

Search and Bargaining in the Product Market and Price Rigidities*

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Abstract

This paper develops a model of pricing dynamics in business to business relationships. The formation of business relationships is a process of search and matching between retailers and wholesalers in the product market. The size of each transaction and the related price are set through bilateral bargaining. There are three key factors that influence the reaction of prices and quantities to cost shocks: the persistence of the shocks, the adjustment of final goods production and the search externalities. These factors determine how firms adjust, whether through the intensive margin, through the extensive margin or through both. Based on this, we assess to what extent wholesale prices affect the allocation of consumption in closed economy and deliver expenditure switching in open economy.

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1 Introduction

Empirical studies document that marginal cost shocks are not fully passed through to prices at the firm level and that prices are substantially less volatile than costs.¹ This is in stark contrast with the monopolistic competition framework usually embedded in macroeconomic models, the one developed by Dixit and Stiglitz (1977), which implies a complete pass-through of costs to prices. Various theories have been proposed to justify the evidence that prices are more stable than costs. For example, recent literature has attributed the low degree of pass-through of exchange rate shocks to prices to either local distribution costs, markup adjustments (due, for instance, to a variable elasticity of demand) or pure nominal rigidities (menu costs).²

In this paper we study to what extent product market frictions, bargaining and search externalities can explain real price rigidity. Our analysis is based on two key assumptions. First, both retail firms and wholesale producers spend resources to engage in new long-term business relationships. Second, once a business relationship is formed, both the wholesale price and the quantity of the good exchanged are bargained between wholesalers and retailers.

There is a vast empirical evidence on the importance of business to business (B2B) long-term relationships and product market imperfections. For example, Blinder et al. (1998) find that 85 percent of the U.S. firms surveyed engage mightily in long-term relationships with their customers and that 77 percent of their customers are other firms. These long-term relationships are mainly governed by contracts, and these contracts typically last for one year.³ As noted by Matha and Pierrard (2011), firms allocate a non-negligible amount of resources in the search for customers or suppliers. In 2006, advertising, marketing and promotion activities in the U.S. amounted to around 600,000 jobs, that is, to almost 0.5 percent of total U.S. employment. A similar amount of people were engaged in purchasing and buying occupations. Moreover, annual expenditures in all media advertising averaged 2.5 percent of U.S. GDP over the last decade.

Empirically, price negotiations between firms seem to be the rule rather than the exception.

¹See, for instance, Hellerstein (2008), for the beer industry, Nakamura and Zerom (2010), for the coffee industry, Goldberg (1995), for the automobile industry, and Kadiyali (1997), for the photographic industry.

²It is also possible that the way the demand elasticity influences the pass-through to prices is a function of the performance of the firm. For example, studying a firm-level dataset of French exporters, Berman, Martin and Mayer (2012) find that the degree of pass-through of exchange rate shocks to export prices depends on the productivity and size of the exporter.

³These findings are corroborated by other studies. See, for instance, Apel et al., 2005 for the case of Sweden.

Zbaracky et al. (2004) find that customer communications and price negotiation costs account for almost 75 percent of the total price adjustment costs and are 20 times as large as the menu costs. According to Fabiani et al. (2006), the firms surveyed by nine Central Banks of the Euro Area report that price rigidity arises mainly as the result of implicit and explicit contracts with their customers. Friberg and Wilander (2008) show that generally exporters and importers negotiate over the invoicing currency of exports.⁴

Nakamura (2008), Gopinath and Itskhoki (2010) and Nakamura and Zerom (2010) all find that delayed pass-through mostly occur at the wholesale level rather than at the retail level. Nakamura (2008) analyses the pass-through of costs to wholesale and retail prices, using a large panel dataset of U.S. retailers. Most of the price variations in the sample arise from retail-level demand and supply shocks rather than manufacturer-level shocks.⁵ Gopinath and Itskhoki (2010) review the closed and open economy empirical literature on real rigidities. A recurrent and consistent finding in this literature is that the variable markup channel of real rigidities is far less important for retail prices than for wholesale prices.⁶ Nakamura and Zerom (2010) study the pass-through of commodity price shocks in the coffee industry. They find that both for wholesale and retail prices, a 1 percent increase in coffee commodity costs leads to about 0.3 percent increase in prices over the subsequent 6 quarters. To use Nakamura and Zerom’s own words, “it is wholesale price rigidity that matters,” so “studies that focus exclusively on retail prices may be incomplete in an important way.”⁷

Motivated by all this evidence, we theoretically investigate the implications of long-term relationships and bargaining for the response of prices and quantities to cost shocks. As in Drozd and Nosal (2012) and Matha and Pierrard (2011), we model the formation of a B2B relationship as a process of search and matching in the product market. If wholesalers invest resources (marketing, advertising and sale managers) to find new customers, retailers make an effort (e.g., their agents engage in negotiations) to conclude new business relationships with the

⁴Moreover, Goldberg and Tille (2009) find that larger transactions are very often invoiced in the importers’ currency. They show that this finding is consistent with a model where the invoicing currency is set by bargaining between exporters and importers.

⁵Specifically, the main determinant of the price variations is temporary sales.

⁶After reviewing the literature, Gopinath and Itskhoki (2010) use unpublished international price data and exchange rate shocks to evaluate the importance of real rigidities in price setting. They show that the pass-through of import prices to exchange rate shocks, even conditionally on changing, is very low and delayed. This suggests the presence of important real rigidities in the wholesale sector.

⁷Nakamura and Zerom (2010), p. 1193.

wholesalers. The resulting B2B relationships lead to contracts for the exchange of intermediate goods, and the volume of the trade depends on two margins of adjustment: an extensive margin (the number of customers) and an intensive margin (the quantity exchanged in each match). The search costs govern the extensive margin of adjustment and generate a surplus within each match. Retailers and wholesalers bargain over this surplus, setting wholesale prices and quantities in accordance with their relative bargaining power.

Our analysis highlights that wholesale prices and retail prices play different roles in industry dynamics. Wholesale prices have to do mainly with the distribution of the rents between the two parties in a contract, whereas retail prices are a reflection of the costs of rapidly adjusting marketing and distribution infrastructures for the sale of final goods. Specifically, studying the response of variables to marginal costs shocks, we find that the pass-through to wholesale and retail prices depends on: the persistence of the shock, the elasticity of the demand of retailers for wholesale goods along the intensive margin, and the bargaining power of retailers.

The persistence of cost shocks determines the incentives for firms to invest in new business relationships. After a cost shock, firms can increase production either by increasing the trade per match, by forming new business relationships or by partially adjusting along both margins. But, due to search costs, setting up new B2B relationships is a difficult task. In the model, firms find this option convenient only if the cost shock is persistent enough. Otherwise, firms tend to adjust only along the intensive margin. The cost of the adjustment along the intensive margin is thus the foremost factor of the pass-through if the cost shock is transitory.

The sensitivity of both wholesale prices and retail prices to cost shocks depends on retailers' bargaining power. While the pass-through to wholesale prices is forcefully increasing in retailers' bargaining power, the pass-through to retail prices is non-monotonically and weakly related to the bargaining power. The reason for this non-monotonic and weak effect is that the bargaining power affects the distribution of the rents between wholesalers and retailers but not the reaction of consumer prices to cost shocks.

The repeated nature of the interactions between firms points towards an intriguing issue: observed wholesale prices may not be allocative, in the sense that they may not affect the retail prices faced by consumers nor their consumption decisions. This issue is very relevant, especially in light of the recent empirical evidence, which suggests that nominal price stickiness

arises mainly at the wholesale rather than at the retail level. In fact, as recognized at least since Barro (1977), the stabilizing role of monetary policy when prices are sticky depends crucially on prices being allocative. The B2B model provides a natural laboratory to address this issue.

We show that wholesale prices have no direct influence on the intensive margin of trade, but affect the value of business relationships and thus the incentive to engage in search activities. For this reason, the allocative power of wholesale prices depends on the perceived persistence of the price change, and on the efficiency of the matching process. The allocative power is large and persistent if changes in wholesale prices are long-lasting and search externalities are substantial. But in all other cases wholesale prices have a rather small allocative power, much smaller than what the standard Dixit-Stiglitz monopolistic competition model implies.

The limited allocative power of intermediate goods prices has very interesting implications for trade in open economy, where B2B relationships and bargaining are pervasive (Gopinath and Rigobon, 2008). The empirical literature has largely analyzed the degree of exchange rate pass-through (ERPT) to import prices, often to quantify the expenditure switching effect of changes in the exchange rate.⁸ The expenditure switching channel implicitly assumes that a shock to the exchange rate affects the consumption of imported goods only to the extent that it translates into the variability of import prices. This can be true only if prices are allocative.

To address this issue, in the last part of the paper we present a simple open economy extension of our model. In the extended model, domestic wholesalers need to establish customer relationships with both local retailers and foreign retailers. We find that, even in situations in which the allocative power of wholesale prices is low, exchange rate shocks maintain a significant expenditure switching effect. In fact, exchange rate changes affect the total surplus of international transactions and, consequently, have direct effect on the intensive margin of trade. This is independent of the reaction of the bargained price, so that the overall amount of expenditure switching is more a function of the costs of adjusting trade along the extensive and intensive margins than of the ERPT to border (wholesale) prices. We conclude that focusing only on the degree of ERPT to measure the expenditure switching effect of exchange rate shocks can be misleading for industries where long-term relationships and bargaining are widespread.

⁸See Burstein and Gopinath (2013) for an extensive discussion of various theories and empirical findings on the relation between exchange rates and prices.

Our work is related to a growing literature that investigates the role of long-term relationships for price and business cycle dynamics.⁹ Most of these works focus on the relationship between a final consumer and a firm, not between two firms. This is conceptually important, for bargaining between firms is arguably more realistic than bargaining between a firm and a consumer.

Our paper builds on Drozd and Nosal (2012) and Matha and Pierrard (2011). Both of these works extend macroeconomic frameworks to include search frictions in the product market. Drozd and Nosal (2012) do so in an international business cycle model, to explain the deviation of the prices of internationally traded goods from the law of one price. Matha and Pierrard (2011) provide some evidence on the relevance of B2B relationships and introduce them in the model by King and Rebelo (1999), to study the effect on standard real business cycle dynamics. Our work differs from theirs in two important dimensions. First, we focus on industry dynamics. This approach is useful to identify the principal industry-level determinants of incomplete pass-through and can be easily related to the empirical literature on pass-through. Second, we address a different question. We carefully study how the intensive margin of adjustment affects the pass-through of cost shocks to prices, and then analyze the role played by wholesale prices in the adjustment of quantities to marginal cost shocks and exchange rate shocks.

Finally, our paper is close, in spirit, to Gopinath and Itskhoki (2010), who develop a static bargaining model between one final good producer and a number of intermediate good suppliers. This model is used as a micro-foundation for a quantitative analysis with variable markups at the wholesale level but constant markups at the retail level. Our paper shares with Gopinath and Itskhoki (2010) the idea that introducing negotiations between firms is key to understand pricing dynamics, but differs in many important aspects. Most prominently, our model is dynamic and takes into account the need for firms to invest in building new long-term relationships.

The rest of the paper is structured as follows. In Section 2 we derive the benchmark closed-economy model. In Section 3 we examine the effects of cost shocks on industry dynamics and the pass-through to wholesale and retail prices. Based on these findings, Section 4 focuses on the role of trading frictions and bargaining and on the allocative power of wholesale prices. Section 5 is devoted to the open economy extension, and Section 6 concludes.

⁹To cite a few, recent works include Hall (2008), Arseneau and Chugh (2007), Kleshchelski and Vincent (2009), Ravn et al. (2010), Michaillat and Saez (2013) and den Haan (2013).

2 Model

Let us consider a generic industry where wholesale firms produce intermediate goods. Retailers transform these products in final consumption goods and sell them to households. Retailers are perfectly competitive firms, but the interaction between retailers and wholesalers is subject to trade frictions. Both types of firms need to search in order to find a party to make deals with, and contracts are signed after bilateral bargaining. The search and matching scheme is the Diamond-Mortensen-Pissarides search model.

2.1 Demand for Retail Goods

The economy is composed of a continuum of sectors (or industries), each producing a specific good. The demand for the good produced in industry i is given by

$$c_t^i = \left(\frac{p_t^i}{P_t} \right)^{-\phi} C_t$$

where $\phi > 0$ is the elasticity of substitution between good i and the good produced in any other industry. P_t and C_t , respectively, denote the aggregate price and consumption levels. Since we focus on industry dynamics, we follow Ravn et al. (2010) and take P_t and C_t as given. This simplifies the demand function for good i to

$$c_t^i = A (p_t^i)^{-\phi} \tag{1}$$

where A is a positive constant.

In industry i , retail firms sell different brands of the same good. But, differently from the case of goods across industries, we assume that brands (within each industry) are perfectly substitutable. We borrow this assumption from Kleshchelski and Vincent (2009). Consistently with our focus on a generic industry, we drop the industry-specific index i from the rest of the paper.

2.2 Search and Matching

Trade of intermediate products within the industry is the result of long-term relationships between firms. At time t , the total number of existing B2B relationships, T_t , is given by the following law of motion:

$$T_{t+1} = (1 - \delta) (T_t + M_t)$$

where δ is the exogenous rate at which business relationships are destroyed and M_t is the number of new B2B relationships. T_t is a state of the product market, for it usually takes time (one month, under our calibration) to establish a business relationship, and this is meant to last for a long time before ending (stochastically).

