Long-term business relationships, bargaining and monetary policy ☆

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Abstract

A growing empirical literature documents the importance of long-term relationships and bargaining for price rigidity and firms' dynamics. This paper introduces long-term business-to-business (B2B) relationships and price bargaining into a standard monetary DSGE model. The model is based on two assumptions: first, both wholesale and retail producers need to spend resources to form new business relationships. Second, once a B2B relationship is formed, the price is set in a bilateral bargaining between firms. The model provides a rigorous framework to study the effect of long-term business relationships and bargaining on monetary policy and business cycle dynamics. It shows that, for a standard calibration of the product market, these relationships reduce both the allocative role of intermediate prices and the real effects of monetary policy shocks. We also find that the model does a good job in replicating the second moments and cross-correlations of the data, and that it improves over the benchmark New Keynesian model in explaining some of them.

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1. INTRODUCTION

The typical business environment often differs dramatically from the standard Dixit-Stiglitz monopolistic competition framework usually adopted in modern DSGE monetary models. As evidenced by empirical research, most firms engage mainly in long-term relationships with their customers, and most of their customers are other firms (see e.g. Blinder et al. (1998) for the US, Fabiani et al. (2006) for the Euro Area and Apel et al. (2005) for Sweden). Most of these long-term relationships are governed by implicit or explicit contracts, and these contracts last on average between one and two years. Therefore, negotiations of prices and quantities are the rule rather than the exception. In

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fact, in surveys firms report that the main reason they wish to keep prices stable is that they are concerned about losing customer relationships. For instance, Fabiani et al. (2006) find, on the basis of surveys conducted by nine Eurosystem national central banks, that the existence of implicit and explicit contracts with customers is the most important explanation for rigid prices. Zbaracki et al. (2004) find that customer communications and price negotiation costs account for almost 75% of the total price adjustment cost and are 20 times bigger than the size of the menu costs.

The repeated nature of the interactions between firms points toward an important issue: bargained intermediate prices may not be allocative, in the sense that they may not affect the final production of firms. For example, if the real intermediate price decreases, selling firms may decide not to adjust production if they expect buyers to compensate them in the future for the reduced profits incurred in the current period.[1] In fact, as first shown by Barro (1977) for the labor market, the real effects of monetary policy when prices are sticky crucially depend on prices being allocative.[2]

Motivated by this literature, in this paper we introduce business-to-business (B2B) long-term relationships and price bargaining into a standard monetary DSGE model. In the model there are two types of firms, upstream producers (wholesalers) and downstream producers (retailers). Wholesalers produce intermediate goods, which are transformed by retailers into final goods and sold to households. The intermediate goods market is characterized by search and matching frictions *à la* Mortensen and Pissarides (1994). Both wholesalers and retailers need to spend time and resources to match and form long-term relationships with other firms. Once a business relationship is formed, the price is bargained between wholesalers and retailers according to a standard Nash bargaining protocol. In the future, this relationship will get destroyed with a certain probability, which is endogenous to the model. In other words, the main novelty is that the change in B2B relationships is determined by the model not only through a process of endogenous creation, but also through the endogenous destruction of inefficient matches. Alternatively, it could be assumed that the goods market adopts a directed search framework. However, this option is not explored in this paper and is left as potential future research.[3] Lastly, the presence of quadratic intermediate-price adjustment costs introduce nominal stickiness and gives a role to monetary policy, which is magnified by the existence of costly search and matching with endogenous separation. The model provides a rigorous framework to study the effect of long-term

[1]This result, and our treatment of endogenous separations, are in line with early papers on firm dynamics where firms optimally decide when to exit the industry. For example, in the model developed by Hopenhayn (1992) it is found that some firms may have negative profits in some periods if they expect to be compensated in the future.

[2]See also Abbritti and Trani (2017) for a discussion.

[3]At this moment we are not aware of any evidence in favor of directed search or random search with bargaining. Therefore, we have chosen random search simply to start with most available mechanism in the (labor) literature and then introduce a novelty (endogenous separation) which creates an asymmetry. Also, as already mentioned, Zbaracki et al. (2004) find that customer communication and price negotiation costs represent about 75% of the total price adjustment costs, and this can encompass both types of interpretations. The communication costs could be linked to directed search and the price negotiation costs to random search and bargaining. And last but not least, Bernard and Moxnes (2018) find that the majority of firm-to-firm relationships are many-to-many, which is in contrast with B2C relationships and the labor market (where most of the literature on directed search has focused) where relationships are dominated by many-to-one matching..

relationships and bargaining on monetary policy and business cycle dynamics.

We highlight three main results. First, we show that the model, once calibrated to capture the main structural features of the US product market, does a remarkably good job in replicating the second moments and cross-correlations of the data, and that it improves over the benchmark New Keynesian (NK) model in explaining some of them.[4] In particular, introducing B2B long-term relationships helps to improve the volatility of employment, intermediate prices and core inflation as well as the cross-correlation of intermediate prices and core inflation with output. It also provides better estimates for the cross-correlation of intermediate prices and final-price inflation with core inflation.

Second, we find that the presence of long-term B2B relationships and bargaining strongly affect the transmission mechanism of monetary policy shocks and the allocative power of the bargained intermediate prices. In particular, we show that the real effects of monetary policy are strictly related to the presence of an endogenous match destruction margin. If match separations are exogenous, a monetary stimulus has a negligible effect on economic activity - even though intermediate prices are sticky. On the contrary, if we allow for endogenous separations of inefficient matches, intermediate prices recover some of their allocative power and positive monetary policy shocks lead to economic expansions. This happens because following a monetary expansion, firms find it optimal to satisfy the increased demand by reducing the endogenous separation rate and allowing more matches to survive.

Finally, we show that for a standard calibration of the product market, the effectiveness of monetary policy in a model with B2B is significantly lower than in the benchmark NK model. In particular, the real effects of an unexpected monetary policy shock are almost 40 percent lower in the B2B model than in the NK model.

Recent research has started to investigate the importance of long-term relationships between firms and customers for price and business cycle dynamics. The vast majority of these papers, however, focus on retail firms to consumers relationships, and do not allow for bilateral negotiations between the parties.[5] These are important distinctions, because the business environment in B2B transactions is very different from the one in business-to-consumer (B2C) transactions.

To the best of our knowledge, only three papers analyze the implications of B2B relationships and bargaining for price and business cycle dynamics. Drozd and Nosal (2012) introduce dynamic frictions of building market shares into an international real business cycle model and show that the model can account for several pricing puzzles of international macroeconomics. Mathä and Pierrard (2011) introduce two-sided search and matching between wholesalers and retailers into the standard RBC model to study the effect of long-term relationships on business cycle dynamics. Abbritti and Trani (2017) study incomplete pass-through and the allocative power of intermediate goods prices in

[4]To allow comparability between the two models, the benchmark New Keynesian model also has two sectors, a wholesale and retail sector, and sticky intermediate prices.

[5]See, e.g, Hall (2008), Arseneau and Chugh (2007), Kleshchelski and Vincent (2009), Ravn et al. (2010), Gourio and Rudanko (2014), Paciello et al. (2014), Den Haan (2013).

a model with product market frictions and bargaining over intermediate prices and quantities.

Our paper differs from these three references in two main aspects: First, we endogenize the match destruction margin. Following the model of Krause and Lubik (2007) for the labor market, we assume that the productivity of each match is match-specific, and that inefficient matches are destroyed. Second, we allow for price adjustment costs in the bargaining problem between wholesalers and retailers. These costs, which are meant to capture customer communications and price negotiation costs, introduce nominal price stickiness and give a role to monetary policy. We show in the following that endogenous match destructions and sticky prices potentially play an important role in B2B relationships, pricing dynamics and the effectiveness of monetary policy.

The structure of the paper is as follows. Section 2 derives the theoretical B2B model. Section 3 describes a two-sectors New Keynesian model that we use as a benchmark. In Section 4 the calibration strategy is explained. Section 5 shows the main results of the paper and Section 6 concludes.

2. THE MODEL

2.1. Firms and Product Market

The product market is composed by two different types of firms, wholesalers and retailers, and follows the search and matching structure developed by Mortensen and Pissarides (1994). In order to sell their products, wholesale producers need to establish long-term customer relationships with retailers. Once both types of firms meet they bargain over the intermediate price at which retailers buy intermediate goods from the wholesalers. The productivity of firms is match-specific and has both an aggregate component and an idiosyncratic one, which we denote as $a_t(i)$ and is drawn from a time-invariant distribution with c.d.f. $F(a_t(i))$ and p.d.f. $f(a_t(i))$. We assume that the aggregate number of business to business (B2B) relationships T_t, follows the law of motion $T_{t+1} = (1 - \delta_{t+1})(T_t + m_t)$ where m_t, the number of new B2B relationships at time t, is a constant returns to scale function of the search effort of retailers V_t (purchase managers) and the search effort of wholesalers S_t (advertising and marketing):

$$m_t = \tilde{m} S_t^{\xi} V_t^{1-\xi}$$

The separation rate is defined as $\delta_t = \delta_x + (1 - \delta_x) F(\tilde{a}_t(i))$, where $\tilde{a}_t(i)$ is an endogenously determined productivity threshold below which matches are not profitable and hence terminated.

