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Effects of product and labor market regulation on macroeconomic outcomes ☆

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ABSTRACT

This paper develops a New Keynesian model with labor search to investigate the effects of product and labor market regulation on macroeconomic outcomes. Product market regulation is proxied by the firm's price markup, and labor market regulation by the worker's bargaining power over the real wage. The results indicate that an increase in both types of regulation leads to a decline in macroeconomic fluctuations, and increases the importance of technology shocks in explaining movements in labor market tightness and employment.

1. Introduction

In the presence of nominal rigidities, structural changes that have an impact on the price-setting behaviour of the firm also affect the way in which real activity fluctuates. Micro-theory indicates that product and labor market regulation changes the underlying structure of the economy by altering the way in which product and labor prices are determined. These considerations suggest that the New Keynesian setting provides a unified, coherent framework in which to investigate the effect of product and labor market regulation on nominal aggregates, namely prices, as well as real ones, such as output. Perhaps surprisingly, as detailed below, no work as yet has studied the effects of regulation in this framework, nor has examined their effect on macroeconomic fluctuations. This paper takes on these tasks, detailing how product and labor market regulation influences the firm's price-setting mechanism, which, to the extent that nominal prices do not adjust immediately, then alters the way in which other real macroeconomic aggregates fluctuate.

Over the past two decades, as documented by Stock and Watson (2005), most developed economies have been characterized by a step change in macroeconomic performance: business cycles have been much less volatile than they were in the 1970s. In particular, during the 1970s and 1980s the volatility of output was about three times of its level during the last decade, while the volatility of inflation fell by approximately four times during the same period. Reductions in product

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and labor market regulation are often regarded as an important component for this change, due to their beneficial effect on the allocation of resources.[1] Would a theoretical model of the business cycle support this consideration?

To this end, Section 2 sets up a standard New Keynesian macroeconomic framework, where firms face a cost to adjusting nominal prices, enriched for labor market search in a similar way to the prototype Diamond–Mortessen–Pissarides model. The outcome is a setting similar to those of Blanchard and Gali (2006) and Krause and Lubik (2007), which offer a detailed description of the optimizing behaviour of households and firms, and their interactions in the determination of labor market outcomes. Such a framework also explicitly incorporates a monetary authority and, hence, can account for the detailed dynamics of nominal variables. As is common in this class of models, as in Krause and Lubik (2007), stochastic disturbances characterize changes in technology and monetary policy actions and are thereby the sources of movements in the variables. In this type of model, the price-setting mechanism is incorporated through monopolistic competition, as first introduced by Rotemberg (1982), such that an optimizing firm would set its price at a constant markup over marginal cost. In the labor market, a job match yields some pure economic surplus for existing matches, such that a long-term employment relationship emerges, and the notion of marginal cost incorporates the wage as well as present and future costs of hiring.

Section 3 details the distinct ways in which product and labor market regulation affect the price-setting behaviour of the firm. Product market regulation affects the size of the rent going to the firm, or, in other words, the firm's price markup, while labor market regulation affects the determination of the wage, which depends on the worker's bargaining power, and consequently, the size of the firm's marginal cost, that is an important component for the price determination. Therefore, both play a crucial role in the determination of prices, and, moreover, due to staggered nominal price adjustment, for fluctuations of real aggregates.[2]

Section 4 presents the calibration and discusses the findings. It starts by investigating how macroeconomic outcomes react to technology and monetary policy shocks for the baseline calibration, so as to lay out the dynamic properties of the model. It then isolates the effect of product and labor market regulation on macroeconomic aggregates by varying, in turn, the calibration of the parameters for product and labor market regulation. An increase in labor market regulation increases the expected probability of not finding a match, so that it is harder for the firm to recruit in the future, and that in turn dampens the response of the wage to shocks. The weak response of the wage triggers a weak response of inflation and, through monetary policy, a more gentle fall in the nominal interest rate. As a result, the response of the real interest rate declines, and the response of output becomes weaker. An increase in product market regulation has a similar effect on macroeconomic aggregates, although the transmission channel works directly through the firm's price-setting decision. The final part of this section uses forecast error variance decompositions to analyze the extent to which productivity and monetary policy shocks can explain movements in each variable, and how the importance of each shock varies with changes in labor and product market regulation. Technology shocks represent the dominant source of movements in output, inflation, and labor market outcomes, while monetary policy shocks play an important role in driving labor market tightness and employment, and a supporting role in driving short-run fluctuations. An increase in either type of regulation increases the effect of technology shocks on labor market tightness and employment, while leaving its influence on the other variables broadly unchanged.

Relatively few theoretical studies focus on the effects of product and labor market regulation on macroeconomic outcomes. Most of them consider only the effects of product market regulation, modelled as entry regulation, on equilibrium labor market outcomes, without considering their effects on other macroeconomic aggregates. For instance, Messina (2006) spells out the channels through which product market regulation interacts with the forces of structural change, determining the equilibrium sectoral allocation of labor as well as labor market outcomes. Similarly, Fang and Rogerson (2007) assess the channel through which product market regulation affects labor market outcomes in different static versions of a simple model of aggregate time allocation. As discussed, these theoretical contributions limit their analysis to the effect of product market regulation on labor market outcomes, and perform the analysis in a static setting. This paper instead, extends the analysis to consider labor market regulation and, by incorporating labor market search, spells out the effects of both product and labor market regulation on a broader set of macroeconomic outcomes such as inflation and output. Ebell and Haefke (2004, 2006) develop an equilibrium model characterized by labor market search. They use this framework to study the impact of product market regulation, in the form of entry regulation, on unemployment, and on the choice between individual or collective bargaining. Although the structure of the labor market is similar to that used here, they do not consider interactions between labor and product market regulation, they use a static setting and, again, do not study macroeconomic outcomes such as inflation and output. Finally, Blanchard and Giavazzi (2003) and Spector (2004) analyze the effect of labor and product market regulation in a simple equilibrium model, where, similarly to this paper, product market regulation is internalized through the degree of competition among firms, and labor market regulation is represented by wage bargaining. But again, their analysis is limited to equilibrium labor market outcomes. Unlike all these papers, this work analyzes the effect of both product and labor market regulation on a broad set of macroeconomic aggregates, and carries out the analysis using a full-blown, dynamic, stochastic, model.

[1] See Schiantarelli (2005) for a recent review of the literature.