M_t is a constant return to scale aggregator of retailers' search effort d_t (e.g., purchase managers' effort) and wholesalers' search effort a_t (advertising and marketing):

$$M_t = \tilde{m} a_t^\xi d_t^{1-\xi}$$

where $\tilde{m} > 0$ and $\xi \in (0, 1)$ is the elasticity of the matching function with respect to the wholesalers. The rate at which a retailer can start a new relationship with a wholesaler is $k^R(\theta_t) = M_t/d_t = \tilde{m}\theta_t^\xi$, where $\theta_t \equiv a_t/d_t$ is the *product market tightness* of the industry—the ratio of advertisement effort per purchasing effort. For a wholesaler, the probability of being successfully matched with a retailer is instead $k^a(\theta_t) = M_t/a_t = \tilde{m}(\theta_t)^{-(1-\xi)}$.

Within each match, retailers purchase q_t units of intermediate inputs, so the overall trade volume in the market comprises both an extensive margin (given by T_t) and an intensive margin (given by q_t).

2.3 Wholesale Firms

There is a continuum of wholesale firms, each indexed by $j \in [0, 1]$. Each wholesaler expends resources and time to find buyers for its products; these search costs are convex in the search intensity of the wholesaler $x_{wt}(j) = a_t(j)/T_t(j)$ and given by:

$$\frac{\gamma}{2} (x_{wt}(j))^2 T_t(j),$$

where $\gamma > 0$. Modelling the search cost in terms of the search intensity has a great advantage for our purpose here. It shuts down the so-called intrafirm bargaining—a feature we are not interested in—because the bargained price is going to be independent of the number of B2B relationships.¹⁰

Therefore, the profits of wholesaler j are the profits from sales net of the search costs:

$$\pi_{wt}(j) = (p_{Wt}(j) - mc_t) q_t(j) T_t(j) - \frac{\gamma}{2} (x_{wt}(j))^2 T_t(j), \quad (2)$$

where $p_{Wt}(j)$ is the price of each intermediate good variety and mc_t is the corresponding marginal cost. We assume that the marginal cost is exogenous and independent of scale. A shock to mc_t is an industry-level shock. The objective of the wholesaler is thus to choose the level of search effort and the number of relationships that maximize current and future profits:

$$\begin{aligned} v_w(T_t(j), mc_t) &= \max_{a_t(j), T_{t+1}(j)} \{ \pi_{wt}(j) + \beta \mathbb{E}_t v_w(T_{t+1}(j), mc_{t+1}) \} \\ \text{s.t. } T_{t+1}(j) &= (1 - \delta) (T_t(j) + a_t(j) k^a(\theta_t)) \end{aligned} \quad (3)$$

and for a given initial condition $T_0(j) > 0$; $\beta \in (0, 1)$ is a constant discount factor.¹¹ The wholesaler solves this problem by taking the number of matches per unit of effort $k^a(\theta_t)$ as given, while $p_{Wt}(j)$ and $q_t(j)$ are decided after the successful match with retailers.

The solution to the maximization problem gives the following first order conditions:

$$\gamma \frac{x_{wt}(j)}{k^a(\theta_t)} = \beta (1 - \delta) \mathbb{E}_t W_{t+1}(j) \quad (4)$$

$$W_t(j) = (p_{Wt}(j) - mc_t) q_t(j) + \frac{\gamma}{2} (x_{wt}(j))^2 + \beta (1 - \delta) \mathbb{E}_t W_{t+1}(j) \quad (5)$$

where $W_t(j) \equiv \partial v_w(T_t(j), mc_t) / \partial T_t(j)$ denotes the marginal value of business relationships to the j -th wholesaler. The first condition equates the expected search cost of an additional match (the left hand side) to its expected benefit. In the second condition, $W_t(j)$ is the sum of three elements: the total profit from established relationships, the savings in the costs of establishing

¹⁰This specification of the search cost is a simplification of the bargaining problem, which has been used in the labor search literature by Gertler and Trigari (2009) and Thomas (2008) for the same purpose of abstracting from intrafirm bargaining.

¹¹In a full-fledged general equilibrium model, the discount factor of the firm would be an endogenous variable given by the representative household's intertemporal marginal rate of substitution. See also Ravn et al. (2010).

new matches, $\gamma (x_{wt}(j))^2 / 2$, and the expected future value of the relationships.

Note that, because of the search frictions, wholesalers' profit maximization is not a static problem but an intertemporal choice. To see this even more clearly, combine equations (4) – (5), which yields:

$$\gamma \frac{x_{wt}(j)}{k^a(\theta_t)} = \beta(1 - \delta) \mathbb{E}_t \left[(p_{Wt+1}(j) - mc_{t+1}) q_{t+1}(j) + \frac{\gamma}{2} (x_{wt+1}(j))^2 + \gamma \frac{x_{wt+1}(j)}{k^a(\theta_{t+1})} \right].$$

That is, it is optimal to search for buyers insofar as the search costs—relative to the probability of a successful match—equal all the future expected benefits from the long-term relationships that can be formed.

2.4 Retail Firms

There are an infinite number of retailers intermediating between wholesale producers and final consumers; retailers are indexed by $r \in [0, 1]$. As any wholesaler, the r -th retailer chooses how much to invest in the formation of new business relationships, and this is captured by the search rate $x_{Rt}(r) = d_t(r) / T_t(r)$. The search cost is convex in this search rate:

$$\frac{\gamma}{2} (x_{Rt}(r))^2 T_t(r).$$

Once matched with wholesalers, each retailer r has a technology that transforms wholesale goods into retail goods. Importantly, we need to introduce a cost of adjusting the quantity of inputs purchased within each match; this is crucial for firms to be willing to invest in B2B relationships. If changing $q_t(r)$ were costless, firms would find it optimal to have few matches (thus minimizing the search costs) and satisfy changes in demand with changes in $q_t(r)$. This would go against the essence of our model, the idea being that firms *must* engage in search and matching to expand their production, and would make the problem not well-defined.

To address this aspect, we introduce costs in changing the quantity sold per match through the production function of retailers. Specifically, we assume that, for each match k , retailers have a technology that transforms $q_t(k)$ units of the wholesale good into $(q_t(k) - \omega_t(k))$ units of retail goods. The term $\omega_t(k) = \frac{\psi}{2} (q_t(k) - \bar{q})^2$ is an adjustment cost in the units bought

per match. Intuitively, \bar{q} is the quantity per match that maximizes the technical efficiency of the production process of retailers. Deviations from this optimal amount decrease the marginal productivity of the intermediate good variety. The total production of retailer r is thus given by:¹²

$$y_t(r) = \int_0^{T_t(r)} (q_t(k) - \omega_t(k)) dk = (q_t(r) - \omega_t(r)) T_t(r) \quad (6)$$

where we have imposed symmetry among the matches. This production function has three main attractive features. First, it displays diminishing returns to q_t for (both upwards and downwards) deviations from the technically optimal level \bar{q} . Second, it introduces an incentive for retailers to buy from different wholesalers (similar to a love for varieties). Third and most importantly, it is very flexible, in that it includes both the linear case and the extensive-margin-only case as special cases. More precisely, for $\psi \rightarrow 0$, the production function is linear in $q_t(k)$ and retailers can adjust their production on the intensive margin very easily. For $\psi \rightarrow \infty$, $q_t(k) = \bar{q}$ at any time t : the intensive margin is closed, and firms can adjust production only by establishing new business relationships.

Given (6), the profit function of the retailer is

$$\pi_{Rt}(r) = p_t y_t(r) - p_{Wt}(r) q_t(r) T_t(r) - \frac{\gamma}{2} (x_{Rt}(r))^2 T_t(r), \quad (7)$$

where p_t is the price at which the price-taking retailer sells goods to final consumers. Therefore, taking the matching probability k_t^R as given, retailer r solves the following problem:

$$\begin{aligned} v_R(T_t(r), mc_t) &= \max_{d_t(r), T_{t+1}(r)} \{ \pi_{Rt}(r) + \beta \mathbb{E}_t v_R(T_{t+1}(r), mc_{t+1}) \} \\ \text{s.t. } T_{t+1}(r) &= (1 - \delta) (T_t(r) + d_t(r) k_t^R(\theta_t)) \end{aligned} \quad (8)$$

¹²A natural alternative would be to endogenize the intensive margin by assuming that each retailer buys differentiated goods from a range of wholesalers and has a ‘love of variety’ motive (common in the trade literature) that leads him to value buying from many wholesalers in itself. The production function of retailers would be:

$$y_t(r) = \left[\int_0^{T_t(r)} q_t^\rho(k) dk \right]^{1/\rho}$$

with $\rho < 1$. The main reason why we chose a different specification is that the production function (6) is more flexible, since it nests both the linear case ($\psi \rightarrow 0$) and the extensive-margin-only case ($\psi \rightarrow \infty$) as special cases. This allows us to analyze more neatly the role of the intensive margin of trade adjustment for the cost pass-through.

and for a given initial condition $T_0(r) > 0$.

The optimal solution is given by:

$$\gamma \frac{x_{Rt}(r)}{k_t^R} = \beta(1 - \delta) \mathbb{E}_t J_{t+1}(r) \quad (9)$$

$$J_t(r) = p_t(q_t(r) - \omega_t(r)) - p_{Wt}(r)q_t(r) + \frac{\gamma}{2}(x_{Rt}(r))^2 + \beta(1 - \delta) \mathbb{E}_t J_{t+1}(r) \quad (10)$$

where $J_t(r) \equiv \partial v_R(T_t(r), mc_t) / \partial T_t(r)$. The first condition equates the expected search costs of an additional match (the left hand side) to its expected benefit, given by the expected value of a business relationship for a retailer. The second equation determines the marginal value of a business relationship to the retailer as the sum of: the gross profits from an established relationship $p_t(q_t(r) - \omega_t(r)) - p_{Wt}(r)q_t(r)$, the savings in the costs of establishing a B2B relationship, and the expected continuation value.

2.5 Bargaining

The presence of a surplus associated with existing long-term relationships implies that there are many combinations of wholesale prices and quantities consistent with the equilibrium (Hall, 2005; 2008). Existing B2B relationships are privately efficient as long as they generate a positive surplus for both the parties involved in the bargaining. Therefore, any price path such that $W_t(j) \geq 0$ and $J_t(r) \geq 0 \forall t$ can be an equilibrium path. Interestingly, as emphasized by Hall (2007), this opens the way for equilibrium sticky prices in customer markets.¹³

In line with the labor market literature, the solution to this issue is the surplus sharing solution of a Nash (1950) bargaining problem.¹⁴ Wholesaler and retailer of a bilateral contract find a joint solution for the price and quantity of a transaction, so to maximize the Nash product $S_t(j, r)$:

$$S_t(j, r) = \left[(W_t(j))^{1-\eta} (J_t(r))^\eta \right]$$

where $\eta \in [0, 1]$ is the bargaining power of retailers. The solution with respect to the wholesale

¹³See also Blanchard and Galí (2010) for a similar argument in the context of a labor search model. Arseneau and Chugh (2007) exploit this insight and analyze the implications of different pricing schemes on the price dynamics in a model with consumer search.

¹⁴See also Matha and Pierrard (2011) and Drozd and Nosal (2012).

price gives an optimal sharing rule

$$\eta W_t(j) = (1 - \eta) J_t(r), \quad (11)$$

which implies:

$$p_{W_t}(j, r) = \eta [mc_t - \Omega_{W_t}(j, r)] + (1 - \eta) \left[p_t \left(1 - \frac{\omega_t(j, r)}{q_t(j, r)} \right) + \Omega_{R_t}(j, r) \right] \quad (12)$$

where $\Omega_{W_t}(j, r) = \frac{\gamma}{2} \frac{(x_{wt}(j))^2}{q_t(j, r)}$ and $\Omega_{R_t}(j, r) = \frac{\gamma}{2} \frac{(x_{Rt}(r))^2}{q_t(j, r)}$ are the savings in the costs of forming B2B relationships—per unit of trade—for wholesalers and retailers, respectively.

The wholesale price is an average of two terms, weighted by the bargaining power of the contracting parties. The two terms express not only the costs of production, but also the valuation of retailers. The first term, $mc_t - \Omega_{W_t}(j, r)$, represents the minimum amount that wholesalers are willing to accept. This depends on marginal costs and on the savings in the cost of forming another business relationship. The second term, $p_t \left(1 - \frac{\omega_t(j, r)}{q_t(j, r)} \right) + \Omega_{R_t}(j, r)$, represents the maximum price that retailers are willing to pay, which is the sum of retailers' marginal revenues and of retailers' savings in the costs of establishing another B2B relationship. The bargaining power η determines which party gets the most of the surplus.

The optimal sharing rule (11) also implies:

$$\eta \frac{\gamma}{k^a(\theta_t)} x_{wt}(j) = (1 - \eta) \frac{\gamma}{k^R(\theta_t)} x_{Rt}(r)$$

Aggregating across all firms and taking log-deviations, this gives:

$$\hat{a}_t = \hat{d}_t \quad \text{and} \quad \hat{\theta}_t = 0$$

This means that the similarity between the search problem of wholesalers and that of retailers implies a one-to-one relationship between changes in retailers' search effort (\hat{d}_t) and in wholesalers' effort (\hat{a}_t). As a consequence, the product market tightness $\hat{\theta}_t$ is invariant to marginal cost shocks. But, note, it is not invariant to other innovations that we explore later on in the

paper.¹⁵

While the bargained price is set in a way to split the surplus between the two parties in proportion to their bargaining power, wholesalers and retailers choose $q_t(j, r)$ in a way to maximize the total surplus from a long term relationship. Specifically, the solution of the maximization problem with respect to quantities gives:

$$p_t \psi (q_t(j, r) - \bar{q}) = p_t - mc_t \quad (13)$$

Thus, the marginal benefit of an additional unit sold in the retail market—given by the total profit margin $p_t - mc_t$ —needs to be equal to the marginal cost of increasing the quantity per match $q_t(j, r)$ above \bar{q} . This cost is larger, the higher the adjustment cost parameter ψ .