2.1.1. Wholesalers

There is a continuum of wholesale producers with unit mass. Each wholesaler j maximizes the expected present value of future profits

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_{0,t} \left\{ \left(\frac{P_{It}(j)}{P_t} - c_t^W(j) \right) T_t(j) - (r_t + \delta_k) K_t(j) - w_t N_t(j) - \gamma_W S_t(j) \right\},$$

subject to the production function

$$Y_t^W(j) = qT_t(j) = A_t K_t(j)^\alpha N_t(j)^{1-\alpha}$$

with q being the quantity produced per match, and the law of motion of the customer base

$$T_t(j) = (1 - \delta_t(j))(T_{t-1}(j) + S_{t-1}(j)\mu_W(\theta_{t-1})).$$

The term $\beta_{t,t+1} = \beta(C_{t+1}/C_t)^{-\sigma}$ denotes the household's stochastic discount factor, while $\gamma_W S_t$ denotes the search costs. Intuitively, the wholesaler chooses how much search effort, S_t, he will execute to find new buyers for his product. Think of this as the firm choosing the number of sales managers it is going to hire.[6] Each unit of effort will provide him with an average of $\mu_W(\theta_t) = \tilde{m}\theta_t^{(1-\xi)}$ retailers at the end of the period, where $\theta_t = V_t/S_t$ is the product market tightness. $P_{It}(j)$ denotes the price of the intermediate good, that is decided after the successful match in a bilateral bargain with the retailers. The term $c_t^W(j) = \frac{\phi_W}{2}(P_{It}(j)/P_{It-1}(j) - \pi_I)^2$ captures quadratic price adjustment costs. We assume that this cost, which is intended to capture price negotiation and communication costs, is proportional to the number of B2B relationships T_t.

The wholesaler also decides how much capital, $K_t(j)$, and labor, $N_t(j)$, he is going to rent. A_t is an AR(1) TFP shock and, for simplicity, we normalize $q = 1$. The real rate of interest is r_t, the depreciation rate of capital is δ_k and the real wage is denoted by $w_t = W_t/P_t$.

From the first-order necessary conditions we get that both the capital-labor ratio

$$\frac{K_t(j)}{N_t(j)} = \frac{\alpha}{1-\alpha}\frac{w_t}{r_t + \delta_k}$$

and the marginal cost

$$mc_t = (A_t)^{-1}\left(\frac{w_t}{1-\alpha}\right)^{1-\alpha}\left(\frac{r_t + \delta_k}{\alpha}\right)^\alpha \tag{1}$$

are equal across wholesalers. This is because *ex-ante* all the wholesale producers are identical since the match-specific productivity draws are not realized until the matches occur and intermediate prices are bargained.

Further combinations of the FOCs give us the following expression:

$$J_t^W(j) = \frac{P_{It}(j)}{P_t} - c_t^W(j) - mc_t + \mathbb{E}_t\beta_{t,t+1}(1 - \delta_{t+1}(j))J_{t+1}^W(j) \tag{2}$$

This equation captures the expected value (across matches) of a B2B relationship for wholesaler j. This depends positively on the intermediate price that the retailer pays him and negatively on

[6] See Gourio and Rudanko (2014).

the marginal cost of production. The last term, $\mathbb{E}_t \beta_{t,t+1} (1 - \delta_{t+1}(j)) J^W_{t+1}$, captures the expected continuation value of a match. This brings dynamic effects into the model coming from the fact that in the next period only a fraction equal to $(1 - \delta_{t+1}(j))$ of the matches survives and both wholesalers and retailers benefit from them.

The optimal amount of search is chosen to equate the expected marginal cost and the marginal benefit of a new business relationship:

$$\frac{\gamma_W}{\mu_W(\theta_t)} = \mathbb{E}_t \beta_{t,t+1} (1 - \delta_{t+1}(j)) J^W_{t+1}(j) \tag{3}$$

This equation makes it clear that the search effort is executed in one period but it does not pay off until the next period and only if the match resulting from it is not destroyed.

2.1.2. Retailers

There is a continuum of retail producers with unit mass that buy the intermediate goods from wholesalers and sell it to consumers in perfectly competitive markets. Each retailer draws a match-specific productivity from a time-invariant distribution with c.d.f. $F(a)$ and p.d.f. $f(a)$. We assume that the draw of productivity takes place after intermediate price bargaining. This timing assumption simplifies considerably the bargaining problem and the solution of the model because it implies that the bargained price is identical for every match. The total production of retailer i is given by

$$T_t(i) \int_{\tilde{a}}^{\infty} a \frac{f(a)}{1 - F(\tilde{a})} da = T_t(i) H(\tilde{a}_t(i))$$

where $T_t(i)$ is the number of productive or functional matches and $H(\tilde{a}_t(i))$ is the conditional expectation of the idiosyncratic shock $\mathbb{E}[a \mid a \geq \tilde{a}_t(i)]$. The productivity threshold $\tilde{a}_t(i)$ is endogenously determined such that below it matches are not profitable and hence destroyed. In a similar way to the case of the wholesale producers, the number of B2B relationships of retailer i follows a law of motion that depends on the current-period separation rate and the previous-period number of functional matches and search effort exercised, $V_{t-1}(i)$

$$T_t(i) = (1 - \delta_t(i)) (T_{t-1}(i) + V_{t-1}(i) \mu_R(\theta_{t-1}))$$

where $\mu_R(\theta_t) = \tilde{m}\theta_t^{-\xi}$ is the average number of wholesalers attracted in the current period per unit of effort.

Retailers maximize the expected present value of profits *before* the realization of the idiosyncratic shock a, i.e. based on the expected output $\mathbb{E}_a Y^R_t(i) = T_t(i) H(\tilde{a}_{it})$. Specifically, every retailer i maximizes:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_{t,t+1} \left\{ T_t(i) H(\tilde{a}_t(i)) - \left(\frac{P_{It}(i)}{P_t} + c^R_t(i) \right) T_t(i) - \gamma_R V_t(i) \right\}$$

subject to the law of motion of the customer base. Retailers also face a cost of changing the bargained price, which is defined as $c_t^R(i) = \frac{\phi_R}{2}\left(P_{It}(i)/P_{It-1}(i) - \pi_I\right)^2$ and it is also proportional to the number of B2B relationships $T_t\left(i\right)$. The last term of the equation captures the cost of search effort.

At the beginning of each period the retailer chooses the level of production and the search effort. The intermediate price P_{It} is decided after the successful match in a bilateral bargaining between retailers and wholesalers.

From the first-order necessary conditions we get the expected value (across matches) of a customer relationship for the retailer

$$J_t^R\left(i\right) = H\left(\tilde{a}_t\left(i\right)\right) - \left(\frac{P_{It}\left(i\right)}{P_t} + c_t^R\left(i\right)\right) + \mathbb{E}_t\beta_{t,t+1}\left(1 - \delta_{t+1}\left(i\right)\right)J_{t+1}^R\left(i\right) \tag{4}$$

The value of a match depends positively on its production and negatively on the marginal cost, which is the relative price the retailer has to pay to the wholesaler. Similar to the case of the wholesaler, the last term in the equation connects the value of the matches in two subsequent periods bringing the dynamic effects into the model. Although (most) variables are connected in general equilibrium, we can notice a *ceteris paribus* effect of the threshold on the value of the matches. In particular, a higher threshold implies a higher average value of the matches because the previously least productive matches are destroyed, leaving operative those with higher productivity.

In equilibrium, the expected cost of a new match in a given period equals the expected marginal benefit that will be realized in the subsequent periods:

$$\frac{\gamma_R}{\mu_R\left(\theta_t\right)} = \mathbb{E}_t\beta_{t,t+1}\left(1 - \delta_{t+1}\left(i\right)\right)J_{t+1}^R\left(i\right) \tag{5}$$

2.1.3. Endogenous separation

We assume that a successful match is endogenously destroyed whenever the realization of the idiosyncratic shock does not make it profitable for at least one of the parties. Since prices are determined before the realization of a_t, the value of a B2B relationship for a wholesaler, $J_t^W\left(j\right)$, does not depend on the idiosynchratic productivity of a match a_t, which affects only retailers. Let us define by $J_t^R\left(a_t\right)$ the marginal value for the retailer of a match with idiosyncratic productivity a_t. The threshold $\tilde{a}_t$ is endogenously determined as solution of $J_t^R\left(\tilde{a}_t\right) = 0$. Combining this equation with the first-order conditions of the retailer the critical threshold below which matches are terminated is implicitly defined as:

$$\tilde{a}_t\left(i\right) = \left(\frac{P_{It}\left(i\right)}{P_t} + c_t^R\left(i\right) - \frac{\gamma_R}{\mu_R\left(\theta_t\right)}\right) \tag{6}$$

The threshold $\tilde{a}_t$ is increasing on the relative intermediate price and on the cost of changing prices because the higher these are the more profitable the match has to be to allow the retailer to pay for them.

2.1.4. Bargaining

After wholesalers and retailers are matched, intermediate prices are determined through a Nash bargaining scheme between them. Precisely, for each match v, intermediate goods prices are determined as the outcome of the following bargaining scheme

$$\max_{P_{It}} SU_t = \left[\left(J_t^W (v) \right)^{\eta} \left(J_t^R (v) \right)^{1-\eta} \right]$$

where η is the bargaining power of wholesalers.

