchases on corporate bond spreads	T Mäkinen, F Li, A Mercatanti and A Silvestrini
893 October 2020	Assessing the fiscal implications of banking crises	Claudio Borio, Juan Contreras and Fabrizio Zampolli
892 October 2020	Banking across borders: Are Chinese banks different?	Eugenio Cerutti, Catherine Koch and Swapan-Kumar Pradhan
891 October 2020	At the crossroads in the transition away from LIBOR: from overnight to term rates	Basil Guggenheim and Andreas Schrimpf
890 October 2020	How does international capital flow?	Michael Kumhof, Phurichai Rungcharoenkitkul and Andrej Sokol

All volumes are available on our website www.bis.org.