To get further intuition, we can rewrite (13) as:

$$q_t(j, r) = \bar{q} + \frac{1}{\psi} \left(\frac{\mu_t^{tot}(j, r) - 1}{\mu_t^{tot}(j, r)} \right) \quad (14)$$

where $\mu_t^{tot}(j, r) = \frac{p_t}{mc_t}$ is the total gross mark-up of retail prices over marginal costs. The volume of trade per match is an increasing function of the total profit margin of retailers and wholesalers. More importantly, note that the units traded in each match depend directly on the final retail price p_t but are set independently of the wholesale price p_{Wt} ; in fact, p_{Wt} does not enter equation (14). This questions the role played by wholesale prices in the adjustment of trade to cost shocks.

2.6 Aggregation and Equilibrium

Industry level relations are found by aggregating across all retailers r and wholesalers j under the assumption of complete symmetry across firms. For instance, the aggregate consumption of the final good of industry i is:

$$c_t = \left[\int_0^1 c_t(r) dr \right] = A(p_t)^{-\phi} = y_t = \left[\int_0^1 y_t(r) dr \right]$$

¹⁵Specifically, the bargaining power shock we study in Section 5 will break the tight link between \hat{d}_t and \hat{a}_t .

All other equations are identical to the individual firm’s case and are therefore not repeated here.

In the symmetric equilibrium all retailers start off with the same number of suppliers, and all wholesalers have similarly the same number of buyers. That is, $T_0(j) = T_0(r) = T_0 \forall j, r$. And since firms are identical on each side of the market, also the initial bargained price and quantity are the same across all the pairs (j, r) : $p_{W0}(j, r) = p_{W0}$ and $q_0(j, r) = q_0$.

2.7 Search Externalities and Constrained Efficient Allocation

In a decentralized equilibrium, wholesalers and retailers decide their search intensity taking the rates at which additional effort leads to a new match, $k^a(\theta_t)$ and $k^R(\theta_t)$, as given. This way each firm chooses its optimal level of search without internalizing the effect of its decision on other firms. Summing up across firms, this may lead to suboptimal choices at the aggregate level. The constrained efficient allocation can be found as the solution of the problem of a benevolent social planner who faces the same technological constraints and search frictions that are present in the decentralized equilibrium.¹⁶

Proposition 1 *The decentralized equilibrium is constrained efficient only if the Hosios condition $\eta = 1 - \xi$ holds.*

Proof. Appendix A. ■

Proposition 1 requires that social and private gains from participating in a matching process are equal, as retailers’ bargaining power η equals the elasticity of the matching function with respect to retailers’ search $1 - \xi$. Otherwise, either retailers’ private gains ($\eta > 1 - \xi$) or wholesalers’ private gains ($\eta < 1 - \xi$) are larger than their respective social gains.

2.8 Calibration and Steady State

The model is calibrated at the monthly frequency. The discount rate β is 0.996. Following in Ravn et al. (2010), the elasticity of substitution ϕ across industries takes the standard value of 6. We set $\psi = 1$, as a baseline value for the size of the adjustment costs along the intensive

¹⁶To derive the constrained efficient allocation in a partial equilibrium setup, we follow Hosios (1990). See also Matha and Pierrard (2011) for a similar analysis in a general equilibrium setting.

margin. The elasticity of the matching function to wholesalers' marketing effort, ξ , and the bargaining power of retailers, η , are both equal to 0.5. This implies that there is complete symmetry between wholesalers and retailers and that the Hosios condition holds. The efficiency of the matching technology \tilde{m} is chosen so that, in steady state, the monthly rate at which search effort leads to new business relationships is $k^a(\theta) = k^R(\theta) = 0.2$. This rate is approximately the monthly equivalent of the quarterly rate of 0.5 used by Matha and Pierrard (2011). We use a similar strategy for the separation rate δ . We set it to 0.10, which is slightly higher than the monthly equivalent of the quarterly rate of 0.25 in Matha and Pierrard (2011).

The total markup of retail prices over marginal costs from equation (14) is an endogenous variable in the model. In the long run, this markup is increasing in both retailers' and wholesalers' search costs:

$$\mu^{tot} = \frac{q}{(q - \omega)} + \frac{\gamma}{mc(q - \omega)} \left[\tilde{b} \left(\frac{x_w}{k^a} + \frac{x_R}{k^R} \right) - \left(\frac{x_w^2}{2} + \frac{x_R^2}{2} \right) \right]$$

where $\tilde{b} = \frac{1-(1-\delta)\beta}{\beta(1-\delta)}$. The first term shows that the markup is above 1 so long as q differs from the optimal value \bar{q} ($\bar{q} = 1$ by normalization), that is, so long as there is a positive cost of transforming intermediate goods into final goods, ω . The second term shows that μ^{tot} is even larger if $\tilde{b} \left(\frac{x_w}{k^a} + \frac{x_R}{k^R} \right) - \left(\frac{x_w^2}{2} + \frac{x_R^2}{2} \right) > 0$, which is true for reasonable values of the search costs. We assume a long-run total markup of 1.10, and this implies a search effort parameter $\gamma = 0.3457$.

Properties of the steady state. The steady state depends crucially on two parameters: ψ , the curvature of the demand of retailers for the variety produced by each wholesaler, and η , retailers' relative bargaining power. We analyze the sensitivity of the steady state to these two parameters, keeping γ fixed and letting μ^{tot} change along with other key variables. The results are in Table 1.

To start with, consider the impact of the adjustment costs along the intensive margin. If $\psi = 100000$, the intensive margin is closed: $q = \bar{q} = 1$ and the total markup of retail prices over marginal costs is 1.105. With a lower ψ ($\psi = 1$), the model displays both intensive and extensive margins of adjustment. Firms optimally trade-off the costs of increasing production along the extensive margin (search and matching costs) with the costs of increasing production along the intensive margin. The steady state stock of business relationships decreases, whereas the

quantity sold per match increases to $q = 1.091 > \bar{q}$. The higher q depresses prices and markups, which are now (slightly) smaller than before. This result is even stronger if we continue to lower ψ , as firms progressively lose the incentive to engage in B2B relationships. For $\psi = 0.00001$, firms find it optimal to have very few matches ($T = 0.007$) and satisfy changes in demand by adjusting q ($q = 144.50$). Prices and markups are now both close to 1. Thus, this numerical exercise confirms that there should be frictions along the intensive margin for firms to be willing to invest in building B2B relationships.

Consider now the role of the bargaining power of retailers. In the baseline calibration ($\eta = 0.5$), the number of B2B relationships is relatively high, and the total markup on a final product is around 1.10. Intuitively, since buyers and sellers have the same bargaining power, they make the same search effort and the product market is very fluid ($\theta = \frac{a}{d} = 1$). This facilitates the formation of new matches. Indeed, since $\xi = 0.5$, the steady state satisfies the Hosios condition and the matching process is Pareto efficient. But an industry displaying a η different from $1 - \xi = 0.5$ is generally characterized by a lower stock of B2B relationships, a higher quantity exchanged per match and total markup, and search externalities. It is precisely the presence of inefficiencies in the matching process that leads to the higher μ^{tot} .

When wholesalers have a very high bargaining power ($\eta = 0.1$), they seize the most of the surplus from a business relationship and their private gains are larger than the socially optimal level. As a consequence, they overinvest in advertising and marketing activities, while retailers have very little interest in searching. In this case, the product market is very ‘tight’ from the point of view of wholesalers ($\theta = 3$), and the process of matching becomes sclerotic (the steady state number of B2B relationships drops). Something similar happens when retailers have most of the bargaining power ($\eta = 0.9$), though this time it is retailers that enjoy private benefits and overinvest. In fact, given the assumption of complete symmetry in the search problem of retailers and wholesalers, upward and downward deviations of equal size from $\eta = 0.5$ have the same effects on T and p . The main difference lies in the evolution of the wholesale price p_W . When η is high, p_W is low and most of the profits go to retailers; when η is low, p_W is high and wholesalers get most of the rents.

3 Cost Shocks: Industry Dynamics and Pass-Through

The pass-through of marginal cost shocks is complete if a 1 percent increase in marginal costs leads to a 1 percent increase in prices; otherwise, prices increase by less than marginal costs and the pass-through is incomplete. To determine the degree of pass-through in our model, we look at the reaction of wholesale and retail prices to innovations in the marginal costs of wholesalers. We assume that the marginal cost shock is industry-specific and follows an $AR(1)$ process:

$$\widehat{mc}_t = \lambda \widehat{mc}_{t-1} + \varepsilon_t \quad (15)$$

where variables with a ‘hat’ denote log deviations from steady state, $\lambda \in [0, 1)$ is the serial correlation of marginal costs and ε_t is an i.i.d. shock.¹⁷ Note that, since firms are symmetric, we omit firm-specific indexes from now on.

We proceed in two steps. We start with the case of purely transitory cost shocks, when the model has a simple analytical solution, and then pass to the case of persistent cost shocks.

3.1 Transitory Cost Shocks

The analytical solution of the model with transitory marginal costs shocks ($\lambda = 0$) is summarized by the following proposition.

Proposition 2 *If marginal cost shocks \widehat{mc}_t are transitory, i.e. if $\lambda = 0$, the solution of the model is:*

$$\hat{T}_t = 0 \quad \hat{q}_t = -B_q \widehat{mc}_t \quad \hat{y}_t = \hat{T}_t + \kappa \hat{q}_t \quad \hat{p}_t = -\frac{1}{\phi} \hat{y}_t$$

implying that the wholesale price equals

$$\hat{p}_{Wt} = \left[\eta \frac{mc}{p_W} + (1 - \eta) \frac{p(q - \omega)}{p_W q} \frac{\kappa}{\phi} B_q + A_q B_q \right] \widehat{mc}_t$$

with $B_q = \frac{1}{\psi \mu^{tot} q + \frac{\kappa}{\phi}}$, $\kappa = \frac{q}{q - \omega} [1 - \psi(q - \bar{q})]$, $A_q = \left[(1 - \kappa)(1 - \eta) \frac{p(q - \omega)}{p_W q} + (1 - \eta) \frac{\Omega_R}{p_W} - \eta \frac{\Omega_W}{p_W} \right] \in [0, 1)$. B_q is the elasticity of \hat{q}_t to changes in the total profit margin, κ captures the increase in retailers’ production due to an increase in \hat{q}_t and A_q represents the elasticity of the wholesale

¹⁷Our strategy follows Ravn et al. (2010).

price to changes in \hat{q}_t .¹⁸

Proof. Appendix B. ■

Put it differently, this proposition indicates that firms do not have incentives to adjust along the extensive margin when the shock is expected to die out immediately in the near future, and the problem becomes static (i.e. $\hat{x}_{wt} = \hat{x}_{Rt} = \hat{T}_t = 0$). In this case, the response of retail quantities and prices depends on the adjustment costs along the intensive margin. The lower the adjustment cost ψ , the easier it is for retailers to adjust their production and distribution structure. In turn, a strong reduction in the production of retail goods increases retail prices by a factor linked to ϕ , the elasticity of the demand for the good produced in the industry. Ceteris paribus, the lower ϕ , the higher the pass-through to retail prices. The pass-through to retail prices is complete only if the adjustment along the intensive margin is entirely frictionless (i.e. for $\psi \rightarrow 0$); otherwise, it is incomplete.

Wholesale prices are affected by three channels. First, there is the direct ‘marginal cost channel,’ the term $\eta \frac{mc}{p_W}$ in the proposition above. This term captures the direct influence of the marginal costs of wholesalers on the bargained price and increases with the bargaining power of retailers. The second channel is related to retailers’ reservation price and is given by $(1 - \eta) \frac{p(q-\omega)}{p_W q} \frac{\kappa}{\phi} B_q$. This term is larger, the more retail prices react to cost shocks or the higher the bargaining power of wholesalers. The final term, $A_q B_q$, is the ‘bargained quantity effect.’ That is, wholesalers are willing to ask for a lower price insofar as retailers are willing to buy more units of the intermediate good. For instance, an increase in marginal costs provokes a reduction in \hat{q}_t , and this—through the ‘bargained quantity effect’—translates into a higher wholesale price \hat{p}_{Wt} . This effect is stronger, the lower are ψ and η .

Corollary 3 When $\lambda = 0$:

- (i) the pass-through to retail prices converges to 1 for $\psi \rightarrow 0$.
- (ii) the pass-through to wholesale prices converges to 1 when one of the following conditions is met: 1) $\psi \rightarrow 0$; 2) $\eta \rightarrow 1$.
- (iii) wholesale prices only play a distributive role, not an allocative one.

¹⁸ B_q is decreasing in ψ and increasing in ϕ and $B_q \rightarrow 0$ if $\psi \rightarrow \infty$. A_q is decreasing in ψ and η and converges to 0 for $\psi \rightarrow \infty$ and for $\eta \rightarrow 1$. κ is decreasing in ψ and $\kappa \rightarrow 1$ for $\psi \rightarrow 0$.

The second point of this corollary is a combined effect of the three channels driving \hat{p}_{Wt} . The last result—that wholesale prices do not have an allocative role—is instead a consequence of the fact that the dynamics of the price and quantity of retail goods is independent of wholesale prices: $\hat{p}_t = -\frac{\kappa}{\phi}\hat{q}_t$ and $\hat{y}_t = \kappa\hat{q}_t$. Thus, in case of one-time cost shocks, the only role of wholesale prices concerns the distribution of the rents between wholesalers and retailers.