We assume that prices are determined *before* the productivity draw of the retailers. Hence, the bargaining problem is the same across matches and the intermediate price will be unique. Let us denote by $\varphi_t = \frac{P_{It}}{P_t}$ the relative intermediate price. Dropping the subscript v, maximization gives:

$$\varphi_t \left[\eta J_t^R - (1-\eta) \left(1 - \frac{\partial H(\tilde{a}_t)}{\partial \tilde{a}_t} \right) J_t^W \right] = (1-\eta)\, \tau_t^R J_t^W + \eta \tau_t^W J_t^R \tag{7}$$

where

$$\tau_t^W = \phi_W \left(\pi_{It} - 1 \right) \pi_{It} - \mathbb{E}_t \beta_{t,t+1} \left[(1 - \delta_{t+1}(j))\, \phi_W + (1-\delta_x) f(\tilde{a}_{t+1}) J_{t+1}^W \phi_R \right] \left(\pi_{It+1} - 1 \right) \pi_{It+1}$$

and

$$\tau_t^R = \left(1 - \frac{\partial H(\tilde{a}_t)}{\partial \tilde{a}_t} \right) \Big\{ \phi_R \left(\pi_{It} - 1 \right) \pi_{It} - \mathbb{E}_t \beta_{t,t+1} \left[(1-\delta_{t+1}) \left(1 - \frac{\partial H(\tilde{a}_{t+1})}{\partial \tilde{a}_{t+1}} \right) \right. \\ \left. + \, (1-\delta_x) f\left(\tilde{a}_{t+1}(i) \right) J_{t+1}^R(i) \right] \phi_R \left(\pi_{It+1} - 1 \right) \pi_{It+1} \Big\}$$

capture the marginal costs of changing the intermediate price for the wholesalers and the retailers respectively.

Notice that if prices were flexible we would have $\tau_t^W = \tau_t^R = 0$ and equation (7) would resemble the standard solution by which each party gets a share of the surplus equal to their bargaining power:

$$\eta J_t^R = (1-\eta) \left(1 - \frac{\partial H(\tilde{a}_t)}{\partial \tilde{a}_t} \right) J_t^W \tag{8}$$

The main difference from a standard solution is the presence of the term $\frac{\partial H(\tilde{a}_t)}{\partial \tilde{a}_t}$, which enters the bargaining solution because firms internalize the fact that a higher bargained price leads retailers to increase the endogenous separation threshold and the average productivity of a match.

2.2. Households

There is a representative household in the economy and his total lifetime utility is given by:

$$\mathbb{E} \sum_{t=0}^{\infty} \beta^t \left\{ \frac{c_t^{1-\sigma}}{1-\sigma} - \varkappa \frac{N_t^{1+\nu}}{1+\nu} \right\}$$

which depends positively on consumption, c_t, and negatively on labor, N_t. The household faces a sequence of flow budget constraints which denoted in real terms can be written as:

$$c_t + \frac{b_{t+1}}{R_t}\pi_{t+1} + I_t = w_t N_t + b_t + (r_t + \delta_k)K_t + d_t \tag{9}$$

$$K_{t+1} = (1-\delta_k)K_t + \left\{1 - \frac{\phi_I}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right\} I_t \tag{10}$$

where b_t denote purchases of bonds, R_t is the nominal interest rate on bonds, w_t is the real wage and d_t are the dividends net of lump sum taxes.

From the first-order necessary conditions we obtain the standard Euler Equation, the labor supply and the no arbitrage condition on the assets:

$$c_t^{-\sigma} = \beta \mathbb{E}_t c_{t+1}^{-\sigma} R_t \pi_{t+1}^{-1} \tag{11}$$

$$w_t = \varkappa N_t^{\nu} c_t^{\sigma} \tag{12}$$

$$Q_t = \beta \mathbb{E}_t \left[\frac{c_{t+1}^{-\sigma}}{c_t^{-\sigma}}(r_{t+1} + \delta_k) + Q_{t+1}(1-\delta_k)\right] \tag{13}$$

$$\begin{aligned} 1 &= Q_t \left[1 - \frac{\phi_I}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 - \phi_I \left(\frac{I_t}{I_{t-1}} - 1\right)\frac{I_t}{I_{t-1}}\right] \\ &\quad + \beta \mathbb{E}_t \frac{c_{t+1}^{-\sigma}}{c_t^{-\sigma}} Q_{t+1} \phi_I \left(\frac{I_{t+1}}{I_t} - 1\right)\left(\frac{I_{t+1}}{I_t}\right)^2 \end{aligned} \tag{14}$$

Where Q_t denotes Tobin's Q. These equations will determine the level of consumption, the demand for bonds and physical capital and the supply of labor.

2.3. Aggregate Constraints and Prices

To close the model we need to aggregate the quantities and the markets to clear. The total output in the economy is the result of adding up the production of every match whose productivity draw was above the threshold:

$$Y_t = T_t H(\tilde{a}_t)$$

and

$$T_t = A_t K_t^{\alpha} N_t^{1-\alpha}$$

And finally notice that output can be either consumed, invested in physical capital or used to pay the cost of changing bargained prices and/or search efforts.

$$Y_t = c_t + I_t + \phi(\pi_{It} - 1)^2 T_t + \gamma_R V_t + \gamma_W S_t$$

where $\phi = \phi_R + \phi_W$.

From the definition of the relative price, $\varphi_t = P_{It}/P_t$, we are able to establish the relationship between Consumer Price Index and Producer Price Index inflations:

$$\frac{\pi_{It}}{\pi_t} = \frac{\varphi_t}{\varphi_{t-1}}$$

2.4. Monetary Policy

The monetary policy is described by a simple Taylor-type rule where the nominal interest rate set by the monetary authority depends on core inflation, output and the previous-period nominal interest rate:

$$\frac{R_t}{R} = \exp(-z_t) \left[\left(\frac{P_{It}}{P_{It-1}} \right)^{\phi_{\pi_I}} \left(\frac{Y_t}{Y_{t-1}} \right)^{\phi_Y} \right]^{1-\phi_R} \left(\frac{R_{t-1}}{R} \right)^{\phi_R}$$

where ϕ_R, ϕ_{π_I} and ϕ_Y are the relative weights on the previous period interest rate, current core (intermediate price) inflation and output growth, respectively, and z_t denotes an i.i.d. monetary policy shock.

3. A BENCHMARK TWO-SECTORS NEW KEYNESIAN MODEL

To validate the importance of our contribution, we compare the results of our product market frictions (B2B) model with the ones of a benchmark New Keynesian (NK) model with monopolistic competition. To make the models comparable, we assume that in the benchmark model there are also two sectors of production, wholesalers and retailers. Wholesalers are monopolistically competitive and face quadratic price adjustment costs. Retailers combine the varieties of the intermediate goods in a single bundle and sell it to households.

Specifically, in the benchmark NK model retailers operate under perfect competition and flexible prices. Their production function is $y_{rt} = y_{It}$, where

$$y_{It} = \left[\int_0^1 y_{It}(j)^{\frac{\varepsilon_{NK}-1}{\varepsilon_{NK}}} dj \right]^{\frac{\varepsilon_{NK}}{\varepsilon_{NK}-1}}$$

is a bundle of intermediate varieties bought from different wholesalers. The optimal demand of each variety j is

$$y_{It}(j) = \left(\frac{P_{It}(j)}{P_t} \right)^{-\varepsilon_{NK}} y_{It} \tag{15}$$

Each wholesaler j operates under monopolistic competition and faces quadratic adjustment costs

$$c_t^P(j) = \frac{\psi_p}{2} \left(\frac{P_{It}(j)}{P_{It-1}(j)} - \pi \right)^2$$

Notice that this cost function is identical to the one faced by wholesalers and retailers in the B2B model. Wholesaler j maximizes the expected present value of future profits

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_{0,t} \left\{ \left(\frac{P_{It}(j)}{P_t} - c_t^P(j) \right) y_{It}(j) - (r_t + \delta_k) K_t(j) - w_t N_t(j) \right\}$$

subject to the production function $y_{It}(j) = A_t K_t(j)^\alpha N_t(j)^{1-\alpha}$ and the demand for each variety $y_{It}(j)$. From the wholesaler's maximization problem we obtain the following FOCs:

$$mc_t = \frac{1}{A_t} \left(\frac{w_t}{1-\alpha} \right)^{1-\alpha} \left(\frac{r_t + \delta_k}{\alpha} \right)^\alpha \tag{16}$$

$$\frac{w_t}{r_t + \delta_k} = \frac{1-\alpha}{\alpha} \frac{K_t(j)}{N_t(j)} \tag{17}$$

$$\frac{P_{It}(j)}{P_t} = \frac{\varepsilon_{NK}}{\varepsilon_{NK} - 1} \left(mc_t + c_t^P(j) - \frac{\tau_{Pt}(j)}{\varepsilon_{NK}} \right) \tag{18}$$

where

$$\tau_{Pt}(j) = \psi_p (\pi_{It}(j) - \pi) \pi_{It}(j) - \mathbb{E}_t \beta_{t,t+1} \frac{y_{It+1}(j)}{y_{It}(j)} \{ \psi_p (\pi_{It+1}(j) - \pi) \pi_{It+1}(j) \}$$

denotes the marginal costs of changing prices. The first two equations capture the marginal costs and the capital-labor ratio. Equation (18) is instead a version of the Phillips curve relating present and future inflation rates to marginal costs. In fact, aggregating across firms and log-linearizing around the steady state one can rewrite equation (18) as:

$$\hat{\pi}_{It} = \beta \mathbb{E}_t \hat{\pi}_{It+1} + \frac{(\varepsilon_{NK} - 1)}{\psi_p} (\widehat{mc}_t)$$

where variables with hats denote log deviations from the steady state.

Importantly, the presence of sticky prices is not sufficient to generate intermediate price variability in the NK model. Notice in fact that in a symmetric equilibrium, equation (15) implies that the relative intermediate price is constant and equal to 1, $\varphi_t = \frac{P_{It}}{P_t} = 1$, and that PPI and CPI inflation are identical:

$$\hat{\pi}_{It} = \hat{\pi}_t$$

4. CALIBRATION

We calibrate the model at the quarterly frequency, so we set the discount factor $\beta = 0.99$ to match a standard annualized interest rate of 4%. We use standard values also for the share of capital in production and the rate of capital depreciation. These are, respectively, $\alpha = 0.33$ and $\delta_k = 0.025$.