[2] In this paper, labor market regulation is limited to the worker's bargaining power. In principle, other forms of regulation, such as changes in unemployment benefits, or hiring costs, or the degree of wage rigidities could be interpreted as labor market reforms and be part of the analysis. Recent works by Hagedorn and Manovskii (2008) and Christoffel et al. (2006) show that these other regulations may have a non-trivial impact on the dynamics of labor market search models. Extending the analysis with a more elaborated model that includes these potential alternative reforms would certainly be a very useful task for future research.

2. The economic environment

The theoretical model resembles those used by Blanchard and Gali (2006) and Krause and Lubik (2007), which combine a standard New Keynesian model with labor market search. The model economy consists of a representative household, a representative goods-producing firm, a continuum of intermediate-goods-producing firms indexed by $i \in [0,1]$, and a central bank.

The labor market is similar to that in Blanchard and Gali (2006), which is based on the Diamond–Mortensen–Pissarides model of search and matching. This framework relies on the assumption that the processes of job search and recruitment are costly for both the firm and worker. Job creation takes place when a firm and a searching worker meet and agree to form a match at a negotiated wage, which depends on the parties' bargaining power. The match continues until the parties exogenously terminate the relationship. When this occurs, job destruction takes place and the worker moves from employment to unemployment, and the firm can either withdraw from the market or hire a new worker.

The goods market is comprised of a representative finished-goods-producing firm, and a continuum of intermediate-goods-producing firms indexed by $i \in [0,1]$. During each period $t = 0,1,2,\ldots$, each intermediate-goods-producing firm hires workers and produces a distinct, perishable good. During each period $t = 0,1,2,\ldots$, the finished-goods-producing firm purchases intermediate-goods from the intermediate-goods-producing firms and sells it at an established price on the market. Each intermediate-goods-producing firm sets the price as a markup over marginal cost, and it faces a cost to adjusting its nominal price, as in Rotemberg (1982). This cost to price adjustment allows the monetary authority to influence the behaviour of real variables in the short-run. Krause and Lubik (2007) adopt a similar goods market setting in the context of a labor search model.

The central bank is modelled with a modified Taylor (1993) rule as in Clarida et al. (1998): it gradually adjusts the nominal interest rate in response to deviations of output and inflation from their steady-state levels.

The next section describes the agents' tastes, technologies, the policy rule, and the structure of the labor and goods market in detail.

2.1. The representative household

During each period $t = 0,1,2,\ldots$, the representative household maximizes the expected utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[C_t^{1-\sigma}/(1-\sigma) - \chi N_t^{1+\phi}/(1+\phi) \right], \tag{1}$$

where the variable C_t is consumption, N_t is units of labor, and β is the discount factor $0 < \beta < 1$. The representative household enters period t with bonds B_{t-1}. At the beginning of the period, the household receives a lump-sum nominal transfer T_t from the central bank and nominal profits F_t from the intermediate-goods-producing firms. The household supplies N_t units of labor at the wage rate W_t to each intermediate-goods-producing firm $i \in [0,1]$ during period t. Then, the household's bonds mature, providing B_{t-1} additional units of currency. The household uses part of this additional currency to purchase B_t new bonds at nominal cost B_t/R_t, where R_t represents the gross nominal interest rate between t and $t+1$. The household uses its income for consumption, C_t, and carries B_t bonds into period $t+1$, subject to the budget constraint

$$P_t C_t + B_t/R_t = B_{t-1} + W_t N_t + F_t + T_t \tag{2}$$

for all $t = 0,1,2,\ldots$. Thus the household chooses $\{C_t, B_t\}_{t=0}^{\infty}$ to maximize its utility (1) subject to the budget constraint (2) for all $t = 0,1,2,\ldots$. Letting $\pi_t = P_t/P_{t-1}$ denote the gross inflation rate, and Λ_t the non-negative Lagrange multiplier on the budget constraint (2), the first order conditions for this problem are

$$\Lambda_t = C_t^{-\sigma} \tag{3}$$

and

$$\Lambda_t = \beta R_t E_t(\Lambda_{t+1}/\pi_{t+1}). \tag{4}$$

According to Eq. (3), the Lagrange multiplier must equal the household's marginal utility of consumption. Eq. (4), once Eq. (3) is substituted in, is the representative household's Euler equation that describes the consumption decision.

2.2. The labor market

During each period $t = 0,1,2,\ldots$, the flow into employment results from the number of workers who survive the exogenous separation, and the number of new hires, H_t. Hence, total employment evolves according to

$$N_t(i) = (1-\delta)N_{t-1}(i) + H_t(i), \tag{5}$$

where $N_t(i)$ and $H_t(i)$ represent the number of workers employed and hired by firm i in period t, and δ is the exogenous separation rate and $0 < \delta < 1$. For all $t = 0,1,2,\ldots$, the fraction of aggregate employment and hires supplied by the representative household must satisfy $N_t = \int_0^1 N_t(i)di$ and $H_t = \int_0^1 H_t(i)di$, respectively. It is convenient to introduce the variable x_t, labor market tightness

$$x_t = H_t/U_t \tag{6}$$

and assume, as in Blanchard and Gali (2006), full participation in the labor market such that

$$U_t = 1 - (1-\delta)N_{t-1} \tag{7}$$

is the beginning of the period unemployment. Finally, it is useful to define

$$u_t = 1 - N_t \tag{8}$$

the fraction of the population left without a job after recruitment. Since all new hires are from the part of unemployed workers, $0 < x_t < 1$. Hence, x_t also represents the probability that an unemployed worker finds a job.

Let $\mathscr{W}_t^N$ and $\mathscr{W}_t^U$ denote the marginal value of the expected income of an employed, and unemployed worker, respectively. The employed worker earns a wage, suffers disutility from work, and might lose her job with probability δ. Hence, the marginal value of a new match is

$$\mathscr{W}_t^N = W_t - \frac{\chi N_t^{\phi}}{\Lambda_t} + \beta E_t \frac{\Lambda_{t+1}}{\Lambda_t}\{[1-\delta(1-x_{t+1})]\mathscr{W}_{t+1}^N + \delta(1-x_{t+1})\mathscr{W}_{t+1}^U\}. \tag{9}$$

This equation states that the marginal value of a job for a worker is given by the wage less the marginal disutility that the job produces to the worker, and the expected-discounted net gain from being either employed or unemployed.