An interesting special case is when retailers face prohibitively high production adjustment costs (i.e., for $\psi \rightarrow \infty$). In this case, intermediate trade takes place only along the extensive margin of adjustment. So, after a purely transitory cost shock, there is *zero* pass-through to retail prices, and the pass-through to wholesale prices is proportional to the bargaining power of retailers η :

$$\begin{aligned}\hat{p}_t &= 0 \\ \hat{p}_{Wt} &= \eta \frac{mc}{p_W} \widehat{mc}_t\end{aligned}$$

The zero pass-through result stems directly from the search frictions. On the one hand, firms can only increase production by forming new business relationships, so output becomes a state variable; it can only adjust with one month delay. On the other hand, since the demand function implies a one-to-one relationship between consumption and prices, the matching frictions impede the reaction of both consumption and retail prices. But, at the same time, firms have no incentive to either create or destroy B2B relationships (modifying their search effort) because the cost shock is purely transitory. Firms absorb the shock completely through changes in the markup. The wholesale price divides the burden of the markup adjustment between wholesalers and retailers, proportionally to the corresponding bargaining power. Hence, in an environment where firms are hit by idiosyncratic cost shocks, our model can yield complete price rigidity and time-varying markups.

3.2 Persistent Cost Shocks

Though firms are reluctant to engage in costly search activities when shocks are transitory, their reaction to persistent cost shocks is quite different.

Table 2 displays the response of marginal costs, prices and markups to a mildly persistent

marginal cost shock ($\lambda = 0.5^{\frac{1}{3}}$) under our baseline calibration. On impact, firms reduce both the units sold per match and their advertising and marketing activities (signalled by the fall in a_t). The reduction in the units per match leads to an increase in retail prices, while the pass-through to wholesale prices is almost proportional to the bargaining power of retailers. The effects of the reduction in advertising and marketing show up in the first period after the shock and persist over time. The disinvestment in long-term relationships causes a prolonged reduction in the stock of B2B and in the total production of the industry. As a result, there is a persistent reaction of wholesale and retail prices. However, the pass-through to both retail and wholesale prices is still quite low, and most of the cost shock is absorbed through movements in the markup.

Figure 1 shows the effects of an increase in marginal costs for different values of the persistence of the shock: $\lambda = 0, 0.6, 0.99$. We see that, although the increase in marginal costs has a positive effect on prices, the degree of pass-through is directly proportional to λ —being very short-lived for $\lambda = 0$. This is because the more persistent the cost shock, the higher the willingness of firms to absorb the shock by reducing advertising and marketing effort. The reduction in advertising and marketing leads to a decline in both B2B relationships and consumption.

Intuitively, if the shock is purely transitory, firms expect costs to go back to normal levels immediately after, and adjusting advertising and marketing is not an option for them. On the other hand, a persistent shock signals that marginal costs shall be high for many periods ahead, so firms do not mind losing business relationships. The real effects on consumption are consequently larger and considerably more persistent in this second case.

These results suggest that firms have a preference for the intensive margin or the extensive margin, depending on the persistence of the shock. Firms absorb cost shocks along the intensive margin when shocks are transitory and along the extensive margin when shocks are persistent.¹⁹ Nonetheless, the pass-through is never complete for reasonable calibrations.

¹⁹This is consistent with the empirical evidence by Ruhl (2008), who finds that the extensive margin of trade responds to permanent shocks but not to transitory shocks.

4 Bargaining, Trading Frictions and Prices

As Corollary 3 shows for the case of transitory cost shocks, the pass-through to prices depends remarkably on the adjustment costs along the intensive margin and the bargaining power of the firms in a contract. In this section, we study the effect of these two factors in the case of persistent cost shocks. Consistently with Nakamura and Zerom’s (2010) finding that cost shocks in the coffee industry are highly persistent, we carry out this exercise setting $\lambda = 0.95$.²⁰

4.1 Adjustment Costs on the Intensive Margin and Pass-Through

Figure 2 shows how production adjustment costs influence the response of the model to the increase in marginal costs. We consider three cases: the baseline scenario of $\psi = 1$ —where firms use both intensive and extensive margins—as well as a lower adjustment costs scenario ($\psi = 0.1$) and higher adjustment costs scenario ($\psi = 100000$). With $\psi = 0.1$, retailers find it convenient to adjust production along the intensive margin. On the other hand, with $\psi = 100000$, firms rely only on the extensive margin.

The response of prices to cost shocks changes considerably with ψ , suggesting that the curvature of retailers’ demand on the intensive margin has a strong effect on the degree of pass-through. Pass-through to wholesale and retail prices is low—and delayed—for medium to high level of adjustment costs ($\psi = 1$ or $\psi = 100000$). It is instead quite larger when adjusting the quantity per match is relatively cheap ($\psi = 0.1$). Having the possibility to adjust along an intensive margin, firms react much faster to marginal cost shocks: retail prices are more responsive, and so are wholesale prices. Nevertheless, the intensive margin is not enough to generate complete pass-through under reasonable calibrations. Pass-through to retail prices remains below 0.6 even when $\psi = 0.1$.²¹

²⁰Nakamura and Zerom (2010) find that, in the coffee industry, a Dickey-Fuller test for the hypothesis of a unit root cannot be rejected at the 5% level. For simplicity, we focus here on very persistent, but stationary, cost processes.

²¹In our model there are two ways to achieve complete pass-through to both retail and wholesale prices. The first way is to eliminate the curvature on q , letting $\psi \rightarrow 0$. The second way is to eliminate search frictions, letting $\gamma \rightarrow 0$.

4.2 Bargaining Power and Pass-Through

Figure 3 displays the pass-through of costs to prices for increasing values of retailers' bargaining power η . The first graph of Figure 3 shows the *impact* response of prices to a one percent increase in marginal costs, the second graph the response of prices to an increase in marginal costs *after one year*.

Retailers' bargaining power affects the pass-through to wholesale prices and to retail prices differently. The pass-through to wholesale prices is increasing in η , both on impact and after one year. On the other hand, the pass-through to retail prices is non-monotonic in η : it is maximum when the Hosios condition is met, and decreases symmetrically as we move away from $\eta = 1 - \xi$.

At first sight, the idea that the reaction of *wholesale* prices to wholesalers' marginal cost shocks gets larger with *retailers'* bargaining power η may seem counterintuitive. It would be reasonable to expect that retailers force wholesalers to absorb the shock keeping the bargained price unchanged, the more, the larger η .

To clarify this result, consider the evolution of the bargained wholesale price:

$$\hat{p}_{Wt} = \eta \left\{ \frac{mc}{p_W} \widehat{mc}_t - \frac{\Omega_W}{p_W} \hat{\Omega}_{Wt} \right\} + (1 - \eta) \left\{ \frac{p}{p_W q} (q - \omega) [\hat{p}_t - (1 - \kappa) \hat{q}_t] + \frac{\Omega_R}{p_W} \hat{\Omega}_{Rt} \right\}$$

The wholesale price depends on the reservation price of wholesalers (first term) and the reservation price of retailers (second term). When wholesalers have most of the bargaining power (i.e., for low η), they get the most of the surplus from a business relationship. In this case, the wholesale price is strictly related to the retailers' reservation price. At the limit (i.e., for $\eta \rightarrow 0$), there is not even a *direct* link between marginal cost shocks, $\frac{mc}{p_W} \widehat{mc}_t$, and wholesale prices. When retailers have most of the bargaining power (i.e. for high η), the effect of wholesalers' marginal costs on \hat{p}_{Wt} is instead strong. It can be shown that, for $\eta \rightarrow 1$, $\frac{mc}{p_W} = 1$ and the pass-through to wholesale prices is complete.

The pass-through to retail prices depends on how easy it is to adjust production, respectively, along the extensive margin and along the intensive margin:

$$\hat{p}_t = -\frac{1}{\phi} \left(\hat{T}_t + \kappa \hat{q}_t \right)$$

The bargaining power does not influence \hat{p}_t directly but only indirectly. The indirect effect is a consequence of the fact that the matching process is more or less efficient depending on η . This affects \hat{T}_t and is the cause of the inverted-U shape of \hat{p}_t with respect to η .²² When $\eta = 1 - \xi = 0.5$, the matching process is Pareto efficient and the search externalities are internalized. The large pass-through to retail prices stems from the large variation along the extensive margin. In contrast, when either retailers or wholesalers have most of the bargaining power (i.e., $\eta = 0.1$ or $\eta = 0.9$), there are search externalities and the adjustment along the extensive margin gets very expensive for either side of the product market. That is, the product market is very tight and the matching process sclerotic. However, the overall effect of η on the pass-through to retail goods is very small in comparison with its effect on the pass-through to wholesale prices.

In general, therefore, conditional on the cost shock being sufficiently persistent, the size of the pass-through depends on two key parameters of the model: ψ (for both the wholesale price and the retail price) and η (especially for the wholesale price). To assess which values of these parameters could be deemed more empirically relevant, we ran a simple experiment and evaluated the ability of the model to reproduce some leading results in the empirical literature. In particular, we simulated our model and determined which calibration allows it to approximately replicate the degree of pass-through estimated by Nakamura and Zerom (2010) for the coffee industry. They find that the pass-through of cost shocks to prices is very low and delayed (starting mostly in the second quarter after the shock), the major cause of the delay being the response of wholesale prices. A characteristic of the coffee industry is that there is a group of big wholesalers in the market (e.g., Procter & Gamble and Kraft), and we acknowledge that our model cannot properly account for this. Yet, if we concede that the results obtained by Nakamura and Zerom (2010) for the coffee industry may actually be more uniform across markets (as the analysis of Gopinath and Itskhoki, 2010, seem to suggest), then it is interesting to see under what conditions and to what extent our model can reproduce those results. Interestingly, running regressions on data simulated from the model, we find that the artificial estimates get close to the empirical ones if wholesalers are indeed powerful ($\eta = 0.1$) and the adjustment of retailers' production to changes in the quantity of inputs is sufficiently sluggish ($\psi = 10$). We describe this experiment in detail in appendix C.

²²See Figure 4.

4.3 On the Allocative Role of Wholesale Prices

When prices are sticky, monetary policy can play a stabilizing role. But, as Barro (1977) points out, even with sticky prices monetary policy has real effects only if prices are allocative, that is, only if prices are relevant signals for consumption decisions.

In our model, the allocative power of wholesale prices depends on the persistence of the change in this price. When the price change is purely transitory, wholesale prices only play a distributive role; they are not allocative (Corollary 3). When the price change is expected to last in the future, there is instead a potentially allocative role for wholesale prices, on top of their distributive role. This happens because the incentive for firms to engage in costly search activities depends on the expected benefits of a B2B relationship, which are in turn influenced by the future expected wholesale price. So the question to answer next is: to what extent are wholesale prices allocative when an industry is exposed to persistent shocks?

To answer this question, we look at the response of retail prices and consumption to a persistent increase in wholesale prices. Interestingly, this can be interpreted as a negative shock to retailers' bargaining power, $\hat{\eta}_t$, for this shock affects wholesale prices but not retail prices. Formally:

$$\hat{p}_{Wt} = \eta \left\{ \frac{mc}{p_W} \widehat{mc}_t - \frac{\Omega_W}{p_W} \hat{\Omega}_{Wt} \right\} + (1 - \eta) \left\{ \frac{p(q - \omega)}{p_W q} [\hat{p}_t - (1 - \kappa) \hat{q}_t] + \frac{\Omega_R}{p_W} \hat{\Omega}_{Rt} \right\} - A_\eta \hat{\eta}_t$$

where $A_\eta = \frac{J}{p_W q} [1 - \beta(1 - \delta) \lambda_\eta]$.²³ An increase in the bargaining power of wholesalers (i.e. a reduction of $\hat{\eta}_t$) raises \hat{p}_{Wt} and is thus equivalent to an exogenous shock to wholesale prices.

Figure 5 compares the effects of wholesale price increases in the B2B model with the ones obtained in the Dixit-Stiglitz (1977) monopolistic competition model. $\hat{\eta}_t$ is assumed to follow an $AR(1)$ process with persistence $\lambda_\eta = 0.95$. In order to facilitate the comparison of the results between the two models, we scale the bargaining shock in the context of the B2B model in such a way that the impact increase in \hat{p}_{Wt} is the same as the one in the Dixit-Stiglitz (1997) model.²⁴

²³Note that, *ceteris paribus*, the persistence of the bargaining power shock λ_η reduces the response of wholesale prices to the bargaining power shock. This is a consequence of the repeated nature of the interactions between firms. So bargaining firms look into the future and account for the expected continuation value of a match. For instance, retailers are willing to accept a higher wholesale price today if they expect to get a high share of the surplus in the future.

²⁴In the Dixit-Stiglitz (1977) model the pass-through of wholesale price shocks to retail prices is complete, i.e. $\hat{p}_t = \hat{p}_{Wt}$. Consumption is then obtained using the sectorial demand condition: $\hat{c}_t = -\phi \hat{p}_t = -\phi \hat{p}_{Wt}$. The

Specifically, wholesale prices increase by 1 percent on impact.