Our calibration of the search and matching with bargaining follows largely the strategy developed by Abbritti and Trani (2017). This is based on survey interviews to business managers from various sectors of the U.S. economy and on survey data on employment in sales-related activities. Given the average opinion of business managers, the most reasonable average duration of firm-to-firm relationships is between 1 and 2 years. This sets a target for the quarterly separation rate, which we calibrate to $\delta = 0.20$. The labor search literature has assumed that the exogenous component explains the most of the separation rate. For example, in Krause and Lubik (2007), the exogenous component is 3/4 of the overall separation rate. Here we adopt a more conservative approach and assume that $\delta_x = 0.60\delta$, which in turn implies that the endogenous component is $\delta_n = F(\tilde{a}) = 0.40\delta/[1 - 0.60\delta]$. By assumption, $F(\tilde{a})$ is a lognormal distribution. We normalize its mean, so that $\mu_{LN} = 1$, and set its volatility σ_{LN} to 0.175. Consequently, $\tilde{a}$ is equal to 0.78.

According to the evidence on sales-related activities, wholesalers' search S is 9% of intermediate goods output. Since in this model the volume of trade between firms coincides with the number of matches (i.e., there is only an extensive margin of trade), this means that wholesalers' search is close to 9% of GDP. This target allows us to determine both the search cost parameter and the matching efficiency. Therefore, assuming $\eta = \xi = 0.5$, we obtain $\gamma = 0.5726$ and $\tilde{m} = 2.8497$. The main justification for a conservative parametrization of the bargaining power η and elasticity of matching ξ is that there is no useful evidence for choosing them, so, setting them to 0.5, we can better relate our results to the endogenous separation of the matches and the other new features of the model.[7]

We then set the time spent producing goods N to 0.2, which implies that working time represents 20% of the total available time (see Mathä and Pierrard (2011)). Together with the elasticity of labor supply, this pins down the labor disutility $\varkappa$. We choose a labor elasticity equal to 1.6 by setting $\nu = 0.625$, which is broadly consistent with macroeconomic estimates (restated recently by Peterman (2016)). Regarding the calibration of the quadratic price adjustment costs, we follow Krause and Lubik (2007), who introduce one-sided price rigidity and calibrate its parameter to a value of 40. Since in our model (B2B) there is two-sided price rigidity, we equally distribute the price rigidity between both sides and set the parameters governing the degree of price rigidities to $\phi_W = \phi_R = 20$.

Lastly, we describe our strategy for calibrating the monetary policy and the TFP shocks. We assume that the strength of the reaction of the Central Bank to core inflation is $\phi_{\pi_I} = 1.5$ and to output growth is $\phi_Y = 0.5/4$. The persistence of the interest rates is $\phi_R = 0.85$. The standard deviation of monetary policy shocks is set to the standard value of 0.1%. As far as the TFP shocks are concerned, we assume that their persistence is 0.9 and choose their volatility to match the volatility of U.S. GDP. The implied value is $\sigma_A = 0.975\%$. Conditional on these choices, we control the relative volatility of investment using the parameter ϕ_I which is set equal to 0.215 in our model.

To understand the role of long term B2B relationships and bargaining for business cycle dynamics, it will be instructive to compare the dynamics of B2B model with the ones of the benchmark NK model. To facilitate comparison, the calibration of the benchmark NK model is identical to the one of the B2B model. Specifically, to calibrate the degree of price rigidity in the NK model we have followed

[7] In a model that abstracts from nominal price rigidity and endogenous destruction, Abbritti and Trani (2017) show that one can choose η to approximate the volatility of the PPI in the data, with little consequence for the other moments.

Krause and Lubik (2007) and set $\psi_p = 40$, which is equal to the sum of the price adjustment costs for wholesalers and retailers. The only additional parameter that we need to specify is the elasticity of demand ε_{NK}, which we set to 6 as, e.g., in Blanchard and Galí (2010).

5. RESULTS

5.1. Steady State Analysis

In order to understand the role and the contribution of the endogenous separation rate, in this section we analyze the steady states of our model with and without endogenous separation rate, for different values of the bargaining power. The model with exogenous separation rate is obtained by simply setting to zero the variance of the match-specific productivity and keeping all the other parameters fixed at their baseline values.[8] Specifically, we compare steady-state equilibria for the following three values of the bargaining power of wholesalers: 0.3, 0.5, and 0.7. The results can be seen in Table 1, where the last column displays the ratio of the final price to total marginal cost, which is introduced as an approximation to the mark-up of producers.[9]

Table 1: Steady State Analysis

	T	θ	$H(\tilde{a})$	Y	δ	mc	P/χ
			B2B Baseline				
$\eta = 0.3$	0.5832	2.3137	1.0034	0.5852	0.1276	0.9343	1.0740
$\eta = 0.5$	0.5795	0.9552	1.0281	0.5958	0.2004	0.9222	1.1148
$\eta = 0.7$	0.5491	0.3930	1.0705	0.5878	0.3430	0.8305	1.2890
			B2B with Exogenous Separation				
$\eta = 0.3$	0.5835	2.3333	1.0000	0.5835	0.1200	0.9352	1.0693
$\eta = 0.5$	0.5854	1.0000	1.0000	0.5854	0.1200	0.9406	1.0632
$\eta = 0.7$	0.5835	0.4286	1.0000	0.5835	0.1200	0.9352	1.0693

Considering that the model with endogenous separation is our baseline assumption, as well as our main contribution, let us start by analyzing its steady state. Since η measures the bargaining power of wholesalers it affects the share of the total surplus of a match that these retain. In particular, the higher it is, the higher the value of a match for wholesalers, and the more they will search. The opposite is true for retailers and this is what explains the observed values of the product market tightness, θ, which is defined as the ratio of the search effort of retailers to that of wholesalers. However, as we can see from equation (8), η is not the only determinant of the solution to the bargaining problem.[10] Actually, the (endogenous) productivity threshold, $\tilde{a}$, below which a match is terminated also affects

[8] When σ_{LN} is exactly equal to zero, the distribution of idiosyncratic productivities is degenerate and its c.d.f. evaluated at the threshold is also zero. Then, the separation rate becomes completely exogenous.

[9] The total marginal cost is computed as the ratio of wholesalers marginal cost to the average productivity of matches, i.e. $\chi = mc/H(\tilde{a})$.

[10] Notice that equation (8) is the solution to the bargaining problem with flexible prices, so by simply removing the time subindices we obtain the solution to the bargaining problem is steady state for the baseline model (i.e. with sticky prices).

how its surplus is shared between wholesalers and retailers. Intuitively, the fact that retailers have a direct control of the separation rate provides them with additional leverage on the bargaining problem.[11] Through this additional wedge, retailers are partially compensated for bearing most of the risk of an adverse realization of the idiosyncratic shock. This allows us to differentiate between the "bargaining power", which is exogenous and is fully captured by the parameter η, and the "*effective* bargaining power", which is endogenous and is jointly determined by η and $\tilde{a}$. In other words, whereas retailers can affect the number of B2B relations both through their search effort and the decision to separate (or not), wholesalers can only adjust through their search effort. This is the reason behind the negative relationship between η and the number of B2B relationships, T, which is driven by the fact that the lower the bargaining power of retailers the more they choose to separate. However, the matches being destroyed are the ones with lower productivity, which increases the average productivity of matches in the economy, $H(\tilde{a})$. This increase in average productivity implies a reduction in the marginal cost of wholesalers, which further reduces the total marginal cost and significantly increases the approximation of the mark-up of wholesalers, P/χ.

Next, let us analyze what happens to the steady-state equilibria with exogenous separation rate. If retailers cannot decide to terminate a B2B relationship, the term with $\tilde{a}$ in equation (8) disappears and we obtain the standard solution to the Nash bargaining problem where only the bargaining power, η, determines how the surplus of a match is shared between both parties. In this case, for the baseline calibration (i.e. $\eta = 0.5$), the Hosios (1990) condition is satisfied and the solution to the bargaining problem is constrained efficient. However, notice that while the number of B2B relationships is lower in the model with endogenous separation than in the model with exogenous separation, total production is higher in the former (for the same value of η). This is explained by the fact that the matches being destroyed in the model with endogenous separation are those with lowest productivity whereas in the exogenous separation model all the matches are equally productive. Another important difference between both model specifications is that in the model with exogenous separation rate different calibrations of the bargaining power do not seem to significantly affect the steady state values. Furthermore, it can be seen that its effect is symmetric. For example, output follows a symmetric inverse-U shape for different values of η, and it is maximized when wholesalers and retailers held the same bargaining power. This happens because wholesalers and retailers can only affect the number of B2B relationships through their search effort and, for this calibration, the search externality is fully internalized. This is not the case in the model with endogenous separation and η equal to 0.5, where the search externality is not fully internalized by producers, which leads to a congestion problem and hence the value of output is not the maximum possible. The nonlinear

[11] The retailer is the one drawing the match-specific productivity and deciding whether a match survives or is terminated. Remember that the threshold below which matches are terminated is such that the marginal value of a match for a retailer is zero.

and symmetric behavior is also observed for the number of B2B relations T, the marginal cost of wholesalers, mc, and therefore in the approximate mark-up, P/χ, as well. Therefore, the results from this analysis indicate that the endogenous separation rate plays an important role in the steady-state equilibrium of the model and is a potential source of asymmetries that might be important for the transmission of different shocks.[12]

5.2. Second Moments

To assess the quantitative validity of our model, Table 2 shows selected second moments of different versions of the model and compare them with the ones of the U.S. data and the benchmark NK model. The data are collected from FRED and cover the period from 1975Q1 to 2015Q2.[13] The simulations of the various economies, except for the one in the last column of the table, are instead based on the preferred calibration of our model, which is the case of the B2B model displayed in column B2B(I).