The unemployed worker expects to move into employment with probability x_t. Hence, the marginal value of unemployment is

$$\mathscr{W}_t^U = \beta E_t \frac{\Lambda_{t+1}}{\Lambda_t}\left[x_{t+1}\mathscr{W}_{t+1}^N + (1-x_{t+1})\mathscr{W}_{t+1}^U\right]. \tag{10}$$

This equation states that the marginal value of unemployment is made up of the expected-discounted capital gain from being either employed or unemployed.[3]

The structure of the model guarantees that a realized job match yields some pure economic surplus. The share of this surplus between the worker and the firm is determined by the wage level, in addition to compensating each side for its costs from forming the job. As in Pissarides (2000), the wage is set according to the Nash bargaining solution. The worker and the firm split the surplus of their matches with the absolute share $0 < \eta < 1$. The difference between Eqs. (9) and (10) determines the worker's economic surplus. The firm's surplus is simply given by the cost per hire, G_t, which, as in Blanchard and Gali (2006), is an increasing function of aggregate technology, a_t, and labor market tightness

$$G_t = a_t B x_t^{\alpha}, \tag{11}$$

where $\alpha \geqslant 0$ and $B \geqslant 0$.[4] Hence, the total surplus from a match is the sum of the worker's and firm's surpluses. The wage bargaining rule for a match is

$$\eta G_t = (1-\eta)(\mathscr{W}_t^N - \mathscr{W}_t^U).$$

Substituting Eqs. (9) and (10) in this last equation produces the agreed wage

$$W_t = \chi N_t^{\phi}/\Lambda_t + \zeta\{G_t - \beta(1-\delta)E_t(\Lambda_{t+1}/\Lambda_t)[(1-x_{t+1})G_{t+1}]\}, \tag{12}$$

where $\zeta = \eta/(1-\eta)$ is the relative bargaining power of the worker. Eq. (12) shows that the wage equals the marginal rate of substitution between consumption and leisure together with current hiring costs, and the expected savings in terms of the future hiring costs if the match continues. The influence of this last two terms on the wage depends, as detailed further below, on the relative power of the worker in the wage bargain.

2.3. The goods market

As described above, the production sector is comprised of a representative finished-goods-producing firm, and a continuum of intermediate-goods-producing firms indexed by $i \in [0,1]$, characterized by staggered price-setting as in Rotemberg (1982).

2.3.1. The representative finished-goods-producing firm

During each period $t = 0, 1, 2, \ldots$, the representative finished-goods-producing firm uses $Y_t(i)$ units of each intermediate-good $i \in [0,1]$, purchased at nominal price $P_t(i)$, to produce Y_t units of the finished product at constant returns to scale technology

[3] Unemployment benefits are omitted from the marginal value of unemployment since they are not part of the analysis.

[4] Note that, in principle, as suggested in Yashiv (2006), the form of hiring costs may affect the way in which regulation influences aggregate fluctuations. In particular, whether hiring costs respond to aggregate productivity shocks, a_t, or the specific numerical values of the parameters that capture their sensitivity to labor market tightness, α, or their share of output, B, may have consequences on aggregate fluctuations. An extensive sensitivity analysis on these parameters and the importance of indexing hiring costs with productivity has established that they do not materially affect the quality of the results.

$$\left[\int_0^1 Y_t(i)^{\frac{\theta-1}{\theta}} di\right]^{\frac{\theta}{\theta-1}} \geqslant Y_t,$$

where $\theta > 1$. Hence, the finished-goods-producing firm chooses $Y_t(i)$ for all $i \in [0,1]$ to maximize its profits

$$P_t\left[\int_0^1 Y_t(i)^{\frac{\theta-1}{\theta}} di\right]^{\frac{\theta}{\theta-1}} - \int_0^1 P_t(i)Y_t(i)di$$

for all $t = 0, 1, 2, \ldots$. the first order conditions for this problem are

$$Y_t(i) = [P_t(i)/P_t]^{-\theta} Y_t \tag{13}$$

for all $i \in [0,1]$ and $t = 0, 1, 2, \ldots$.

Competition drives the finished-goods-producing firm's profit to zero at the equilibrium. This zero profit condition implies that

$$P_t = \left[\int_0^1 P_t(i)^{1-\theta} di\right]^{\frac{1}{1-\theta}}$$

for all $t = 0, 1, 2, \ldots$.

2.3.2. The representative intermediate-goods-producing firm

During each period $t = 0, 1, 2, \ldots$, the representative intermediate-goods-producing firm hires $N_t(i)$ units of labor from the representative household, in order to produce $Y_t(i)$ units of intermediate-good i according to the constant return to scale technology

$$Y_t(i) = a_t N_t(i). \tag{14}$$

The aggregate technology shock, a_t, follows the autoregressive process:

$$\ln(a_t) = \rho_a \ln(a_{t-1}) + \varepsilon_{at}, \tag{15}$$

where $\rho_a < 1$. The zero-mean, serially uncorrelated innovation ε_{at} is normally distributed with standard deviation σ_a.

Since the intermediate-goods are not perfect substitutes in the production of the final goods, the intermediate-goods-producing firm faces an imperfectly competitive market. During each period $t = 0, 1, 2, \ldots$ it sets the nominal price $P_t(i)$ for its output, subject to satisfying the representative finished-goods-producing firm's demand. The intermediate-goods-producing firm faces a quadratic cost to adjusting nominal prices, measured in terms of the finished-goods and given by

$$\frac{\phi_p}{2}\left[\frac{P_t(i)}{\pi P_{t-1}(i)} - 1\right]^2 Y_t,$$

where $\phi_p > 0$ is the degree of adjustment cost and π is the steady-state gross inflation rate. This relationship, as stressed in Rotemberg (1982), looks to account for the negative effects of price changes on customer–firm relationships. These negative effects increase in magnitude with the size of the price change and with the overall scale of economic activity, Y_t.