In the standard monopolistic competition model, an increase in wholesale prices causes a proportional increase in retail prices (the pass-through is complete) and a strong reduction in final goods consumption \hat{y}_t . In the B2B model, the response of retail prices and consumption depends crucially on the initial conditions in the product market. Specifically, it depends on the initial bargaining power of the two parties. When wholesalers have most of the bargaining power ($\eta = 0.1$), the increase in wholesale prices leads to a reduction in consumption and to an increase in retail prices, as in Dixit-Stiglitz. When retailers are the dominant party in the negotiations ($\eta = 0.9$), an increase in wholesale price has opposite effects to those in Dixit-Stiglitz: consumption *increases* and retail prices *falls*. Finally, if the two parties have fully symmetric bargaining power ($\eta = 0.5$), wholesale price shocks *do not* affect both retail prices and consumption. In this case, \hat{p}_{Wt} does not have any allocative power.

These, perhaps surprising, results are due to the search externalities in the product market. A persistent increase in wholesale prices raises the expected value of business relationships for wholesalers but reduces that for retailers. Consequently, following the shock wholesalers increase their search intensity, while retailers reduce it. But the intensity of these reactions depends on the initial bargaining power. When wholesalers have most of the bargaining power ($\eta = 0.1 < 1 - \xi$), the product market is very tight on the side of wholesalers, and the bargaining power shock only worsens the situation. The formation of new matches is strongly reduced because retailers are reluctant to make search efforts, and this is only partly compensated by an increase in the intensive margin. Total consumption decreases and the pass-through to retail prices is positive but delayed. On the contrary, when wholesalers are the weak party in the negotiations ($\eta = 0.9 > 1 - \xi$), the wholesale price shock reduces the tightness of the market, and improves the efficiency of the matching process. The number of business relationships increases, leading to *higher* consumption and *lower* retail prices. When the Hosios condition is verified ($\eta = 0.5 = 1 - \xi$), the additional search effort by wholesalers offsets the reduction in retailers' search effort one-for-one, so the stock of business relationships, final consumption and retail prices remain *constant*.²⁵

evolution of wholesale prices, \hat{p}_{Wt} , in the Dixit-Stiglitz model is modeled as an $AR(1)$ process with persistence λ_η . This is identical to the evolution of \hat{p}_{Wt} in the B2B model when $\eta = 0.5$.

²⁵See also Figure 6.

These results suggest two conclusions regarding the allocative power of wholesale prices. First, persistent wholesale price fluctuations do retain some signalling power in industries characterized by long-term contracts and efficient bargaining. Yet, this allocative power works through a different channel, which depends on the incentives of firms to engage in costly advertising and purchasing activities. For this reason, the effect is considerably delayed and much more persistent than in the standard monopolistic competition model. Second, the effect of wholesale price fluctuations on retail prices and consumption depends on search externalities. Search externalities show up whenever the Hosios condition fails to apply, that is, whenever $\eta < 1 - \xi$ or $\eta > 1 - \xi$.

5 Product Market Equilibrium in Open Economy

There are, at least, three reasons why our model can have interesting implications for the dynamics of an industry in open economy. First, border prices are sluggish and their behaviour reflects B2B contracts between exporters and importers (Gopinath and Rigobon, 2008). Second, exchange rate shocks are the most direct way to test the reaction of prices to shocks, for changes in the exchange rate are shocks that are truly exogenous to the dynamics of an industry. On the other hand, the closed economy literature on the pass-through of marginal cost shocks to prices needs to rely on indirect tests (Gopinath and Itskhoki, 2010). Lastly, since our model predicts that the allocative power of wholesale prices depends on the search externalities of each long-term relationship, the application of the model to international trade allows us to examine the expenditure switching effect of the response of wholesale prices to exchange rate shocks. According to the standard channel, exchange rate shocks cause expenditure switching—that is, affect consumption in the importing country—to the extent that import prices vary and adjust to these shocks.²⁶ In the context of our model, the border prices are the wholesale prices set through long-term relationships between firms of different countries, so search and bargaining frictions can affect the responsiveness of border prices to exchange rate shocks. An interesting question is thus to determine how important the reaction of wholesale prices to exchange rate

²⁶The expenditure switching effect of exchange rate shocks works either through the variability of consumption goods prices (Friedman, 1953), provided that imports are priced in the currency of the country of the producer (Devereux and Engel, 2003), or through the variability of intermediate goods prices (Obstfeld, 2001).

shocks is for expenditure switching.

In what follows, we present an open economy extension of our model, under the standard assumption that changes in the exchange rate are exogenous to the dynamics of the industry under analysis. Foreign variables are denoted by a ‘star.’

5.1 An Extended Framework

Wholesale firms produce intermediate goods in the home country and sell these goods both in their own country and in the foreign country. To this end, wholesalers need to establish long-term relationships with retailers operating in each market.²⁷ Retailers of a given country transform intermediate goods into final goods and sell these goods only to resident consumers. To keep the analysis simple, we assume that home country wholesalers are specialized in the production of industry i goods and, consequently, do not face competition from foreign wholesalers. We leave this interesting extension for future research. Moreover, since there is symmetry between firms, we continue to save notation and omit firm-specific indexes.

Retailers. The retail sector in the home country is identical to the retail sector of the closed-economy version of the model. The demand function for the goods produced by this sector is given by equation (1), and the first order conditions of its profit maximization problem are equations (9) – (10).

The foreign retail sector is analogous to the home country retail sector, with the only difference that price variables are denominated in foreign currency. Foreign retailers are an infinite number of firms with unit measure, and the demand function for the consumption goods these firms produce is:

$$c_t^* = A^* (p_t^*)^{-\phi}$$

where p_t^* is the foreign retail price in units of the foreign currency and A^* is a parameter.²⁸ The

²⁷As in Drozd and Nosal (2012), the need to establish B2B relationships with both home and foreign retailers represents a natural justification for the international segmentation among product markets.

²⁸This parameter is a replacement for aggregate consumption, C_t^* , and the aggregate price level, P_t^* . C_t^* and P_t^* are both exogenous to the industry under analysis, and the standard demand function— $c_t^* = (p_t^*/P_t^*)^{-\phi} C_t^*$ —simplifies as shown.

first-order conditions for the maximization of current and future expected profits are:

$$\frac{\gamma^f}{k^{*R}(\theta_t^*)} x_{Rt}^* = \beta(1 - \delta) \mathbb{E}_t J_{t+1}^* \quad (16)$$

$$J_t^* = p_t^*(q_t^* - \omega_t^*) - p_{Wt}^* q_t^* + \frac{\gamma^f}{2} (x_{Rt}^*)^2 + (1 - \delta) \beta \mathbb{E}_t J_{t+1}^* \quad (17)$$

where the cost parameter γ^f , the marginal value of B2B relationships to the foreign retailer, J_t^* , and the bargained wholesale price of B2B contracts in the foreign country, p_{Wt}^* , are all expressed in units of the foreign currency. $x_{Rt}^* = d_t^*/T_t^*$ is the search intensity of the foreign retailer, which leads to the formation of new business relationships with home country wholesalers at rate $k^{*R}(\theta_t^*)$. This rate depends on the foreign goods market tightness— $\theta_t^* \equiv a_t^*/d_t^*$ —and is taken as given by the retailer.

Wholesalers. Home country wholesalers make deals not only with local retailers, but also with foreign retailers. The value function of the wholesaler is now given by:

$$v_w(T_t, T_t^*, \mathbf{s}_t) = \max_{a_t, a_t^*, T_{t+1}, T_{t+1}^*} \{ \pi_{wt}^* + \beta \mathbb{E}_t v_w(T_{t+1}, T_{t+1}^*, \mathbf{s}_{t+1}) \}, \quad (18)$$

where T_t^* is the number of business relationships with the foreign country, $\mathbf{s}_t = (mc_t, e_t)$ is the vector of exogenous states and π_{wt}^* are the current profits. These are denominated in units of the domestic currency and given by:

$$\pi_{wt}^* = (p_{Wt} - mc_t) q_t T_t - \frac{\gamma}{2} (x_{wt})^2 T_t + (e_t p_{Wt}^* - mc_t) q_t^* T_t^* - \frac{e_t \gamma^f}{2} (x_{wt}^*)^2 T_t^*,$$

where $x_{wt} = a_t/T_t$ and $x_{wt}^* = a_t^*/T_t^*$ are the intensities to search for buyers in the home market and in the foreign market, respectively. Therefore, the firm is not only exposed to industry-specific marginal cost shocks, but also to the aggregate fluctuations in the nominal exchange rate e_t , which alter the valuation of the foreign sales price and search costs.²⁹

The value function (18) is constrained by the law of motions for home and foreign customer bases, which are given by equation (3) and an analogous process for the foreign market, as well

²⁹The implicit assumption is that wholesalers produce all of their output in the home country and no part of the process is carried out in the foreign country. Producing part of the intermediate inputs in the foreign country is another sources of exposure to exchange rate shocks (Gopinath and Itskhoki, 2010). But, for the purpose of understanding the mechanism, we can safely leave this and other mixed cases out of the current analysis.

as by the initial conditions $T_0, T_0^* > 0$. The first order condition for the choice of the search intensity and the number of matches in the local market are the same as in closed economy (equations (4)-(5)). The optimal choices for transactions with foreign customers are instead as follows:

$$\frac{\gamma^f}{k^a(\theta_t^*)} x_{wt}^* = \beta(1-\delta) \mathbb{E}_t \frac{e_{t+1}}{e_t} W_{t+1}^* \quad (19)$$

$$W_t^* = \left(p_{Wt}^* - \frac{mc_t}{e_t} \right) q_t^* + \frac{\gamma^f}{2} (x_{wt}^*)^2 + (1-\delta) \beta \mathbb{E}_t \frac{e_{t+1}}{e_t} W_{t+1}^* \quad (20)$$

where $W_t^* \equiv \partial v_w(T_t, T_t^*, \mathbf{s}_t) / \partial T_t^*$ is in units of the home currency. Therefore, accounting for the expected change in the exchange rate, both equations are expressed in units of the foreign currency.

Equation (19) shows that the marginal cost of search in the foreign market (on the left hand side) must equal the future value of a B2B relationship with foreign retailers. Equation (20) shows that the current value of customer relationships W_t^* must equal the current and future benefits of getting into these relationships. The exchange rate influences these benefits in two ways. First, the current exchange rate affects the profit margin of the wholesale sector, acting as a marginal cost shock with opposite sign. Second, the expected change in the exchange rate interacts with the future value of B2B relationships, as a reflection of the reward needed to invest in search activities (equation (19)).

5.2 Bargaining and Expenditure-Switching

Home wholesalers and foreign retailers bargain over prices and quantities to maximize the total surplus in the foreign product market. The solution of this Nash bargaining problem for foreign wholesale prices and quantities are, respectively,

$$p_{Wt}^* = \eta^* \left[\frac{mc_t}{e_t} - \Omega_{Wt}^* \right] + (1-\eta^*) \left[p_t^* \left(1 - \frac{\omega_t^*}{q_t^*} \right) + \Omega_{Rt}^* \right] \quad (21)$$

$$p_t^* \psi(q_t^* - \bar{q}^*) = p_t^* - \frac{mc_t}{e_t} \quad (22)$$

where η^* is the bargaining power of foreign retailers and $\Omega_{Wt}^* = \frac{\gamma^f}{2} \frac{(x_{wt}^*)^2}{q_t^*} + \frac{\gamma^f}{k^a(\theta_t^*)} \frac{x_{wt}^*}{q_t^*}$ and $\Omega_{Rt}^* = \frac{\gamma^f}{2} \frac{(x_{Rt}^*)^2}{q_t^*} + \frac{\gamma^f}{k^*R(\theta_t^*)} \frac{x_{Rt}^*}{q_t^*}$ are the savings in the costs of searching for and forming B2B relationships.

According to equation (21), the optimal wholesale price is a weighted average of the valuation of the intermediate good by home wholesalers and that by foreign retailers—first and second terms, respectively. This opens the way to pricing to market. Equation (22) suggests that the marginal cost of adjusting production along the intensive margin (the left hand side) equals the benefit of exchanging one additional unit of the good in the foreign retail market (the total profit margin on the right hand side).

The nominal exchange rate influences both the bargained price and the bargained quantity per match. Equation (22) shows that an exchange rate appreciation—a reduction in e_t —leads to a negative adjustment along the intensive margin. The quantity per match q_t^* falls below the desired long-run level \bar{q}^* , and this decline is more pronounced, the easier for retailers to absorb the shock by adjusting their production (i.e., the lower ψ). In fact, formally, $\hat{q}_t^* = [mc / (ep^*\psi q^*)] (\hat{p}_t^* - \widehat{mc}_t + \hat{e}_t)$. Intuitively, the reduction in e_t raises the foreign currency value of the marginal costs of producing intermediate goods at home, causing the total surplus generated by contracts in the foreign market to fall, and so does q_t^* .

This mechanism influences the response of the wholesale price as well. In fact, from equation (21), one of the effects of the exchange rate appreciation is that p_{Wt}^* needs to increase as a result of the marginal increase in the costs mc_t/e_t in the wholesale sector. Yet note that, differently from its effect on q_t^* , the effect of the increase in mc_t/e_t on p_{Wt}^* depends forcefully on the bargaining power of the parties in the contract; specifically, on the bargaining power of foreign retailers η^* . The response of the wholesale price to the exchange rate appreciation is also a function of the way wholesalers adjust their savings in the costs of search, Ω_{Wt}^* ,³⁰ and on the change in retailers' reservation price through p_t^* and q_t^* . While the effect of the reaction of Ω_{Wt}^* gets stronger for increasing values of η^* , as it does that of the response of mc_t/e_t , the reaction of retailers' valuation gets progressively smaller.