The B2B model with endogenous separations, column B2B(I), does a fairly good job in replicating most second moment statistics of the data. Specifically, it captures the relative volatilities of employment and intermediate prices, and the cross-correlations of most variables with GDP and PPI inflation. The model instead fails to match the relative volatility and cross-correlation of CPI inflation. This can be explained by the fact that, to clarify the mechanism of the model, we have assumed that retail prices are perfectly flexible.

Column B2B(II) shows the results of a nested B2B model with an exogenous separation rate. A comparison between the two models reveals that closing down the match destruction margin strongly increases the relative volatilities of employment, wages, real intermediate prices and CPI inflation, while the volatility of output is not affected. The B2B model with endogenous separations also provides a better fit of the cross-correlation of PPI inflation with intermediate prices and CPI inflation. Overall, the fact that the B2B model with endogenous separation rate provides a better match of the relative volatility of the intermediate price suggests that allowing firms to decide whether they want to continue with a business relationship has important effects on price dynamics.

To provide a deeper understanding of the role of the endogenous separation rate, we compare the dynamics of models B2B(I) and B2B (II) following a TFP shock (see Figure 3 in Appendix). A positive TFP shock makes wholesalers more productive, increasing total production. In the B2B(I) model, the increase in the number of business relationships comes from two different sources. On one hand, the reduction of wholesalers' marginal costs increases the total value of each match and induces both wholesalers and retailers to increase their search efforts, which results in the creation of a higher number of matches. On the other hand, the threshold of the idiosyncratic productivity

[12] See sections 5.2 and 5.3 for an analysis of the contribution of the endogenous separation rate on the transmission of technology and monetary policy shocks.

[13] For the intermediate price we use "PPI Final Demand Finished Goods Less Energy" and for the final price we use "CPI All Goods Less Energy".

Table 2: Second Moments

	Data	B2B (I)	B2B (II)	NK (I)	NK (II)
Volatility GDP	1.39	1.39	1.39	1.51	1.39
Vol(x)/Vol(GDP)					
Investment	3.49	3.49	3.36	3.65	3.49
Employment	0.96	0.84	1.19	0.71	0.71
Wages	0.42	0.93	1.23	0.72	0.74
Interm. Price	0.40	0.37	0.63	0.00	0.00
CPI Inflation	0.20	0.53	0.89	0.18	0.19
PPI Inflation	0.33	0.16	0.18	0.18	0.19
Corr(x, GDP)					
Investment	0.89	0.96	0.97	0.98	0.97
Employment	0.85	0.56	0.57	0.63	0.55
Wages	0.85	0.73	0.70	0.90	0.89
Interm. Price	0.22	0.10	0.31	0.00	0.00
CPI Inflation	0.43	-0.20	-0.35	0.24	0.20
PPI Inflation	0.25	0.21	0.26	0.24	0.20
Corr(x,PPI Infl.)					
Interm. Price	0.28	0.40	0.31	0.00	0.00
CPI Inflation	0.25	0.08	-0.04	1.00	1.00

Notes: B2B (I) denotes the baseline model specification with endogenous separation rate. B2B (II) is the model specification with exogenous separation rate (computed by setting to zero the variance of the match-specific productivity). NK (I) denotes the benchmark New Keynesian model with the same calibration as the B2B model. NK (II) denotes the benchmark New Keynesian model with an alternative calibration that sets the investment adjustment costs and the standard deviation of TFP shocks to match output volatility and the relative investment volatility.

below which matches are destroyed declines, bringing down both the endogenous separation rate and the average productivity of matches. The high persistence of output is mainly driven by the high persistence of the number of B2B relationships, while the endogenous separation margin mainly affects the short-run response of output and B2B relationships. Overall, the shock reduces wholesalers' marginal costs and leads to lower relative intermediate prices and PPI inflation. Closing down the endogenous separation rate mainly affects the short-run ability of firms to adjust to the technology shock. In the B2B(II) model, since firms can adjust production only through the match creation margin, the reaction of search efforts, employment and intermediate prices are amplified, while the short-run response of production and the number of matches is reduced. The next section elaborates more on the contribution and importance of the endogenous separation rate of matches and how it shapes the transmission of monetary policy.

The second moments of the B2B model differ significantly from the ones of the benchmark New Keynesian model (see column NK (I) in Table 2). Adopting exactly the same calibration, the NK model generates a higher volatility of both output and investment. More importantly, as we mentioned before, the presence of sticky intermediate prices is not sufficient to generate intermediate price variability in the NK model, and implies a one to one relationship between PPI and CPI inflation. As a consequence, the relative volatility and cross correlation of intermediate prices are 0, and the relative volatilities and cross-correlations of PPI and CPI inflation with output are identical. In other words, the B2B model fits the data at least as well as the NK model, and this is not an artifact of an advantageous calibration. Indeed, column NK (II) shows the results of re-calibrating the NK model using the same calibration strategy as the B2B model. In particular, we reset the standard deviation of technology shocks and the investment adjustment costs of the NK model to match the U.S. output volatility and relative volatility of investment.[14] The fit of the NK model slightly improves for what concerns CPI inflation volatility, but the cross-correlations of employment, CPI and PPI investment worsen.

Once again, we believe that it is interesting to compare the dynamics of the economy under the B2B and NK model following a TFP shock. In particular, we perform this comparison using the calibrations B2B(I) and NK (I) and obtain the results in Figure 4 of the Appendix. Our findings show that the presence of product market frictions and bargaining reduces the responses on impact of output and investment, wages and PPI inflation, which is in line with the intuition obtained from the second moments.

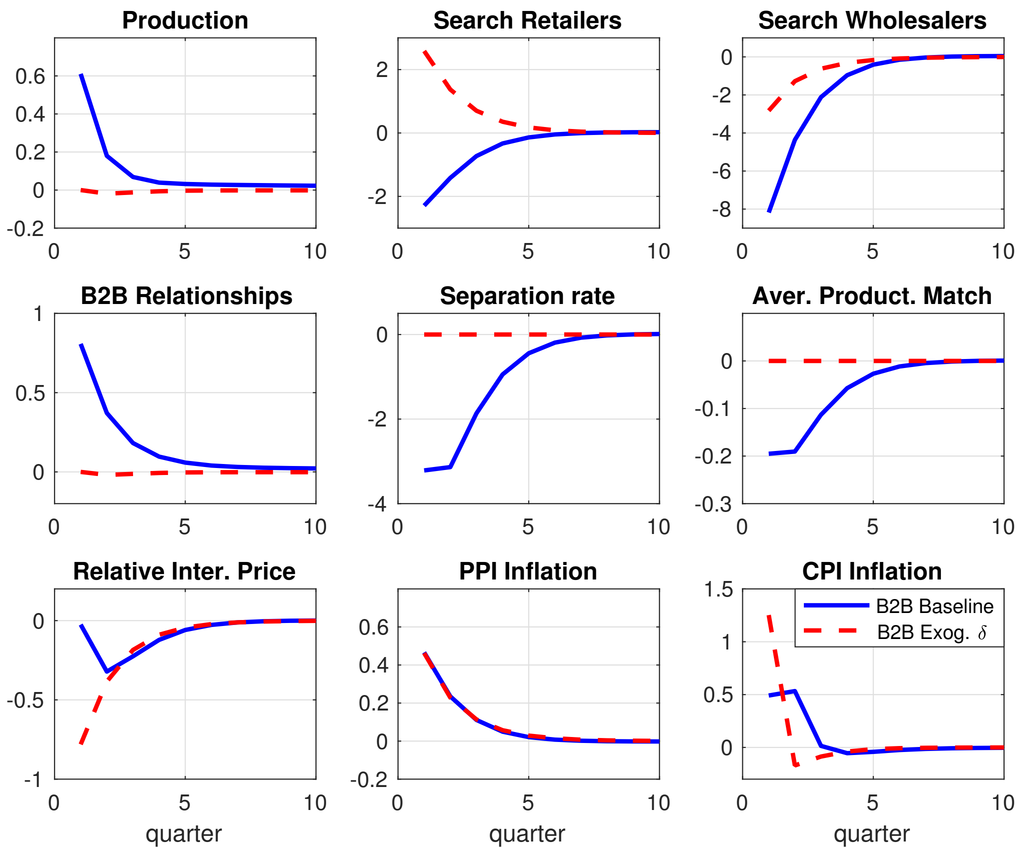
5.3. The Transmission of Monetary Policy Shocks

In this section we show that the presence of long-term business relationships and bargaining crucially determines both the real effects of monetary policy as well as its transmission mechanism. In our baseline model, the number of B2B relationships, and therefore overall production, changes through both the endogenous destruction and endogenous creation of matches. This implies that the presence of sticky intermediate prices can in principle affect production through both channels. On one hand, changes in the relative intermediate price have a direct effect on the separation threshold. By looking at equation (6) it can be seen that a lower relative intermediate price decreases the separation threshold, $\tilde{a}$. Therefore, both the separation rate and the average productivity of surviving matches decrease. Through this mechanism, intermediate prices have a direct allocative role on the number of B2B relationships and hence on final output. This implies that, in the presence of sticky prices, monetary policy can directly affect the number of endogenous separations, the average productivity of surviving business relationships and final and intermediate output.