The problem for the firm is to choose $\{P_t(i), N_t(i), H_t(i)\}_{t=0}^{\infty}$ to maximize its total market value given by

$$E_0 \sum_{t=0}^{\infty} (\beta^t \Lambda_t / P_t) F_t(i), \tag{16}$$

subject to the constraints imposed by Eq. (5) and Eqs. (13)–(15). In Eq. (16), $\beta^t \Lambda_t / P_t$ measures the marginal utility value to the representative household of an additional dollar in profits received during period t and

$$F_t(i) = P_t(i)Y_t(i) - N_t(i)W_t - H_t(i)G_t - \frac{\phi_p}{2}\left[\frac{P_t(i)}{\pi P_{t-1}(i)} - 1\right]^2 Y_t \tag{17}$$

for all $t = 0, 1, 2, \ldots$. Solving Eq. (5) for $H_t(i)$, and Eq. (14) for $N_t(i)$ and then using the outcome, together with Eq. (13), into Eq. (17) permits to write the first order conditions for this problem as

$$\phi_p\left[\frac{\pi_t(i)}{\pi} - 1\right]\frac{\pi_t(i)}{\pi} = (1-\theta)\left[\frac{P_t(i)}{P_t}\right]^{-\theta} + \left[\frac{W_t}{P_t a_t} + \frac{G_t}{P_t a_t} - E_t \frac{\Lambda_{t+1}}{\Lambda_t a_t}\frac{G_{t+1}}{P_t}\beta(1-\delta)\right]\theta\left[\frac{P_t(i)}{P_t}\right]^{-(1+\theta)} + \beta\phi_p E_t\left\{\frac{\Lambda_{t+1}}{\Lambda_t}\left[\frac{\pi_{t+1}(i)}{\pi} - 1\right]\left[\frac{\pi_{t+1}(i)}{\pi}\frac{Y_{t+1}}{Y_t}\right]\right\}, \tag{18}$$

where $\pi_t(i) = P_t(i)/P_{t-1}(i)$ is the gross inflation rate for all $t = 0, 1, 2, \ldots$. Eq. (18) is the New Keynesian Phillips curve in its non-linearized form and, as shown below, it highlights that the firm sets prices as a markup over marginal cost, accounting for price adjustment costs.

2.4. The central bank

During each period $t = 0, 1, 2, \ldots$, the central bank conducts monetary policy using a modified Taylor (1993) rule

$$\ln(R_t/R) = \rho_r \ln(R_{t-1}/R) + \rho_y \ln(Y_t/Y) + \rho_\pi \ln(\pi_t/\pi) + \varepsilon_{rt}, \tag{19}$$

where R, Y, and π are the steady-state values of the nominal interest rate, output, and gross inflation rate, respectively. According to Eq. (19), the central bank gradually adjusts the nominal interest rate in response to movements in output and inflation. The zero-mean, serially uncorrelated policy shock ε_{rt} is normally distributed, with a standard deviation σ_r. As pointed out in Clarida et al. (1998), this modelling strategy for the central bank is broadly consistent with the actual monetary policy in the US and the UK.

2.5. Symmetric equilibrium

In a symmetric, dynamic, equilibrium, all intermediate-goods-producing firms make identical decisions, so that $Y_t(i) = Y_t$, $N_t(i) = N_t$, $H_t(i) = H_t$, $F_t(i) = F_t$, and $P_t(i) = P_t$, for all $i \in [0,1]$ and $t = 0, 1, 2, \ldots$. In addition, the market clearing conditions $T_t = M_t - M_{t-1}$ and $B_t = B_{t-1} = 0$ must hold for all $t = 0, 1, 2, \ldots$. These conditions, together with the firm's profit conditions (17) and the household's budget constraint (2), produce the aggregate resource constraint

$$Y_t = C_t + (\phi_p/2)(\pi_t/\pi - 1)^2 Y_t + G_t H_t. \tag{20}$$

Substituting the Lagrange multiplier, Λ_t, from Eq. (3) into Eqs. (4), (12), and (18), and substituting the number of hires, H_t, from the evolution of employment (5) into the definition of labor market tightness (6), the model describes the behaviour of eight endogenous variables $\{Y_t, C_t, G_t, N_t, W_t, x_t, \pi_t, R_t\}$, and two exogenous shocks $\{a_t, \varepsilon_{rt}\}$. The equilibrium is then described by the representative household's Euler equation (4), the definition of labor market tightness (6), the definition of cost per hire (11), the agreed wage (12), the production function (14), the New Keynesian Phillips curve (18), the central bank policy rule (19), the aggregate resource constraint (20), and the specification of the shocks.

3. Product and labor market regulation

In this economic environment, the effects of product and labor market regulation are captured, respectively, by the firm's price markup, and the worker's relative bargaining power. First, consider the product market. Higher elasticity of demand for the produced goods, caused, for instance, by a reduction of tariff barriers, generates a reduction in the markup that decreases the price. Intuitively, as more intermediate-goods are produced, the more similar they are, and, hence, the more substitutable they become and less market power firms can enjoy. To see this more formally, consider Eq. (18) in the case of costless price adjustment, $\phi_p = 0$, such that it collapses to

$$P_t(i) = \frac{\theta}{(\theta - 1)}\left[\frac{W_t}{a_t} + \frac{G_t}{a_t} - \beta(1-\delta)E_t\frac{\Lambda_{t+1}}{\Lambda_t a_t}G_{t+1}\right], \tag{21}$$

where $\theta/(\theta - 1)$ measures the markup, and the term in square brackets is the marginal cost. This term, in presence of labor market search, as first emphasized by Krause and Lubik (2007), is composed of the wage as well as the present marginal cost of hiring a new worker, and the expected marginal benefit from the undergone costs of future hiring. Hence, an increase in the elasticity of product demand, θ, raises competition, and implies a lower price markup, $\theta/(\theta - 1)$. Eq. (21) also highlights that the price dynamics rely on the wage dynamics, which in turn depend on the structure of the labor market and, consequently, as shown below, on the worker's relative bargaining power. Moreover, Khan (2005) points out that the impact of the elasticity of demand for the produced goods on the price dynamics depends on the price-setting behaviour of the firm. In the context of Rotemberg's (1982) quadratic costs of price adjustment higher elasticity increases price flexibility, while in Calvo's (1983) random price adjustment, it would not imply any difference in pass-through of marginal costs on inflation, as in Trigari (2006).

Now consider the labor market. Eq. (12) describes the wage as it is determined by the Nash bargaining solution. It states that the dynamics of the wage depend on the marginal disutility of labor and, due to the presence of labor market search, on the term in curly brackets which is composed of the present marginal cost of hiring a new worker, and the expected savings of future hiring. The worker's relative bargaining power, ζ, is a key parameter for the dynamics of the wage. When this parameter is positive, such that $\zeta > 0$, wage fluctuations also reflect the effect of labor market frictions, through the terms involving hiring costs. On the other hand, when the worker's relative bargaining power is low, such that ζ is close to zero, the wage tends to fluctuate according to the marginal rate of substitution between consumption and leisure, as in a labor market without search. Accordingly, the worker's bargaining power determines to what extent the wage incorporates the effect of labor market frictions.