All in all, since exchange rate shocks affect both the bargained quantity per match q_t^* and the bargained wholesale price p_{Wt}^* , the exchange rate has expenditure switching effects but not through the conventional channel. In the model, a shock to the exchange rate affects the

³⁰Optimal bargaining with foreign retailers implies a bargaining rule similar to the one for the home product market. This is $\eta^*W_t^* = (1 - \eta^*)J_t^*$. There is however a difference between the two cases. The difference stems from the fact that the bargaining rule for the foreign market is expressed in foreign currency value terms, as it is the cost of search at foreign. So, wholesalers need to account for future evolutions in the exchange rate, while retailers do not. See equations (16)-(19).

total surplus maximized in a match between home wholesalers and foreign retailers. Working through the total profit margin $p_t^* - mc_t/e_t$, this effect of the shock on the total surplus has direct implications for q_t^* and foreign consumption, independently of the response of the intermediate border price p_{Wt}^* . In fact, the quantity per match reacts to the shock, unless the costs of adjusting production along the intensive margin are extraordinarily high (ψ is very large). In this sense, there is a sort of disconnect between the reaction of quantities and that of wholesale prices. The reaction of q_t^* is not a direct function of the degree of the exchange rate pass-through (ERPT) to wholesale prices. The ERPT to wholesale prices can change with η^* , but neither η^* nor p_{Wt}^* are direct determinants of q_t^* .

5.3 Quantitative Results

Let the nominal exchange rate be an $AR(1)$ process:

$$\hat{e}_t = \lambda_e \hat{e}_{t-1} + \varepsilon_{e,t}$$

where $\lambda_e \in [0, 1)$ is the persistence of fluctuations in the exchange rate and $\varepsilon_{e,t}$ is an i.i.d. shock. Since nominal exchange rates are often close to a unit root, we set $\lambda_e = 0.99$ and study the effects of a decrease in the nominal exchange rate on prices and on search and matching.

In general, prices and quantities are driven by the same key factors affecting the dynamics of prices and quantity in closed-economy.³¹ Figure 7 shows the effects of the currency appreciation on prices and quantity for different values of the adjustment cost parameter ψ . In particular, the first two diagrams measure the pass-through to prices *on impact* (left graph) and *after one year* (right graph). The remaining four diagrams show the responses of variables concerning the extensive and intensive margins of adjustment.

Regardless of the size of the adjustment costs, the ERPT to retail prices is systematically lower than the ERPT to wholesale prices. This is consistent with the large set of empirical findings reviewed by Burstein and Gopinath (2013). Moreover, for intermediate values of ψ (i.e., for $\psi = 1$), exchange rate shocks have a rather limited impact effect on prices. The effect

³¹For the sake of brevity, we do not discuss how the persistence of the shock affects the industry dynamics under exchange rate shocks and keep the analysis centered around aspects relevant for the expenditure switching effect of such shocks. Nonetheless, we have found that the persistence of exchange rate shocks is important mostly for the incentives of firms to engage in B2B relationships across the border.

of the shock grows larger twelve months after its occurrence, yet the ERPT remains incomplete: it is around 60 percent, for retail prices, and around 75 percent, for wholesale prices. This is due to the fact that home wholesalers and foreign retailers react to the currency appreciation adjusting along both the intensive margin and the extensive margin. The adjustment of q_t^* along the intensive margin is due to the increase in the foreign currency value of the marginal costs of intermediate goods production. The adjustment of p_{Wt}^* along the extensive margin is due to both this reaction of the marginal costs and the effect of the shock on the search effort by wholesalers, which in fact falls alongside the number of B2B relationships established in the foreign country. For smaller adjustment costs (i.e., for $\psi \rightarrow 0$), there is a sounder decline in the quantity per match, a larger degree of ERPT to prices, and correspondingly less need to reduce the number of B2B relationships in place. The reverse is true for industries where foreign retailers find it very hard to adjust their production (i.e., for $\psi = 100000$), in which case the ERPT is rather limited.

Figure 8 shows the effects of the currency appreciation for various assumptions about the bargaining power of foreign retailers η^* . The currency appreciation acts as a negative stimulus for both the quantity traded within each match and the formation of new B2B relationships. The degree of pass-through to wholesale prices depends markedly on the value assumed by η^* , but η^* has limited effects on both retail prices and consumption. The pass-through to p_{Wt}^* is increasing in η^* , both on impact and after 12 months. But the increase in the pass-through to p_{Wt}^* has weak consequences for the real side of trade. The response of the quantity per match to the appreciation is almost independent of the bargaining power of the firms. This has a slightly larger effect on the extensive margin of trade, for the efficiency of the matches in the international product market is a function of η^* . Overall, the responses of B2B relationships, of retail prices and of final consumption reach a maximum when $\eta^* = 0.5$ —i.e., when the Hosios condition holds—and decrease symmetrically as we move away from this value.

Interestingly, this confirms that there is a sort of disconnect between the ERPT to the price of imported intermediate goods and final consumption. When foreign retailers' bargaining power goes from 0.5 towards 1, the increase in the ERPT to wholesale prices is associated with a reduction in the ERPT to retail prices and in expenditure switching. In this sense, Figure 8 provides a visual indication of the fact that the expenditure switching effect of the exchange

rate appreciation is not necessarily either captured or triggered by a change in import prices. It rather depends on the costs of adjusting production along the intensive and extensive margins.

Robustness. We have made the assumption that home wholesalers and foreign retailers bargain over p_{Wt}^* , which is denominated in foreign currency. This assumption is, for instance, in line with the fact that U.S. imports are priced in dollars (Gopinath and Rigobon, 2008) and that large transactions are likely to be invoiced in the importers' currency (Goldberg and Tille, 2009). However, as it is simple to see, the results do not depend on the currency of denomination of the wholesale price. Specifically, the results would not change if we assumed that firms bargained over a price denominated in home currency. This is because what the alternative assumption implies is a change in the currency of denomination of firms' profits and hence of the optimal sharing rule of the Nash-bargaining problem. While equation (21) is the optimal solution of a sharing rule expressed in units of the foreign currency, under the alternative assumption the bargained price is the solution of a sharing rule denominated in the home currency. We have in fact checked that, converted back into foreign currency, the latter solution is equivalent to equation (21).

6 Conclusion

This paper has developed a simple model of pricing in the context of business relationships between wholesalers and retailers in the product market. This characterization of the product market is in line with a number of recent studies emphasizing that firms need to establish long-term relationships to expand trade. The search frictions that affect the adjustment of the customer base to shocks are thus key to the behaviour of prices.

We have specifically distinguished between intensive and extensive margins of adjustment. We have found that the intensive margin of adjustment depends mostly on how costly is for retailers to transform wholesale goods into final goods. The convenience to invest in new B2B relationships along the extensive margin is instead a function of the persistence of shocks. We have analyzed how these two sources of adjustment interplay and found that this interaction affects the pass-through of exchange rate and other cost shocks to prices. The pass-through tends to be low under various parametrizations and is almost always incomplete. One of the main

drivers of the pass-through is the bargaining power of retailers, which can limit the allocative power of wholesale prices, in closed economy, and can restrain the expenditure switching effect of exchange rate shocks, in closed economy. But we have found that in none of these two cases the pass-through of cost shocks to wholesale prices is informative of how wholesalers and retailers agree to adjust trade after a cost shock. In this sense, our results suggests that, when it comes to industries where bargaining and long-term relationships are the rule, it could be misleading to use the ERPT as the sole metric of the expenditure switching effect of exchange rate shocks.

Appendix

A Proof of Proposition 1

Following Hosios (1990), the constrained efficient allocation is the solution to the problem of a benevolent social planner, who is subject to the same technological constraints and search frictions that firms confront in a decentralized equilibrium. The idea is that the social planner cannot circumvent the search frictions, but she can internalize the effect of changes in product market tightness on the costs of search and on the resource constraint.

The maximization problem of the social planner is

$$\max_{\{y_t, q_t, T_t, a_t, d_t\}} E_0 \sum_{t=0}^{\infty} \beta^t \left\{ p_t y_t - m c_t q_t T_t - \frac{\gamma}{2} x_{Rt}^2 T_t - \frac{\gamma}{2} x_{wt}^2 T_t \right\} \quad (23)$$

subject to the technological constraints on the extensive margin (matching frictions) and intensive margin (adjustment costs):

$$\begin{aligned} T_t &= (1 - \delta) \left(T_{t-1} + \tilde{m} a_{t-1}^{\xi} d_{t-1}^{1-\xi} \right) \\ y_t &= \left(q_t - \frac{\psi (q_t - \bar{q})^2}{2} \right) T_t \end{aligned}$$

Equation (23) is based on the fact that, due symmetry in preferences and technology, efficiency requires that identical quantities of each good be produced by each wholesaler and each retailer. The first order conditions are:

$$p_t \psi (q_t - \bar{q}) = p_t - m c_t \quad (24)$$

$$\tau_t = p_t \left(q_t - \frac{\psi (q_t - \bar{q})^2}{2} \right) - m c_t q_t + \frac{\gamma}{2} x_{Rt}^2 + \frac{\gamma}{2} x_{wt}^2 + \beta (1 - \delta) \tau_{t+1} \quad (25)$$

$$\frac{\gamma x_{wt}}{\tilde{m} \theta_t^{-(1-\xi)}} = \xi \beta ((1 - \delta)) \tau_{t+1} \quad (26)$$

$$\frac{\gamma x_{Rt}}{\tilde{m} \theta_t^{\xi}} = (1 - \xi) \beta (1 - \delta) \tau_{t+1} \quad (27)$$

where τ_t is the social value of a match at the margin. To compare the social planner's optimality conditions with those of the decentralized equilibrium, let us rewrite the latter as follows:

$$p_t \psi (q_t - \bar{q}) = p_t - m c_t \quad (28)$$

$$\tau_t = p_t \left(q_t - \frac{\psi (q_t - \bar{q})^2}{2} \right) - m c_t q_t + \frac{\gamma}{2} x_{wt}^2 + \frac{\gamma}{2} x_{Rt}^2 + (1 - \delta) \beta \tau_{t+1} \quad (29)$$

$$\frac{\gamma x_{wt}}{\tilde{m} \theta_t^{-(1-\xi)}} = \beta (1 - \delta) W_{t+1} = (1 - \eta) \beta (1 - \delta) \tau_{t+1} \quad (30)$$

$$\frac{\gamma x_{Rt}}{\tilde{m} \theta_t^{\xi}} = \beta (1 - \delta) J_{t+1} = \eta \beta (1 - \delta) \tau_{t+1} \quad (31)$$

where $\tau_t = W_t + J_t$. It is now easy to see that $1 - \eta = \xi$ is a necessary and sufficient condition for the constrained efficient solution (24) – (27) to be equivalent to the decentralized solution

(28) – (31). ■

B Proof of Proposition 2

When it is purely transitory, a marginal cost shock has no effect on the expected future value of a business relationship ($E_t \hat{W}_{t+1} = E_t \hat{J}_{t+1} = 0$). Consequently, wholesalers and retailers have no incentive to adjust their search intensities to the shock: $\hat{x}_{wt} = E_t \hat{W}_{t+1} = \hat{x}_{Rt} = E_t \hat{J}_{t+1} = 0$. The problem becomes static because, with search efforts being constant, also the number of B2B relationships remains unchanged.

From the log-linearization of the market clearing condition, $-\phi \hat{p}_t = \hat{y}_t$, follows:

$$\hat{p}_t = -\frac{1}{\phi} \left(\hat{T}_t + \kappa \hat{q}_t \right) = -\frac{\kappa}{\phi} \hat{q}_t \quad (32)$$

where $\kappa = \frac{q}{q-\omega} (1 - \psi (q - \bar{q}))$ captures the curvature of the production function of retailers with respect to \hat{q}_t . Plugging (32) into the log-linearization of (13) yields:

$$\hat{q}_t = \frac{1}{\psi} \frac{mc}{pq} (\hat{p}_t - \widehat{mc}_t) = -B_q (\widehat{mc}_t) \quad (33)$$

where $B_q = \frac{\Phi_q}{1 + \frac{\kappa}{\phi} \Phi_q}$ captures the elasticity of \hat{q}_t to changes in the total profit margin, and $\Phi_q = \frac{1}{\psi \mu^{\text{tot}} q}$ is a decreasing function of ψ . Using equation (33) back into (32), we get

$$\hat{p}_t = \frac{\kappa}{\phi} B_q (\widehat{mc}_t) \quad (34)$$

where $\frac{\kappa}{\phi} B_q$ is decreasing in both ψ and ϕ .

Combining (33) and (34) with the log-linearization of (12), we finally obtain:

$$\hat{p}_{Wt} = \left\{ \eta \frac{mc}{pW} + (1 - \eta) \frac{p(q - \omega)}{pWq} \frac{\kappa}{\phi} B_q + A_q B_q \right\} \widehat{mc}_t$$

where A_q captures the elasticity of the wholesale price to changes in \hat{q}_t , and is a decreasing function of ψ . ■

C Reconciling the Model with Nakamura and Zerom (2010)

Analyzing data on trade in the coffee market, Nakamura and Zerom (2010) obtain three major results: 1) the pass-through of marginal cost shocks to wholesale and retail prices is quite low (less than a third of a percent in total); 2) it is delayed, in the sense that prices start to adjust in the second quarter after the shock or later; 3) most of the delayed pass-through occurs at the wholesale level, in the sense that wholesale and retail prices move very closely together.

The coffee market presents features that our model cannot properly account for. In particular, in the coffee market there are a few large wholesalers with some market power; we abstract from this in our model. Nevertheless, if we concede that the results obtained by Nakamura and Zerom (2010) for the coffee industry may actually be more regular across many markets (as the analysis by Gopinath and Itskhoki, 2010, seem to suggest), then it is interesting to see to what extent our model can account for those results. This means finding the right mix of parameters that can deliver a low and delayed pass-through, without imposing price stickiness from the very beginning.