On the other hand, the intermediate price also affects the value of a B2B relationship to wholesalers and retailers, modifying their incentives to engage in costly search activities. Moreover, it is straightforward to see from equations (2) and (4), that the change in the value of a match and hence in incentives is opposite across the two sides of the market: while a decrease in the relative intermediate price induces wholesalers to decrease their search effort, it also increases the search effort of retailers. In the end, the two effects tend to cancel out. The overall effect on the formation of new matches depends on the initial product market tightness, on the presence of search externalities and on the separation rate.

[14] The implied parameters for the NK model are $\sigma_A = 0.95\%$ and $\phi_I = 0.35$.

Figure 1: Comparison of the IRFs of the B2B Model With and Without Endogenous Separation Rate to a Monetary Policy Shock



To gauge the relative size of these two channels, Figure 1 compares the effects of an expansionary monetary policy shock in our model with endogenous separation rate and the same model but with exogenous separation rate. Let us consider first the model with endogenous separation. The monetary policy shock, which corresponds to a 0.25 percent reduction of the nominal interest rate, stimulates the economy increasing the levels of consumption and investment, and therefore aggregate demand. As a result, final and intermediate prices increase. However, since price rigidity occurs in the intermediate level, the final price increases more than the intermediate price and hence the relative intermediate price goes down. As previously explained, this change in the intermediate price leads to a decrease in the separation threshold which reduces the separation rate and increases the number of matches. In other words, to satisfy the increase in aggregate demand retail firms increase their production adjusting through the endogenous separation margin, that is by keeping alive matches with lower productivity. Nevertheless, wholesalers and retailers are aware of the transient nature of the shock and, anticipating the need to reduce their stock of B2B relationships in the future, both reduce their search effort. The overall effect is a short-lived increase in production and in the number of matches, which goes hand in hand with a reduction of the average productivity of matches.

A completely different pattern is observed when firms are not allowed to adjust production through the endogenous separation of inefficient matches. As before, the monetary policy shock leads to an increase in aggregate demand and a reduction of the relative intermediate price. Consequently, the value of a match for a wholesaler decreases, whereas that of the retailer increases. Accordingly, the change in search effort of retailers is positive whereas in the model with endogenous separation it was negative. This is key because it reveals the different transmission mechanisms of monetary policy between both models. The differences arising from the endogenous separation also imply that there is an endogenous response of the effective bargaining power. In the end, in the model with exogenous separation, the opposite effects in searching effort of wholesalers and retailers cancel out and there is no change at all neither in production nor on the number of B2B relationships. Actually, there is no change in any other real variable except for search effort. This implies that intermediate prices have (almost) no allocative role for output dynamics along the endogenous match creation margin, and monetary policy shocks have negligible real effects in a model with exogenous separations.

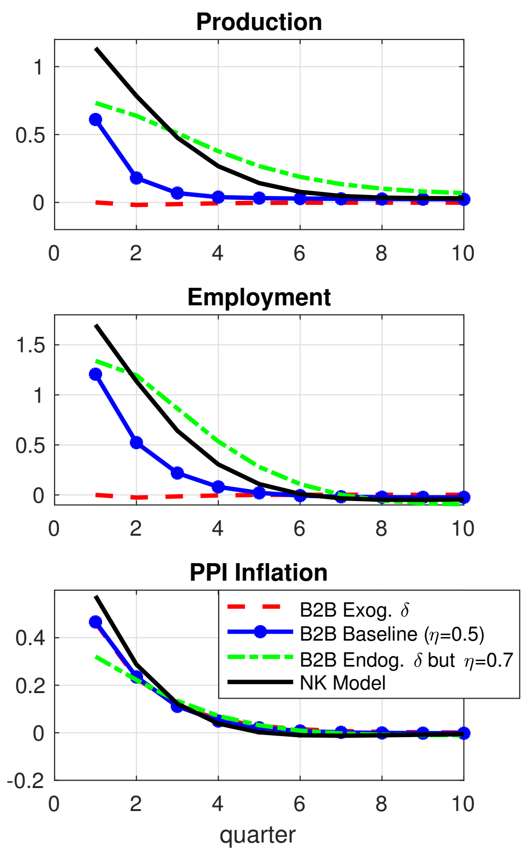
This analysis suggests that monetary policy shocks can still have real effects on output and consumption dynamics, but that these effects work almost entirely through the endogenous separation margin. But how big are these real effects? To answer this question, Figure 2 compares the effects of an unexpected monetary shock in the baseline B2B model with the ones in the B2B model with exogenous separation, the B2B model with endogenous separation and $\eta = 0.7$, and the benchmark NK model.

The comparison between the baseline B2B model ($\eta = 0.5$) and the same model with $\eta = 0.7$ is aimed at complementing the discussion provided in section 5.1 about the effect of the bargaining power on the equilibrium of the model. In particular we want to see how much the allocative role of prices changes with different values of η.[15] The first aspect we notice is that, on impact, the effect of monetary policy on output is almost the same in both models. However, we observe that the shock is more persistent for the higher value of the bargaining power of wholesalers. This higher persistence is shared in other variables such as investment, employment and wages. Furthermore, the effect of a monetary policy shock on investment is twice as high on impact in the model with $\eta = 0.7$. This can be explained by the fact that now retailers have less bargaining power and therefore the endogenous separation margin (which is solely controlled by them) becomes more important and has a greater effect on the dynamics of the model. In other words, the real effects of monetary policy are increasing in the bargaining power of wholesalers.

Comparing both versions of the baseline B2B and the NK models we see that the effects of a monetary policy shock are qualitatively similar but quantitatively rather different. Most notably,

[15] We do not include a comparison with the baseline B2B with $\eta = 0.3$ because that calibration will provide too much bargaining power to retailers, considering that they are the ones deciding if a match should be destroyed or not.

Figure 2: Comparison of the IRFs of the B2B and NK Models to a Monetary Policy Shock



while the responses of PPI and CPI inflation in the three models resemble each other, the responses of output and employment are significantly larger - and more persistent - in the NK model than in the baseline B2B model. Overall, notwithstanding the relatively generous calibration of the endogenous separation margin, the real effects of monetary policy shocks on output dynamics are 50 percent smaller in the latter model than in the NK model. This is consistent with the idea of a lower allocative role of intermediate prices in B2B relationships. However, notice that the real effects of monetary policy on investment increase in the B2B model if the bargaining power of wholesalers is increased. Even though, on impact, the response of output and employment is lower in the B2B model with $\eta = 0.7$ than in the NK model, the effect of the monetary policy shock is more persistent in the former. The higher persistence B2B model with $\eta = 0.7$ is also observed in investment and wages which, on top of that, have a higher response on impact than the NK model. As explained above, the reason behind this is the increased use of the endogenous separation margin made by retailers as a response to their reduction in bargaining power.

6. CONCLUSIONS

A growing empirical literature shows that most transactions are firm-to-firm and that price rigidities mainly arise at the intermediate goods level, in relationships governed by implicit or explicit long-term contracts. This paper studies theoretically the implications of long-term business relationships and bargaining over sticky prices for monetary policy and business cycles dynamics. To this aim, it introduces search and matching frictions, endogenous separations and bargaining between firms into an otherwise standard monetary DSGE model. The different business environment has important effects on monetary policy and business cycle dynamics. The model outperforms the benchmark New Keynesian model in replicating some of the second moments and cross-correlations of US product market and business cycle data. We show that, in the presence of long-term business relationships and bargaining, monetary policy is less effective. This happens because, for standard calibrations, the long-term nature of the relationships between firms reduces the allocative role of intermediate good prices and the real effects of monetary policy shocks.

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8. APPENDIX

A. BARGAINING PROBLEM

Intermediate prices are determined through a Nash bargaining scheme between the retailer and the wholesaler. Precisely, for each match v, intermediate goods prices are determined as the outcome of the following bargaining scheme

$$\max_{P_{It}} SU_t = \left[\left(J_t^W(v)\right)^{\eta} \left(J_t^R(v)\right)^{1-\eta} \right]$$

where η is the bargaining power of retailers.

Recall the endogenous separation rate:

$$\tilde{a}_t(i) = \left[\frac{P_{It}(i)}{P_t} + \frac{\phi_R}{2} \left(\frac{P_{It}(i)}{P_{It-1}(i)} - 1 \right)^2 - \mathbb{E}_t \beta_{t,t+1} \left(1 - \delta_{t+1}(i)\right) J_{t+1}^R(i) \right] \tag{19}$$

Necessary derivations for the bargaining problem:

$$\frac{\partial \tilde{a}_t(i)}{\partial P_{It}} = \left[\frac{1}{P_t} + \phi_R \left(\frac{P_{It}(i)}{P_{It-1}(i)} - 1 \right) \frac{1}{P_{It-1}(i)} - \mathbb{E}_t \beta_{t,t+1} \left[-\frac{\partial \delta_{t+1}(i)}{\partial P_{It}} J_{t+1}^R(i) + \left(1 - \delta_{t+1}(i)\right) \frac{\partial J_{t+1}^R(i)}{\partial P_{It}} \right] \right]$$