Therefore, labor market frictions affect the wage to the extent that there is always some worker bargaining power, while they always affect the price because they are part of the firm's marginal cost. More formally, this can be seen by substituting Eq. (12) into Eq. (21) to obtain

$$P_t(i) = \frac{\theta}{(\theta-1)}\left\{\frac{\chi N_t^{\phi}}{\Lambda_t a_t} + (1+\zeta)\frac{G_t}{a_t} - [1+\zeta(1-E_t x_{t+1})]\beta(1-\delta)E_t\frac{\Lambda_{t+1}}{\Lambda_t a_t}G_{t+1}\right\}.$$

This equation shows that when $\zeta \to 0$, such that the worker has no bargaining power, the real wage is the same as that in a labor market without search, while the marginal cost always incorporates the terms accounting for the present cost and future savings of hiring implied by labor market frictions. Empirically, this change in the notion of marginal cost may have non-trivial consequences for the estimation of markups in a way that the existing literature has not considered. For instance, Galì and Gertler (1999) and Rotemberg and Woodford (1992) quantify the marginal cost without accounting for the extra terms that labor market search implies.

4. Calibration and findings

4.1. Calibration

The system of equations describing the equilibrium does not have an analytical solution. Instead, the model's dynamics is characterized by log-linearizing the relevant equilibrium conditions around the steady-state. In this way, a linear dynamic system describes the path of the endogenous variables' relative deviations from their steady-state value, accounting for the exogenous shocks. The solution to this system is derived using Klein (2000), which is a modification of Blanchard and Khan (1980).

To analyze the quantitative implications of the model economy, numerical values need to be assigned to each structural parameter. The benchmark economy is calibrated to reproduce the structural characteristics of the UK economy for the period 1971:Q1–2006:Q3. The model is calibrated on a quarterly frequency and the value for each parameter is as follows. Following the standard business cycle literature, as in King and Rebelo (2000), the discount factor, β, equals 0.99. The coefficient of relative risk aversion, σ, equals 1.5. The Frish labor supply elasticity, ϕ, is equal to 1, and the parameter $\chi = 0.5$. The steady-state unemployment rate is set equal to 5.5%, by averaging the observed average unemployment claimant count rate over the sample period. The job separation rate, δ, is set equal to 4.5%, as estimated by Jolivet et al. (2006) and Hobijn and Sahin (2007). Given these values, Eqs. (5)–(8) imply a job finding rate, x, of 0.43.[5] Since there is no empirical evidence on the parameter of elasticity of hiring costs with respect to labor market tightness, α, its value is chosen by mapping the expected duration of a vacancy in the standard search model, as suggested in Blanchard and Gali (2006). Hence, α equals 1. For the same reason we calibrate the relative bargaining power $\zeta = 1$.[6] The level of hiring costs, B, is set such that hiring costs represent approximately 1% of aggregate output. This implies $B = 0.05$.

The parameter θ, which measures the degree of market power of firms in the retail sector, is set equal to 6. Since the markup is $\theta/(\theta - 1)$, such a value implies a markup of 20% which is suggested as a benchmark value by Rotemberg and Woodford (1992). As shown in Ireland (2000), given $\theta = 6$, by setting the degree of price rigidity, ϕ_p, equal to 50% implies that 10% of the firms adjust their price each period. As in Krause and Lubik (2007), steady-state inflation is assumed to be $\pi = 1$.

The parameters of the monetary policy rule are calibrated using Taylor (1993) and UK evidence from Nelson (2003). Hence, the interest rate response to inflation, ρ_π, is set equal to 1.5, the interest rate response to output, ρ_y, equals 0.5, and the degree of interest rate smoothing, ρ_r, is set equal to 0.32.[7]

Finally, consider the shock processes. The value of the standard deviation of the policy shock is in line with Clarida et al. (1998), who estimate a similar specification for this shock with the generalized method of moments for the UK. Its standard deviation, σ_r, equals 0.001. The steady-state level of the technology shock, a, is set equal to 7, as in Zanetti (2008). Following the standard practice in the literature, the serial correlation for the technology shock, ρ_a, equals 0.95, and its standard deviation is chosen such that the baseline model predictions replicate the standard deviation of output, which is 1.19%. Consequently, the standard deviation of the technology shock, σ_a, equals 0.008.

Before proceeding, Table 1 reports the steady-state values of output, consumption, employment, wages, and unemployment duration. Table 2 reports selected second moments from the actual data and the simulated model. This is useful to check whether a stochastic version of the model can closely reproduce the time series properties of the data. These figures show that, overall, the model performs reasonably well in replicating the empirical evidence.

[5] Note that $x = \delta(1-u)/[u + \delta(1-u)]$.

[6] This calibration is in line with the empirical evidence in Petrongolo and Pissarides (2001). Moreover, as pointed out in Hosios (1990), since $\zeta = \alpha$, the equilibrium allocations of the economy are Pareto optimal.

[7] Given the importance of monetary policy for the propagation of shocks, an extensive sensitivity analysis has verified that the qualitative results hold for $\rho_y = 0$, and for values of ρ_r between 0 and 0.99.

Table 1
Steady-state of the variables.

Output	6.625
Consumption	6.618
Employment	0.945
Wage	13.861
Unemployment duration	2.293

Note: Entries are based on a relative bargaining power of the worker equal to one, so that the total surplus is equally shared between the worker and the firm.

Table 2
Selected moments, UK data and baseline model.

Standard deviation (relative to output)	1971:Q1–2006:Q3	Baseline model
Output	1.19	1.19
Employment	0.73	0.95
Wage	0.96	1.84
Inflation	3.94	0.96
Correlation with output		
Employment	0.53	0.68
Wage	0.21	0.96
Inflation	−0.10	−0.48

Note: Observed (UK) and simulated (from the baseline model, calibrated for the period 1971:Q1–2006:Q3) standard deviations relative to output, and correlation with output. The observed statistics are based on seasonally adjusted quarterly data from 1971:Q1 to 2006:Q3. Variables, except inflation, are transformed in logarithms. All the series, except inflation, are HP filtered so that only the cyclical component remains. The simulated business cycle statistics are based on 1000 simulations over 142 quarter horizon and are HP-filtered for comparison purposes. Simulated figures are averages across simulations.