In particular, since in our model firms do not feel the need to search unless cost shocks are sufficiently persistent (corresponding, for example, to exchange rate shocks being empirically close to a unit root), we seek to determine what combination (ψ, η) can reproduce the results of Nakamura and Zerom (2010) for $\lambda = 0.95$. This is our baseline calibration for the persistence of the shock.

We simulated our model and obtained samples of 2900 quarters, by changing the frequency of the artificial data from monthly (our baseline calibration) to quarterly (Nakamura and Zerom, 2010). The selected sample size is close to the number of observations that Nakamura and Zerom (2010) use in two of the three exercises that we aim to replicate with our model.³² We ran the simulations for 500 times. To assess the degree of pass-through of marginal costs shocks to wholesale and retail prices, we then run the following regressions on the simulated data:

$$\Delta \ln p_{zt} = \alpha_z + \sum_{k=0}^6 \beta_{zk} \Delta \ln mc_{t-k} + u_{zt},$$

where the index z is simply capturing the fact that we run a regression for the wholesale price and one for the retail price. α_z and β_{zk} are the parameters to estimate and u_{zt} is a zero-mean residual term. Note that this equation has the same form, and the same number of lags, as the one estimated by Nakamura and Zerom (2010).³³ The coefficients β_{zk} can be interpreted as the percentage change in prices associated with a one percent change in marginal costs that took place k quarters before. The sum $\sum_{k=0}^6 \beta_{zk}$ measures the *long-run* pass-through.³⁴

Table 3 presents the results of the pass-through regression for wholesale and retail prices. First, we need wholesalers to have most of the bargaining power: we set $\eta = 0.1$. In fact, when wholesalers have a strong bargaining power, wholesale prices are closely related to retail prices. In this case, wholesalers internalize most of the surplus from a match, and the pass-through to wholesale prices is rather limited. Second, we need a relatively high curvature along the intensive margin (i.e., $\psi = 10$) to prevent the quantity of intermediate inputs transacted within a match from displaying a large impact reaction. Under these two assumptions, the model can replicate the low and delayed pass-through of costs shocks to wholesale and retail prices. The long-run pass-through of cost shocks to retail and wholesale prices, however, is still slightly higher than that in the data. This is mainly because the effects of the cost shock are more persistent in the model than in the data.

Finally, to measure the extent to which the delayed pass-through is due to the reaction of wholesale prices, which then feeds into retail prices, we measure the sensitivity of the retail price to the intermediate goods price by estimating:

$$\Delta \ln p_t = \tilde{\alpha} + \sum_{k=0}^2 \tilde{\beta}_{ik} \Delta \ln p_{Wt-k} + \tilde{u}_t,$$

where we use the *tilde* to distinguish the coefficients and residual of this regression from the

³²In particular, the sample size of 2900 quarters is close to the number of observations that Nakamura and Zerom (2010) use for estimating the pass-through of cost shocks to wholesale prices and the pass-through of changes in the wholesale prices to retail prices. For the pass-through of cost shocks to retail prices, they actually have a bigger sample, but using a bigger sample of simulated data does not affect our estimates. However, there is no exact correspondence between our samples and theirs. Nakamura and Zerom (2010) work with panel data, while we only have the time dimension.

³³The only difference is that, to account for seasonality, Nakamura and Zerom (2010) include in their regressions a quarter of the year dummy.

³⁴See also Goldberg and Campa (2006).

previous one. As before, the form of this regression is consistent with the empirical strategy of Nakamura and Zerom (2010). The results of this exercise—shown in Table 4—are more mixed. On one side, the pass-through of wholesale prices to retail prices is more delayed in the model than in the data. In the model most of the reaction of the wholesale price passes through to the retail price in the first two quarters, especially in the second. In contrast, in the data most of the adjustment occurs in the first quarter. On the other side, however, we get close to the data in that the overall pass-through (i.e., $\sum_{k=0}^2 \tilde{\beta}_{ik}$) approaches 1; it is about 0.9 in both cases. The model takes three quarters to reproduce this long-run pass-through of wholesale prices to retail prices.

Overall, considering that our model is fairly simple and abstracts from many important aspects (e.g., local costs and price negotiation costs), the results of this experiment seem encouraging, in the sense that search and bargaining between businesses has the potential to contribute to explaining the low and delayed pass-through in the data.

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Parameter	Effect on Variables							
	T	q	θ	p	p_W	μ_R	μ_W	μ^{tot}
Adjustment Cost (ψ)								
100000	0.551	1.000	1.000	1.105	1.052	1.050	1.052	1.105
1	0.519	1.091	1.000	1.100	1.048	1.050	1.048	1.100
0.00001	0.007	144.50	1.000	1.001	1.000	1.001	1.000	1.001
Bargaining Power (η)								
0.1	0.358	1.140	3.000	1.163	1.138	1.022	1.138	1.163
0.5	0.519	1.091	1.000	1.100	1.048	1.050	1.048	1.100
0.9	0.358	1.140	0.333	1.163	1.015	1.145	1.015	1.163

Table 1: Sensitivity of the Steady State to Adjustment Costs and Bargaining Power of Firms. *Note:* The sensitivity analysis is conducted keeping γ fixed to its calibrated value of 0.3457 and letting the adjustment cost ψ and the bargaining power η vary, each one at a time. Wholesalers and retailers' markups are defined, respectively, as $\mu_W \equiv p_W/mc$ and $\mu_R \equiv p/p_W$.

Month	mc_t	Reaction of Variables						
		p_{Wt}	μ_{Wt}	p_t	μ_{Rt}	q_t	T_t	a_t
0	1	0.57	-0.43	0.11	-0.46	-0.74	0	-1.27
3	0.5	0.30	-0.20	0.10	-0.21	-0.34	-0.28	-0.67
6	0.25	0.17	-0.08	0.08	-0.09	-0.14	-0.35	-0.36
9	0.125	0.10	-0.03	0.06	-0.03	-0.05	-0.33	-0.19

Table 2: Persistent Marginal Cost Shock and Pass-Through. *Note:* The variables react to a unit increase in marginal costs, which is mildly persistent: $\lambda = 0.5^{\frac{1}{3}}$. Wholesalers and retailers' markups are defined, respectively, as $\mu_W \equiv p_W/mc$ and $\mu_R \equiv p/p_W$.

Coefficient	Retail price		Wholesale price	
	NZ(2010) Data	Model	NZ(2010) Data	Model
$\Delta \ln mc_t$	0.063 (0.013)	0.043 (0.001)	0.115 (0.018)	0.137 (0.001)
$\Delta \ln mc_{t-1}$	0.104 (0.008)	0.090 (0.001)	0.169 (0.013)	0.081 (0.001)
$\Delta \ln mc_{t-2}$	0.013 (0.007)	0.070 (0.001)	-0.010 (0.010)	0.063 (0.001)
$\Delta \ln mc_{t-3}$	0.031 (0.006)	0.054 (0.001)	-0.016 (0.009)	0.049 (0.001)
$\Delta \ln mc_{t-4}$	0.048 (0.007)	0.042 (0.001)	0.007 (0.013)	0.038 (0.001)
$\Delta \ln mc_{t-5}$	0.007 (0.006)	0.031 (0.001)	0.025 (0.011)	0.028 (0.001)
$\Delta \ln mc_{t-6}$	-0.015 (0.008)	0.023 (0.001)	-0.026 (0.012)	0.021 (0.001)
Constant	0.033 (0.003)	-0.000 (0.000)	-0.004 (0.003)	-0.000 (0.000)
Long-run	0.252 (0.007)	0.354 (0.003)	0.262 (0.018)	0.417 (0.003)

Table 3: ‘Quantitative’ Experiment: Degree of Pass-Through. *Note:* The calibration that supports these results is: $\eta = 0.1$, $\psi = 10$. The model is simulated 500 times for 2900 periods. The coefficients estimated by Nakamura and Zerom (2010) are from columns 1 and 2 of Table 1 in their paper. As in this paper and in Goldberg and Campa (2006), we compute the simulated long-run pass-through as $\sum_{k=0}^6 \beta_{ik}$. Standard errors are in parentheses.

Coefficient	NZ(2010) Data	Model
$\Delta \ln p_{Wt}$	0.958 (0.131)	0.379 (0.004)
$\Delta \ln p_{Wt-1}$	-0.050 (0.180)	0.429 (0.004)
$\Delta \ln p_{Wt-2}$	-0.027 (0.129)	0.102 (0.003)
Constant	0.005 (0.001)	-0.000 (0.000)

Table 4: ‘Quantitative’ Experiment: Pass-Through of Wholesale to Retail Price. *Note:* The calibration that supports these results is: $\eta = 0.1$, $\psi = 10$. The model is simulated 500 times for 2900 periods. The coefficients estimated by Nakamura and Zerom (2010) are from Table 2 in their paper. Standard errors are in parentheses.

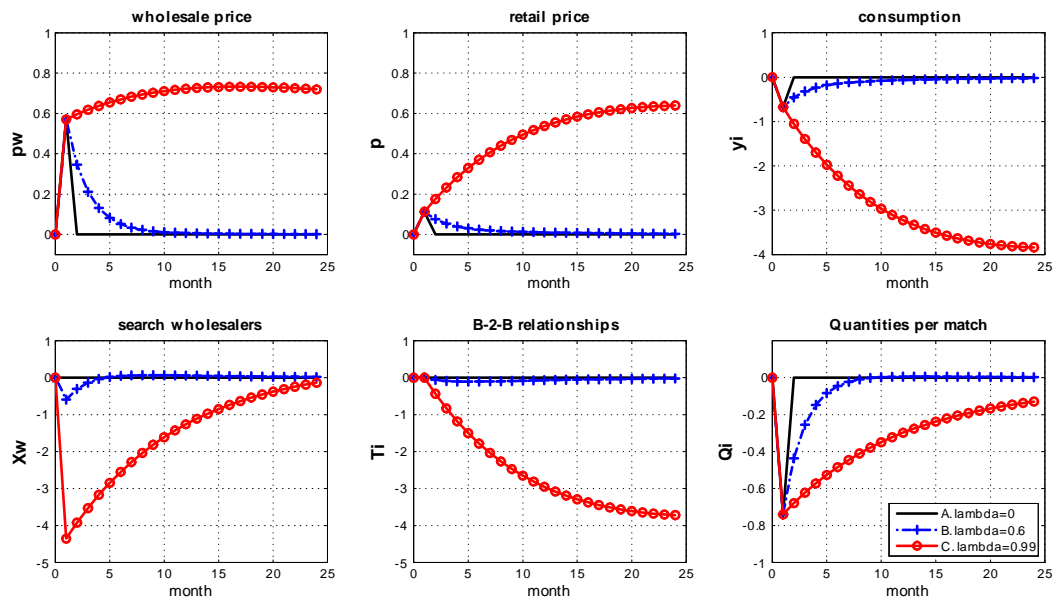


Figure 1: Marginal Cost Shock: Persistence of the Shock. *Note:* The shock is a one unit increase in marginal costs. All of the parameters assume their baseline values, except for the persistence of the shock λ .

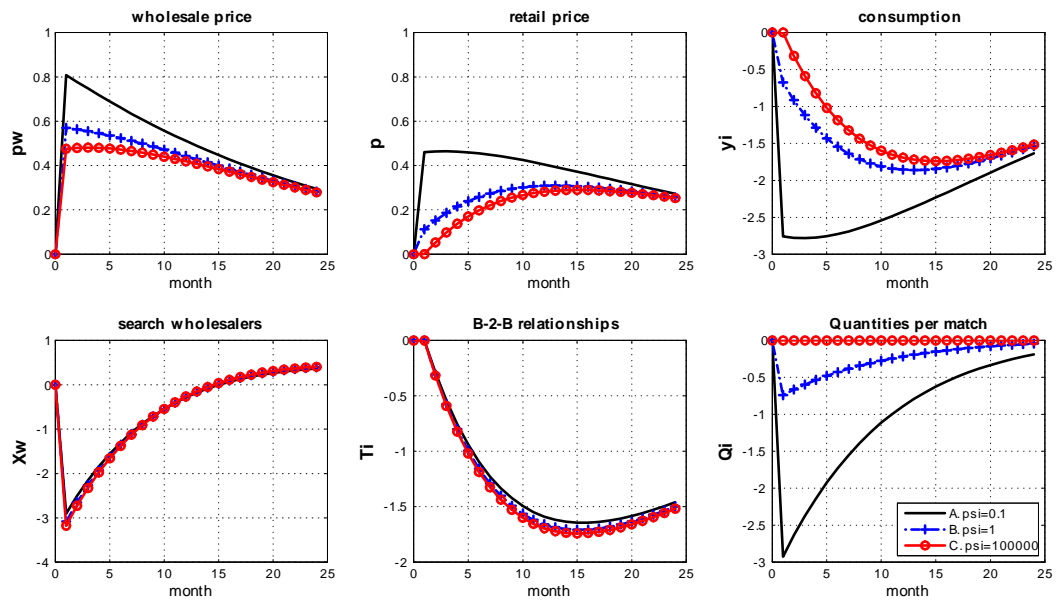


Figure 2: Persistent Marginal Cost Shock: Intensive Margin of Adjustment. *Note:* The shock is a one unit increase in marginal costs. For each adjustment cost ψ , the persistence of the shock is set to $\lambda = 0.95$.