Since

$$\begin{aligned}
\frac{\partial \delta_{t+1}(i)}{\partial P_{It}} &= \frac{\partial \delta_{t+1}(i)}{\partial \tilde{a}_{t+1}(i)} \frac{\partial \tilde{a}_{t+1}(i)}{\partial P_{It}} \\
&= (1 - \delta_x) f\left(\tilde{a}_{t+1}(i)\right) \phi_R \left(\frac{P_{It+1}(i)}{P_{It}(i)} - 1 \right) \left(-\frac{P_{It+1}(i)}{P_{It}(i)^2} \right) \\
&= -(1 - \delta_x) f\left(\tilde{a}_{t+1}(i)\right) \phi_R \left(\frac{P_{It+1}(i)}{P_{It}(i)} - 1 \right) \left(\frac{P_{It+1}(i)}{P_{It}(i)^2} \right)
\end{aligned}$$

and

$$\begin{aligned}
\frac{\partial J_{t+1}^R(i)}{\partial P_{It}} &= \frac{\partial H\left(\tilde{a}_{t+1}(i)\right)}{\partial \tilde{a}_{t+1}(i)} \frac{\partial \tilde{a}_{t+1}(i)}{\partial P_{It}} + \phi_R \left(\frac{P_{It+1}(i)}{P_{It}(i)} - 1 \right) \left(\frac{P_{It+1}(i)}{P_{It}(i)^2} \right) \\
&= \frac{\partial H\left(\tilde{a}_{t+1}(i)\right)}{\partial \tilde{a}_{t+1}(i)} \phi_R \left(\frac{P_{It+1}(i)}{P_{It}(i)} - 1 \right) \left(-\frac{P_{It+1}(i)}{P_{It}(i)^2} \right) + \phi_R \left(\frac{P_{It+1}(i)}{P_{It}(i)} - 1 \right) \left(\frac{P_{It+1}(i)}{P_{It}(i)^2} \right) \\
&= \left(1 - \frac{\partial H\left(\tilde{a}_{t+1}(i)\right)}{\partial \tilde{a}_{t+1}(i)} \right) \phi_R \left(\frac{P_{It+1}(i)}{P_{It}(i)} - 1 \right) \left(\frac{P_{It+1}(i)}{P_{It}(i)^2} \right)
\end{aligned}$$

we obtain

$$\begin{aligned}
\frac{\partial \tilde{a}_t(i)}{\partial P_{It}} &= \left\{ \frac{1}{P_t} + \phi_R \left(\frac{P_{It}(i)}{P_{It-1}(i)} - 1 \right) \frac{1}{P_{It-1}(i)} \right. \\
&- \mathbb{E}_t \beta_{t,t+1} \left[(1-\delta_x) f\left(\tilde{a}_{t+1}(i)\right) \phi_R \left(\frac{P_{It+1}(i)}{P_{It}(i)} - 1 \right) \left(\frac{P_{It+1}(i)}{P_{It}(i)^2} \right) J^R_{t+1}(i) \right. \\
&+ \left. \left. (1-\delta_{t+1}(i)) \left(1 - \frac{\partial H\left(\tilde{a}_{t+1}(i)\right)}{\partial \tilde{a}_{t+1}(i)} \right) \phi_R \left(\frac{P_{It+1}(i)}{P_{It}(i)} - 1 \right) \left(\frac{P_{It+1}(i)}{P_{It}(i)^2} \right) \right] \right\}
\end{aligned}$$

Rearranging terms

$$\begin{aligned}
\frac{\partial \tilde{a}_t(i)}{\partial P_{It}} &= \left\{ \frac{1}{P_t} + \phi_R \left(\frac{P_{It}(i)}{P_{It-1}(i)} - 1 \right) \frac{1}{P_{It-1}(i)} \right. \\
&- \mathbb{E}_t \beta_{t,t+1} \left[(1-\delta_{t+1}(i)) \left(1 - \frac{\partial H\left(\tilde{a}_{t+1}(i)\right)}{\partial \tilde{a}_{t+1}(i)} \right) \right. \\
&+ \left. \left. (1-\delta_x) f\left(\tilde{a}_{t+1}(i)\right) J^R_{t+1}(i) \right] \phi_R \left(\frac{P_{It+1}(i)}{P_{It}(i)} - 1 \right) \left(\frac{P_{It+1}(i)}{P_{It}(i)^2} \right) \right\}
\end{aligned} \tag{20}$$

Recall

$$J^W_t(j) = \frac{P_{It}(j)}{P_t} - \frac{\phi_W}{2} \left(\frac{P_{It}(j)}{P_{It-1}(j)} - 1 \right)^2 - mc_t + \mathbb{E}_t \beta_{t,t+1} \left(1 - \delta_{t+1}(j)\right) J^W_{t+1}(j)$$

Differentiating with respect to P_{It}

$$\frac{\partial J^W_t(j)}{\partial P_{It}} = \frac{1}{P_t} - \phi_W \left(\frac{P_{It}(j)}{P_{It-1}(j)} - 1 \right) \frac{1}{P_{It-1}(j)} + \mathbb{E}_t \beta_{t,t+1} \left[-\frac{\partial \delta_{t+1}(j)}{\partial P_{It}} J^W_{t+1}(j) + \left(1-\delta_{t+1}(j)\right) \frac{\partial J^W_{t+1}(j)}{\partial P_{It}} \right]$$

Since

$$\frac{\partial J^W_{t+1}(j)}{\partial P_{It}} = \phi_W \left(\frac{P_{It+1}(j)}{P_{It}(j)} - 1 \right) \left(\frac{P_{It+1}(j)}{P_{It}(j)^2} \right)$$

We obtain

$$\begin{aligned}
\frac{\partial J^W_t(j)}{\partial P_{It}} &= \frac{1}{P_t} - \phi_W \left(\frac{P_{It}(j)}{P_{It-1}(j)} - 1 \right) \frac{1}{P_{It-1}(j)} \\
&+ \mathbb{E}_t \beta_{t,t+1} \left[(1-\delta_x) f\left(\tilde{a}_{t+1}(j)\right) \phi_R \left(\frac{P_{It+1}(j)}{P_{It}(j)} - 1 \right) \left(\frac{P_{It+1}(j)}{P_{It}(j)^2} \right) J^W_{t+1}(j) \right. \\
&+ \left. \left(1-\delta_{t+1}(j)\right) \phi_W \left(\frac{P_{It+1}(j)}{P_{It}(j)} - 1 \right) \left(\frac{P_{It+1}(j)}{P_{It}(j)^2} \right) \right]
\end{aligned}$$

Rearranging terms

$$\begin{aligned}
\frac{\partial J_t^W(j)}{\partial P_{It}} &= \frac{1}{P_t} - \phi_W \left(\frac{P_{It}(j)}{P_{It-1}(j)} - 1 \right) \frac{1}{P_{It-1}(j)} \\
&+ \mathbb{E}_t \beta_{t,t+1} \left[(1 - \delta_{t+1}(j)) \phi_W \right. \\
&+ \left. (1 - \delta_x) f\left(\tilde{a}_{t+1}(i)\right) J_{t+1}^W(j) \phi_R \right] \left(\frac{P_{It+1}(j)}{P_{It}(j)} - 1 \right) \left(\frac{P_{It+1}(j)}{P_{It}(j)^2} \right) \qquad (21)
\end{aligned}$$

Also recall

$$J_t^R(i) = H\left(\tilde{a}_t(i)\right) - \left[\frac{P_{It}(i)}{P_t} + \frac{\phi_R}{2} \left(\frac{P_{It}(i)}{P_{It-1}(i)} - 1 \right)^2 \right] + \mathbb{E}_t \beta_{t,t+1} \left(1 - \delta_{t+1}(i)\right) J_{t+1}^R(i)$$

Differentiating with respect to P_{It}

$$\begin{aligned}
\frac{\partial J_t^R(i)}{\partial P_{It}} &= \frac{\partial H\left(\tilde{a}_t(i)\right)}{\partial \tilde{a}_t(i)} \frac{\tilde{a}_t(i)}{\partial P_{It}} - \left[\frac{1}{P_t} + \phi_R \left(\frac{P_{It}(i)}{P_{It-1}(i)} - 1 \right) \frac{1}{P_{It-1}(i)} \right] \\
&+ \mathbb{E}_t \beta_{t,t+1} \left[- \frac{\partial \delta_{t+1}(i)}{\partial P_{It}} J_{t+1}^R(i) + (1 - \delta_{t+1}(i)) \frac{\partial J_{t+1}^R(i)}{\partial P_{It}} \right] \\
&= \frac{\partial H\left(\tilde{a}_t(i)\right)}{\partial \tilde{a}_t(i)} \left\{ \frac{1}{P_t} + \frac{\phi_R}{P_{It-1}(i)} \left(\frac{P_{It}(i)}{P_{It-1}(i)} - 1 \right) - \mathbb{E}_t \beta_{t,t+1} \left[(1 - \delta_{t+1}(i)) \left(1 - \frac{\partial H\left(\tilde{a}_{t+1}(i)\right)}{\partial \tilde{a}_{t+1}(i)} \right) \right. \right. \\
&+ \left. \left. (1 - \delta_x) f\left(\tilde{a}_{t+1}(i)\right) J_{t+1}^R(i) \right] \phi_R \left(\frac{P_{It+1}(i)}{P_{It}(i)} - 1 \right) \left(\frac{P_{It+1}(i)}{P_{It}(i)^2} \right) \right\} - \left[\frac{1}{P_t} + \frac{\phi_R}{P_{It-1}(i)} \left(\frac{P_{It}(i)}{P_{It-1}(i)} - 1 \right) \right] \\
&+ \mathbb{E}_t \beta_{t,t+1} \left[(1 - \delta_x) f\left(\tilde{a}_{t+1}(i)\right) \phi_R \left(\frac{P_{It+1}(i)}{P_{It}(i)} - 1 \right) \left(\frac{P_{It+1}(i)}{P_{It}(i)^2} \right) J_{t+1}^R(i) \right. \\
&+ \left. (1 - \delta_{t+1}(i)) \left(1 - \frac{\partial H\left(\tilde{a}_{t+1}(i)\right)}{\partial \tilde{a}_{t+1}(i)} \right) \phi_R \left(\frac{P_{It+1}(j)}{P_{It}(i)} - 1 \right) \left(\frac{P_{It+1}(i)}{P_{It}(i)^2} \right) \right]
\end{aligned}$$