4.2. Findings

To investigate how each variable of the model reacts to each shock, Figs. 1 and 2 plot, in solid line, the impulse responses of the benchmark calibration of the model to one-standard-deviation of productivity and monetary policy shock, respectively. Fig. 1 shows that output, the cost per hire, the real wage and inflation all react instantaneously to a productivity shock.[8] Hence, after a one-standard-deviation technology shock, output and the cost per hire each rises. The real wage increases, while inflation falls. The fall in inflation allows for an easing in monetary policy such that the nominal interest rate falls. Finally, the increase in employment leads to a rise in hiring – from Eq. (5) – and a decline in unemployment; on balance, these last changes generate a rise in labor market tightness.

Fig. 2 shows that a one-standard-deviation monetary policy shock has a direct effect on the nominal interest rate, and, hence, on the modified Taylor rule and the Euler equation for consumption. This shock translates into an increase in the nominal interest rate, and into a fall in consumption and output. The fall in output generates a decrease in employment, which is mirrored by an increase in unemployment and a consequent fall in the number of hires. Opposite shifts in the number of hires and unemployment generate a fall in labor market tightness. The reaction of each variable dies off over a period of 2 years, which is shorter than in the case of a productivity shock. This is because the policy disturbance is serially uncorrelated and the smoothing parameter, ρ_r, in the modified Taylor rule is small.

Looking across all these impulse responses also provides some insights into how product and labor market regulation affects the transmission mechanism of a standard New Keynesian framework. For both shocks, the presence of product and labor market regulation leave the baseline transmission mechanism of a New Keynesian setting qualitatively unaffected: all the variables respond to shocks in the same way they would in a labor market without product and labor market regulation.[9] But, as explained below, product and labor market regulation affect the magnitude of the responses.

To investigate this, Figs. 1 and 2 compare impulse responses to a one-standard-deviation technology and monetary policy shock for two different calibrations of the worker's relative bargaining power ζ. The first calibration, in solid line, where the worker has the benchmark value of the bargaining power, such that $\zeta = 1$, and the second, in dashed line, where the worker has virtually all the bargaining power, such that $\zeta = 20$.[10] To analyze the predictions of the model the analysis illustrates the case of a technology shock, but it applies equally to the case of a monetary policy shock. According to Fig. 1, as expected, the wage displays the strongest reaction to changes in the worker's relative bargaining power ζ; in particular, an increase of ζ dampens the response of the wage to the technology shock. Why is it? The answer is in Eq. (12), which is the equation that

8 In fact, the productivity shock appears into Eqs. (14), (11), (12), and (18) which determine output, the cost per hire, the nominal wage, and inflation, respectively.

9 For the standard response of the New Keynesian model see, for instance, Ireland (2004).

10 For $\zeta = 20$, the corresponding value of the worker's absolute bargaining power, η, is 0.95.

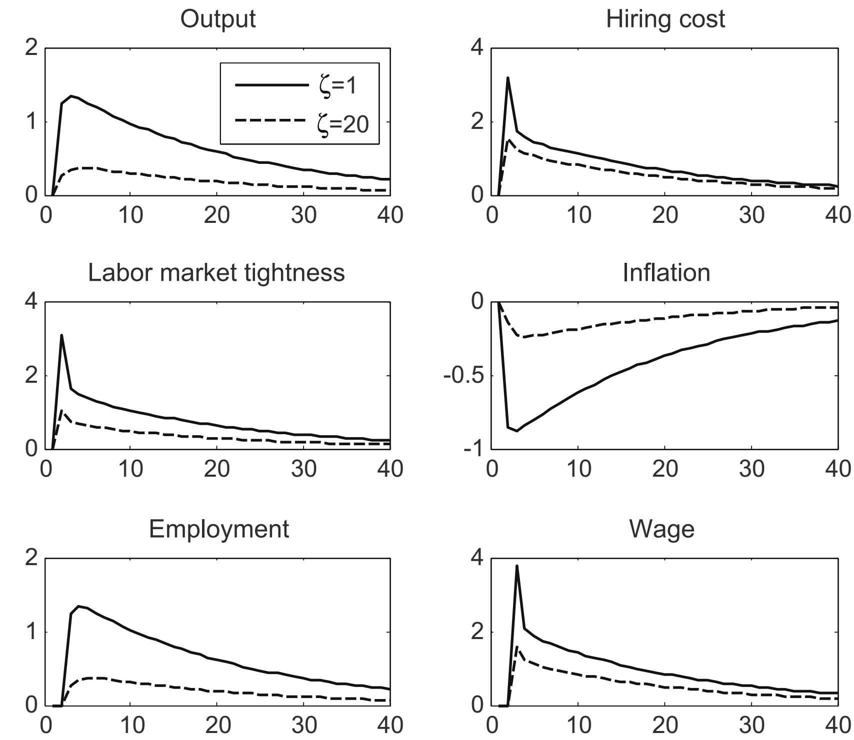

Fig. 1. Impulse response functions to a technology shock, different calibration for ζ.

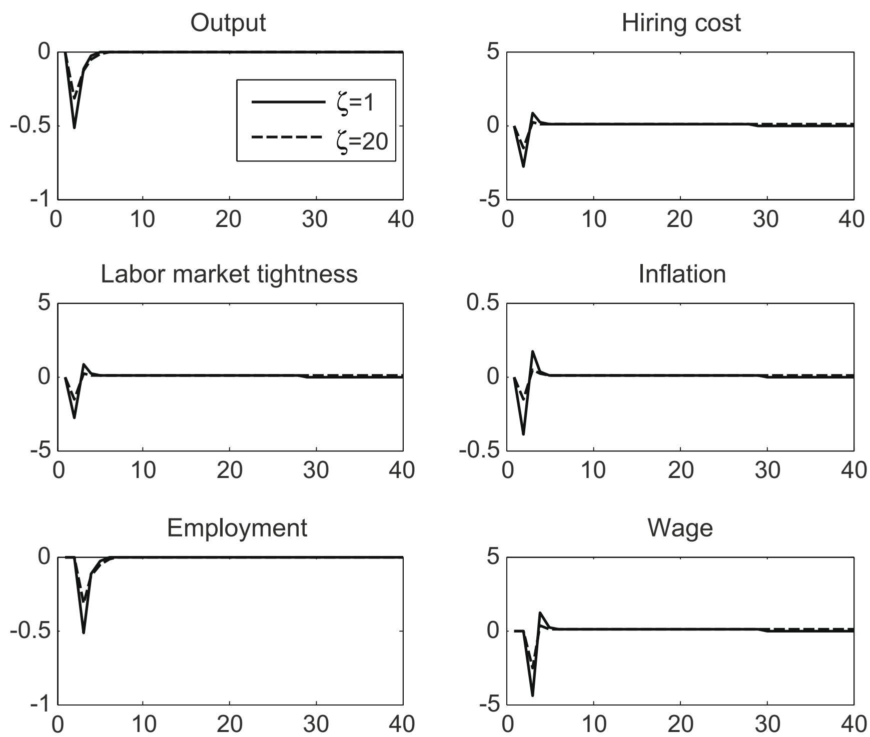

Fig. 2. Impulse response functions to a monetary policy shock, different calibration for ζ.

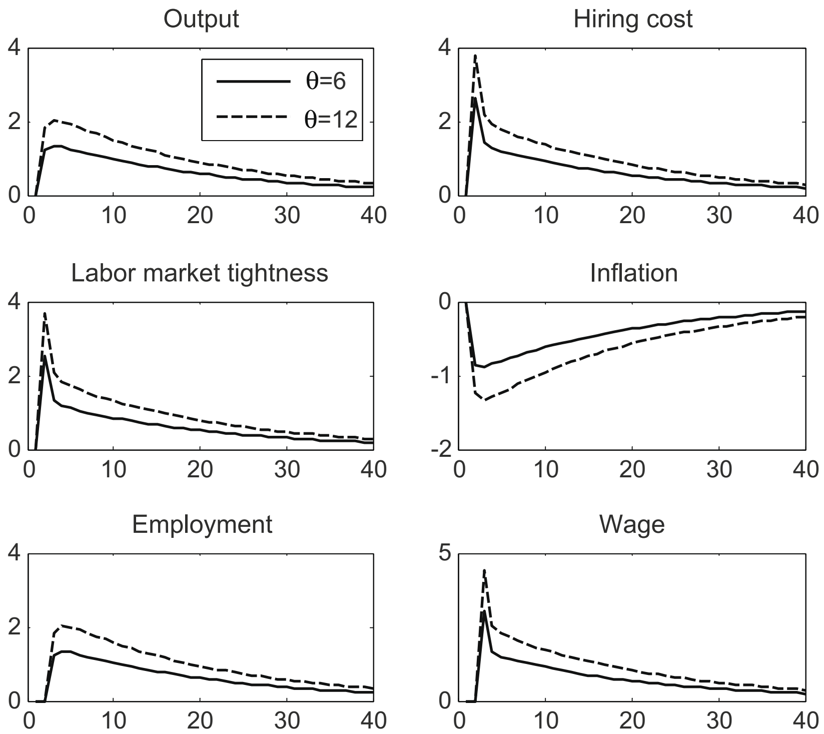

Fig. 3. Impulse response functions to a technology shock, different calibration for θ.

contains ζ. What dampens the response of the wage is the reduction of the response of hiring costs, G_t, which become an important part of the wage when ζ increases. This is driven by the more gentle reaction in labor market tightness, x_t, when the worker's relative bargaining power is high. The fall is less pronounced because an increase in the worker's relative bargaining power decreases the response of output to shocks and, hence, employment has to raise less to match the increase in technology. As detailed above, a more gentle reaction in employment dampens the reaction of hiring and, consequently, also, labor market tightness. Since labor market tightness can be interpreted as the probability that an unemployed worker will find a job, if it is less reactive, the expected costs from hiring are also less sensitive to disturbances and, thereby, the positive response of the wage to the technology shock diminishes. Intuitively, when there is some worker's relative bargaining power, the probability of finding a match becomes important for the determination of the wage. Since the technology shock decreases the reaction of the probability of the match, x_t, it is easier for a firm to recruit, and the cost of hiring decreases so that the technology shock would dampen the cost of recruitment and, therefore, the wage. The weak response of the wage leads to a weak response of inflation and, through monetary policy, allows for a more gentle fall in the nominal interest rate. The combined reaction of inflation and the nominal interest rate generates an increase in the real interest rate which triggers a low response of output and consumption.

Let's now turn to analyze the effects of product market regulation. Figs. 3 and 4 compare impulse responses to a one-standard-deviation technology and monetary policy shock for two different calibrations of the elasticity of demand θ, which, as shown above, determines the price markup. The first calibration, in solid line, where the markup is 20%, such that $\theta = 6$, as in the benchmark calibration, and the second, in dashed line, where the markup is approximately 10%, such that $\theta = 12$. Also in this instance, the analysis is limited to the case of a technology shock, but it applies equally to the case of a monetary policy shock. Eq. (18) determines the effect of a change in the markup on the system dynamics. Since it is difficult to interpret Eq. (18), to gain more intuition, the log-linear approximation of it around the steady-state is

$$\hat{\pi}_t = \beta\hat{\pi}_{t+1} + \frac{\theta}{\phi a}\left\{w(\hat{w}_t - \hat{a}_t) + g[\hat{g}_t - \hat{a}_t - \beta(1-\delta)(\sigma\hat{c}_t - \sigma\hat{c}_{t+1} + \hat{g}_{t+1} - \hat{a}_t)]\right\}, \tag{22}$$

where $\hat{\pi}_t$, $\hat{w}_t$, $\hat{a}_t$, $\hat{g}_t$, and $\hat{c}_t$, denote the percentage, or logarithmic, deviation of inflation, the real wage, technology shock, cost per-hire and consumption from their steady-state, or average, levels π, w, a, g, and c.[11] Eq. (22) is the standard New Keynesian Phillips curve, that links the dynamics of current inflation with expected inflation, the wage, $\hat{w}_t$, the technology shock, $\hat{a}_t$, and, in

[11] Note that changes in both product and labor market regulation, by modifying the worker's bargaining power, ζ, and the elasticity of demand, θ, affects the dynamics of Eq. (22). The effect of θ is to change the reaction of inflation in response to the terms in the curly brackets, and instead ζ changes the steady-state level of the wage which also affects how the terms in curly brackets have an impact on inflation.