Rearranging terms

$$\begin{aligned}
\frac{\partial J_t^R(i)}{\partial P_{It}} &= - \left(1 - \frac{\partial H\left(\tilde{a}_t(i)\right)}{\partial \tilde{a}_t(i)} \right) \left\{ \frac{1}{P_t} + \frac{\phi_R}{P_{It-1}(i)} \left(\frac{P_{It}(i)}{P_{It-1}(i)} - 1 \right) - \mathbb{E}_t \beta_{t,t+1} \left[(1 - \delta_{t+1}(i)) \left(1 - \frac{\partial H\left(\tilde{a}_{t+1}(i)\right)}{\partial \tilde{a}_{t+1}(i)} \right) \right. \right. \\
&+ \left. \left. (1 - \delta_x) f\left(\tilde{a}_{t+1}(i)\right) J_{t+1}^R(i) \right] \phi_R \left(\frac{P_{It+1}(i)}{P_{It}(i)} - 1 \right) \left(\frac{P_{It+1}(i)}{P_{It}(i)^2} \right) \right\} \qquad (22)
\end{aligned}$$

From the bargaining problem:

$$\begin{aligned}
\eta\frac{\partial J_t^W}{\partial P_{It}}J_t^R &= -\left(1-\eta\right)\frac{\partial J_t^R}{\partial P_{It}}J_t^W \\
\eta J_t^R\begin{pmatrix} \frac{1}{P_t}-\phi_W\left(\frac{P_{It}(j)}{P_{It-1}(j)}-1\right)\frac{1}{P_{It-1}(j)} \\ +\mathbb{E}_t\beta_{t,t+1}\left[\left(1-\delta_{t+1}(j)\right)\phi_W\right. \\ \left.+\left(1-\delta_x\right)f\left(\tilde{a}_{t+1}(i)\right)J_{t+1}^W(j)\phi_R\right] \\ \left(\frac{P_{It+1}(j)}{P_{It}(j)}-1\right)\left(\frac{P_{It+1}(j)}{P_{It}(j)^2}\right)\end{pmatrix} &= \left(1-\eta\right)J_t^W\begin{pmatrix} \left(1-\frac{\partial H(\tilde{a}_t(i))}{\partial\tilde{a}_t(i)}\right)\left\{\frac{1}{P_t}+\frac{\phi_R}{P_{It-1}(i)}\left(\frac{P_{It}(i)}{P_{It-1}(i)}-1\right)\right. \\ -\mathbb{E}_t\beta_{t,t+1}\left[\left(1-\delta_{t+1}(i)\right)\left(1-\frac{\partial H(\tilde{a}_{t+1}(i))}{\partial\tilde{a}_{t+1}(i)}\right)\right. \\ \left.+\left(1-\delta_x\right)f\left(\tilde{a}_{t+1}(i)\right)J_{t+1}^R(i)\right] \\ \left.\phi_R\left(\frac{P_{It+1}(i)}{P_{It}(i)}-1\right)\left(\frac{P_{It+1}(i)}{P_{It}(i)^2}\right)\right\}\end{pmatrix} \\
\eta J_t^R\begin{pmatrix} \varphi_t-\phi_W\left(\pi_{It}-1\right)\pi_{It} \\ +\mathbb{E}_t\beta_{t,t+1}\left[\left(1-\delta_{t+1}\right)\phi_W\right. \\ \left.+\left(1-\delta_x\right)f\left(\tilde{a}_{t+1}\right)J_{t+1}^W\phi_R\right] \\ \left(\pi_{It+1}-1\right)\pi_{It+1}\end{pmatrix} &= \left(1-\eta\right)J_t^W\begin{pmatrix} \left(1-\frac{\partial H(\tilde{a}_t(i))}{\partial\tilde{a}_t(i)}\right)\left\{\varphi_t+\phi_R\left(\pi_{It}-1\right)\pi_{It}\right. \\ -\mathbb{E}_t\beta_{t,t+1}\left[\left(1-\delta_{t+1}\right)\left(1-\frac{\partial H(\tilde{a}_{t+1}(i))}{\partial\tilde{a}_{t+1}(i)}\right)\right. \\ \left.+\left(1-\delta_x\right)f\left(\tilde{a}_{t+1}(i)\right)J_{t+1}^R(i)\right] \\ \phi_R\left(\pi_{It+1}-1\right)\pi_{It+1} \\ \\ \end{pmatrix} \\
\eta J_t^R\left(\varphi_t-\tau_t^W\right) &= \left(1-\eta\right)J_t^W\left(\left(1-\frac{\partial H(\tilde{a}_t)}{\partial\tilde{a}_t}\right)\varphi_t+\tau_t^R\right) \\
\left(\eta J_t^R-\left(1-\eta\right)\left(1-\frac{\partial H(\tilde{a}_t)}{\partial\tilde{a}_t}\right)J_t^W\right)\varphi_t &= \left(1-\eta\right)\tau_t^R J_t^W+\eta\tau_t^W J_t^R
\end{aligned}$$

where

$$\begin{aligned}
\tau_t^W &= \phi_W\left(\pi_{It}-1\right)\pi_{It}-\mathbb{E}_t\beta_{t,t+1}\left[\left(1-\delta_{t+1}\right)\phi_W+\left(1-\delta_x\right)f\left(\tilde{a}_{t+1}\right)J_{t+1}^W\phi_R\right]\left(\pi_{It+1}-1\right)\pi_{It+1} \\
\tau_t^R &= \left(1-\frac{\partial H\left(\tilde{a}_t\right)}{\partial\tilde{a}_t}\right)\left\{\phi_R\left(\pi_{It}-1\right)\pi_{It}-\mathbb{E}_t\beta_{t,t+1}\left[\left(1-\delta_{t+1}\right)\left(1-\frac{\partial H\left(\tilde{a}_{t+1}\right)}{\partial\tilde{a}_{t+1}}\right)\right.\right. \\
&+ \left.\left.\left(1-\delta_x\right)f\left(\tilde{a}_{t+1}(i)\right)J_{t+1}^R(i)\right]\phi_R\left(\pi_{It+1}-1\right)\pi_{It+1}\right\} \\
\varphi_t &= \frac{P_{It}}{P_t}
\end{aligned}$$

Figure 3: Comparison of the IRFs of the B2B Model With and Without Endogenous Separation Rate to a Technology Shock

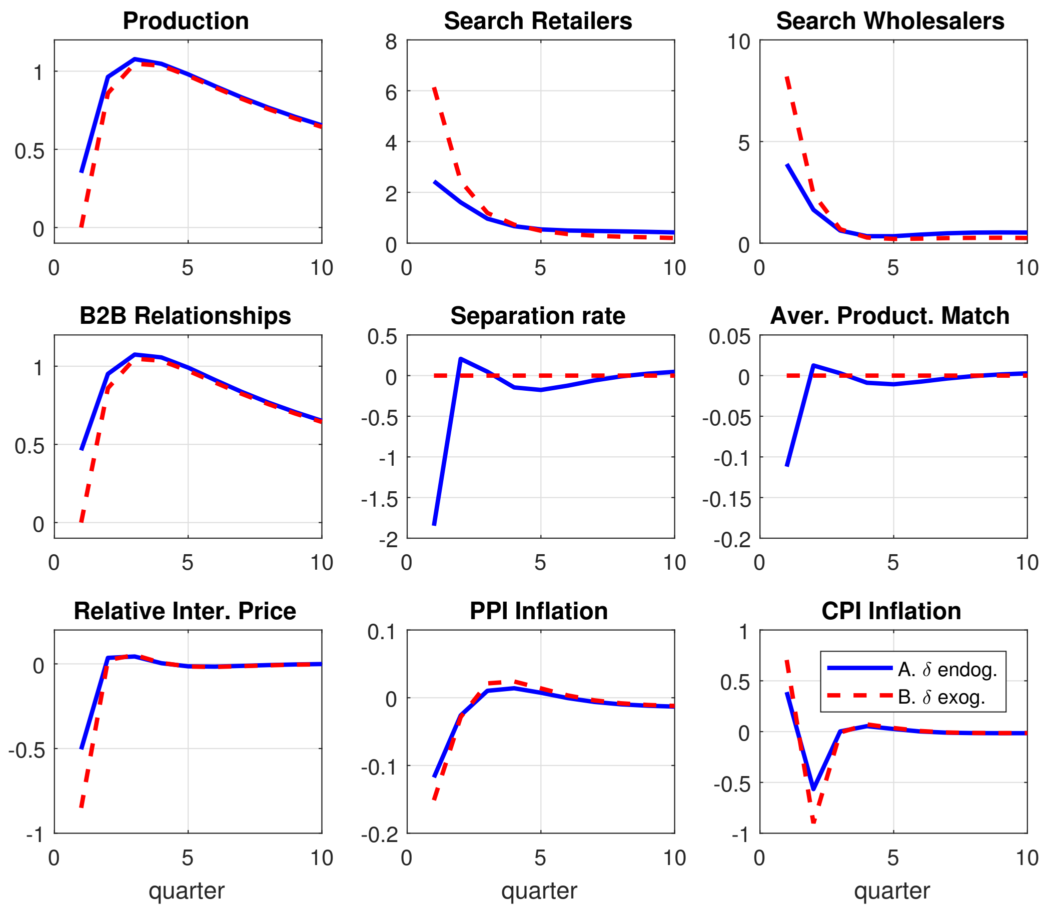

Figure 4: Comparison of the IRFs of the B2B and NK Models to a Technology Shock