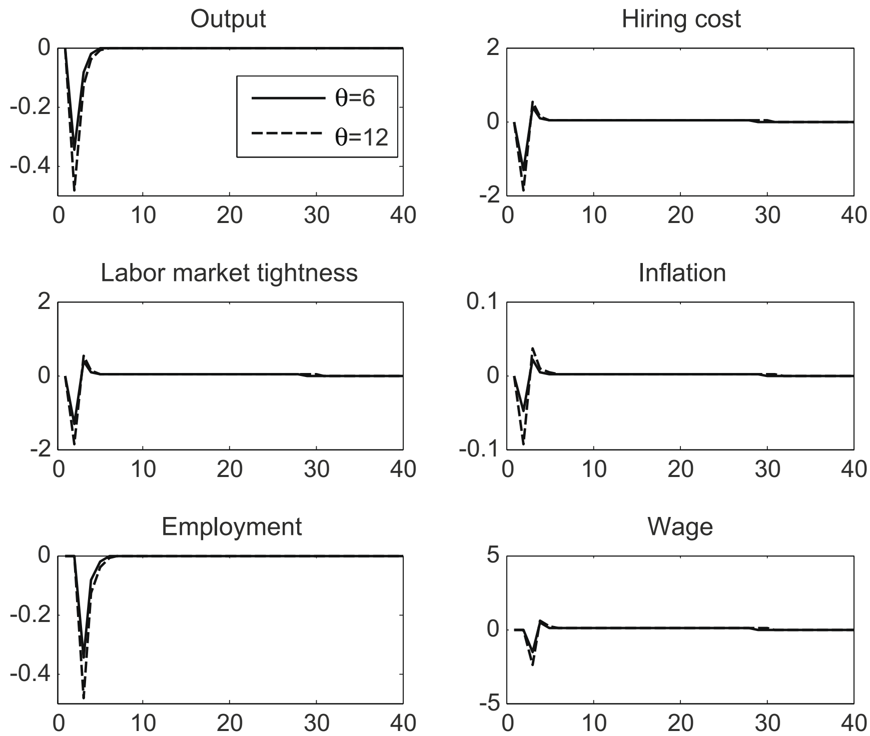

Fig. 4. Impulse response functions to a monetary policy shock, different calibration for θ.

Table 3
Variance decompositions, baseline model and different calibrations.

Output	Baseline calibration, $\zeta = 1$ and $\theta = 6$ (1)		Higher household bargaining power, $\zeta = 20$ (2)		Higher degree of elasticity of demand, $\theta = 12$ (3)	
Quarters ahead	*Technology*	*Monetary policy*	*Technology*	*Monetary policy*	*Technology*	*Monetary policy*
1	61	39	59	41	76	24
12	94	6	93	7	97	3
40	96	4	95	6	98	2
Hiring costs						
1	18	82	9	91	44	56
12	84	16	77	23	92	8
40	88	12	83	17	94	6
Labor market tightness						
1	26	74	41	59	10	90
12	26	74	56	44	37	63
40	26	74	60	40	46	54
Inflation						
1	94	6	88	12	92	8
12	98	2	97	3	98	2
40	99	1	97	3	98	2
Employment						
1	26	74	41	59	10	90
12	26	74	58	42	38	62
40	26	74	62	38	48	52

Note: Entries decompose the forecast error variance in each variable at each forecast horizon into percentages due to technology or monetary policy shock. Note that in the case of higher household bargaining power, $\zeta = 20$, the steady-state value of the wage is 15.239, while in the case of higher degree of elasticity of demand, $\theta = 12$, is 13.857.

this instance, due to search frictions, also with the present and expected labor market costs of hiring a new worker, $\widehat{g}_t$ and $\widehat{g}_{t+1}$, respectively. An increase in the elasticity of demand, θ, which reduces the price markup, magnifies the effect that the technology shock, fluctuations of the wage and present and expected hiring costs have on inflation. Therefore, a decrease in the markup leads to a more pronounced decrease in inflation in response to the technology shock and, since the price cannot fully absorb the shock due to adjustment costs, the firm's marginal cost has to increase.[12] For this reason, the wage and the cost per hire are more procyclical. Moreover, because of the higher elasticity of demand that goods-producing firms face, the technology shock triggers a more pronounced increase in employment, output and, consequently, consumption. Finally, the larger fall in inflation leads to a more pronounced fall in the nominal interest rate.

To understand the extent to which the movements of each variable are explained by the two shocks, and how the importance of the shocks varies with changes in product and labor market regulation, Table 3 reports forecast error variance decompositions for different calibrations of the model. Column 1 reports figures for the baseline calibration of the model. Columns 2 reports the figures obtained when the worker's relative bargaining power, ζ, is increased to 20, and column 3 where the elasticity of demand, θ, is increased to 12. The results in column 1 show that for the baseline calibration technology shocks explain, low-frequencies movements in output, the cost per hire, and inflation, while only a small fraction of fluctuations in labor market tightness and employment. Monetary policy shocks though, play a supporting role in driving short-run fluctuations in the cost per hire and labor market tightness. An increase in the worker's relative bargaining power, as shown in column 2, has a remarkably large effect on the role of technology shocks in explaining labor market tightness and employment: in the presence of higher worker bargaining power, technology shocks explain twice as much of the volatility of these two labor market variables, while their importance on the other variables remains substantially unchanged. A decrease in the markup, as shown in column 3, has a similar – perhaps slightly smaller – quantitative effect.

5. Conclusions

This paper has developed a New Keynesian model enriched with labor market search to study the effects of product and labor market regulation on macroeconomic outcomes such as inflation and output. More labor market regulation is represented by a higher worker's bargaining power over the wage, while more product market regulation is represented by a lower degree of competition in the economy, which is captured by a higher firm's price markup. The effect of labor and product market regulation is to reduce the variability of both wages and prices and, since, in this framework, nominal variables affect fluctuations in real aggregates, it also acts to lower the fluctuations in real macroeconomic outcomes. The degree of regulation also affects the ability of technology shocks to explain fluctuations of macroeconomic aggregates. An increase in either type of regulation makes technology shocks a more important source of movements in labor market aggregates such as labor market tightness and employment, without affecting their explanatory power for other variables.

Given the predictions of the model, a decrease in either product or labor market regulation is unable to account for the increased stability of macroeconomic fluctuations that most developed countries experienced over the last two decades. Thus, other factors are likely to have been responsible for generating this macroeconomic outcome. The investigation of these is left for future research.

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[12] As mentioned, Khan (2005) points out that this result impinges on the use of Rotemberg's (1982) quadratic costs of price adjustment.

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