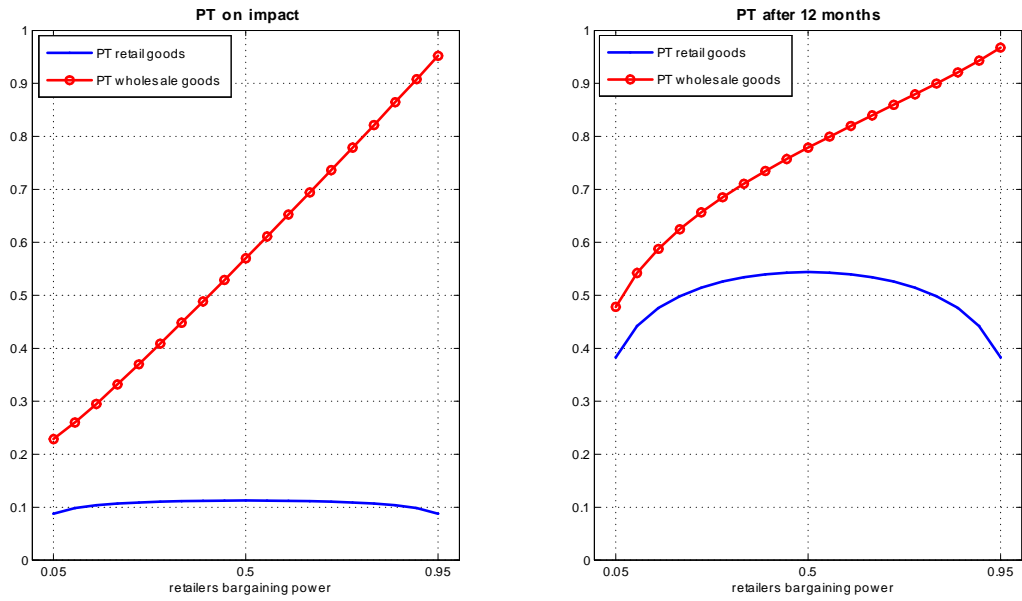


Figure 3: Bargaining Power of Firms and Pass-Through. *Note:* The pass-through is the effect of marginal cost shocks on prices for various values of the bargaining power η . For each η , the persistence of the shock is set to $\lambda = 0.95$.

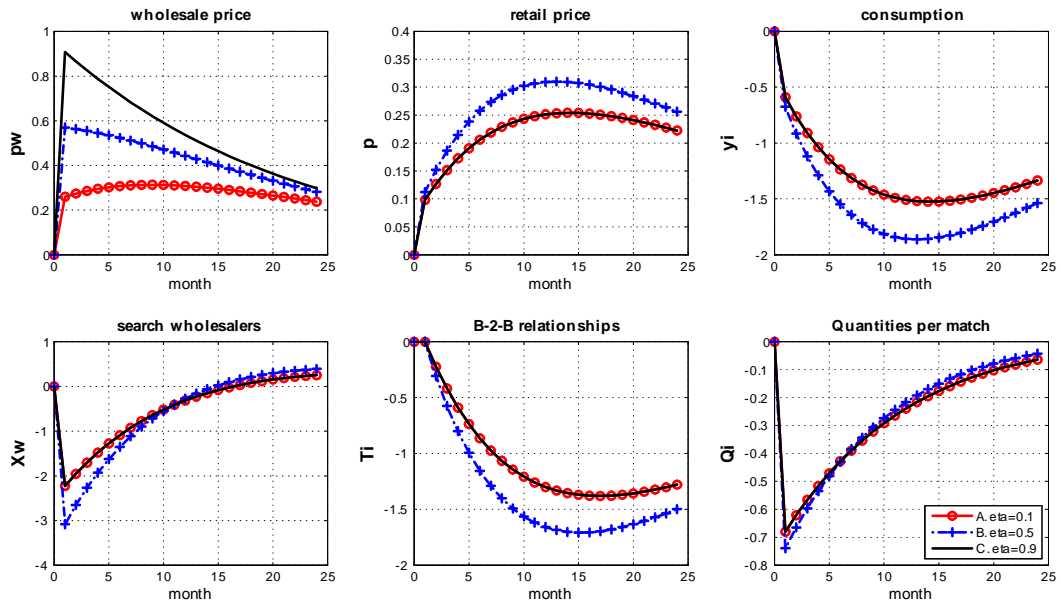


Figure 4: Persistent Marginal Cost Shock: Bargaining Power of Firms. *Note:* The shock is a one unit increase in marginal costs. For each bargaining power η , the persistence of the shock is set to $\lambda = 0.95$.

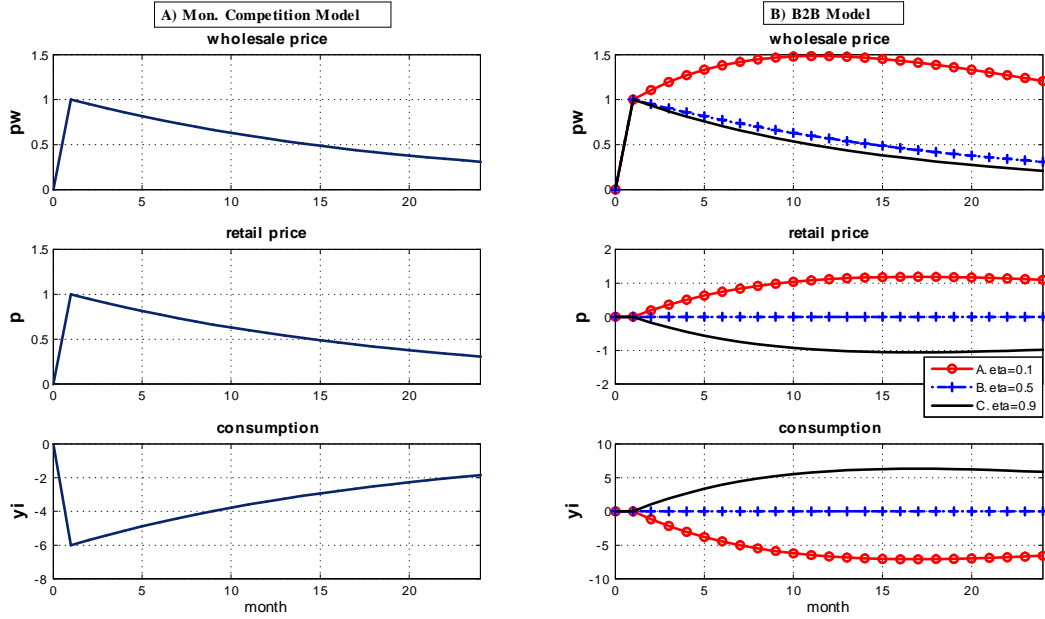


Figure 5: Allocative Power of Wholesale Prices: Monopolistic Competition vs. B2B. *Note:* The shock is an increase in the wholesale price p_{Wt} caused by a one unit decrease in the bargaining power η . The persistence of the shock is set to $\lambda_\eta = 0.95$. For the B2B model, we consider three initial values of η .

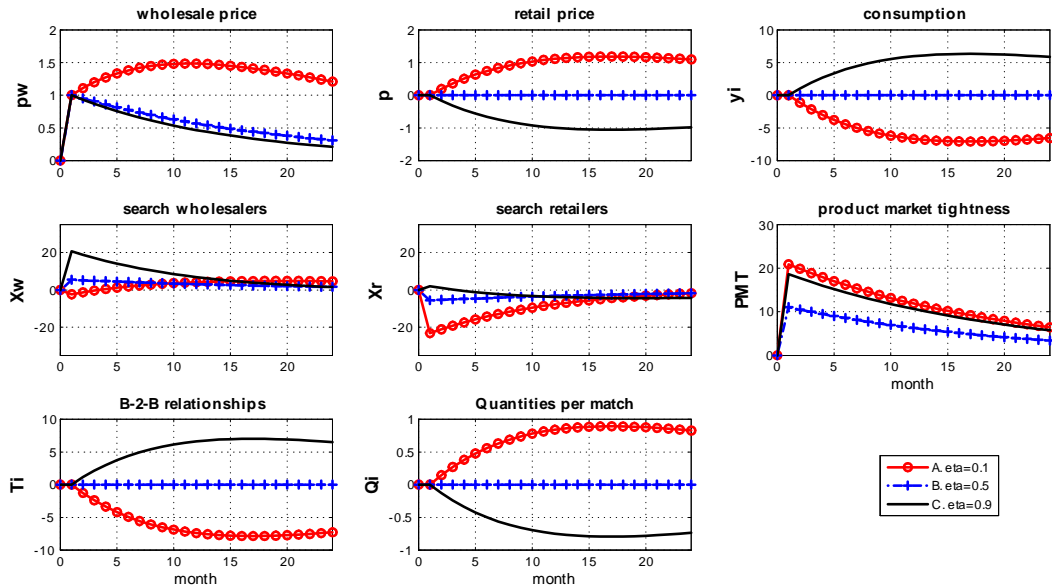


Figure 6: Persistent Wholesale Price Shock in the B2B Model. *Note:* The shock is an increase in the wholesale price p_{Wt} caused by a one unit decrease in the bargaining power η . For each initial value of η , the persistence of the shock is set to $\lambda_\eta = 0.95$.

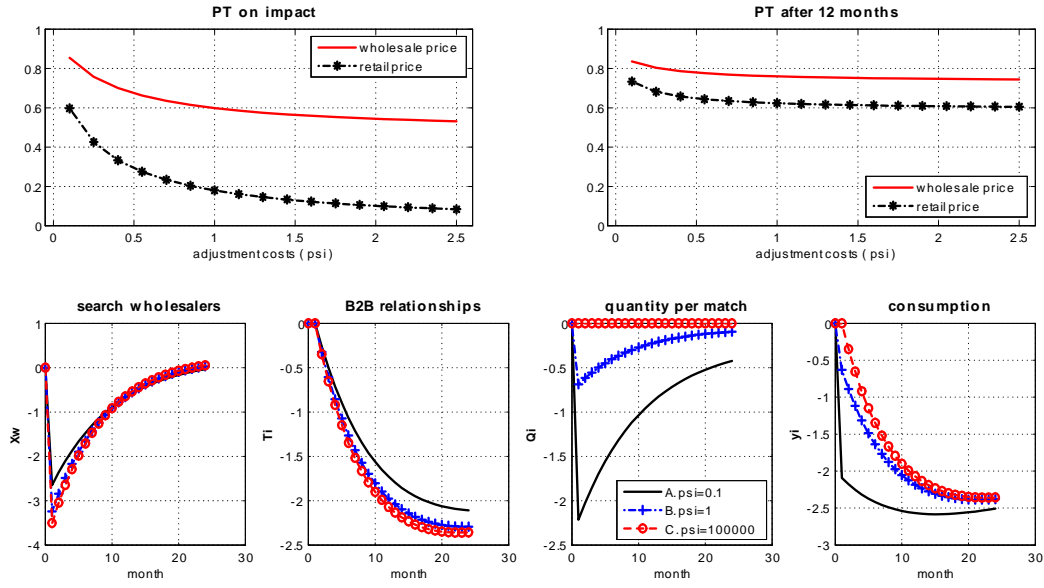


Figure 7: Persistent Currency Appreciation: Pass-Through and Intensive Margin in the Foreign Country. *Note:* The shock is a one unit decrease in the nominal exchange rate. For each adjustment cost ψ , the persistence of the shock is set to $\lambda_e = 0.99$.

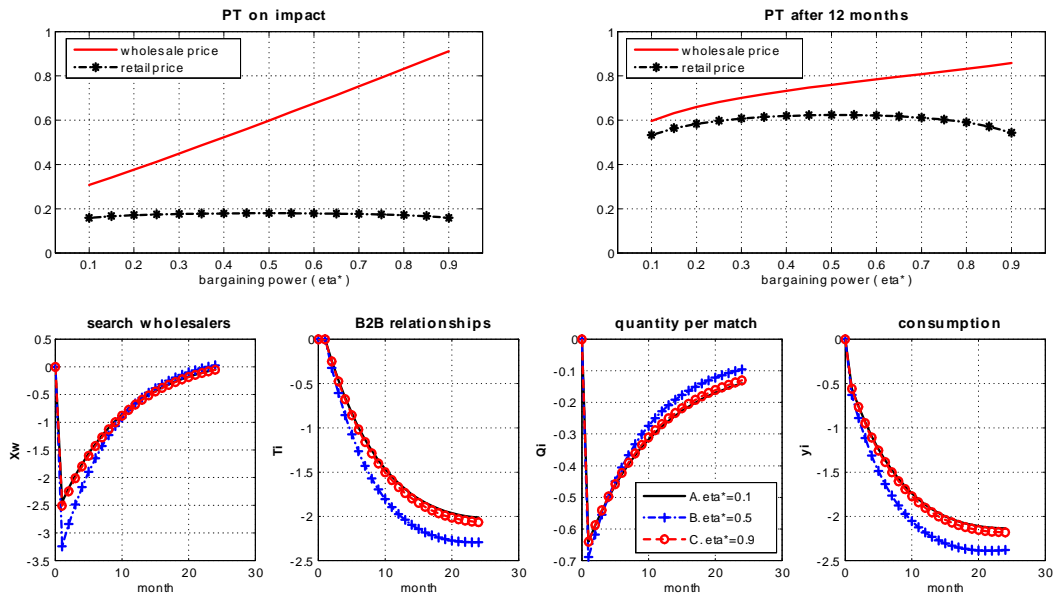


Figure 8: Persistent Currency Appreciation: Pass-Through and Bargaining Power of Foreign Retailers. *Note:* The shock is a one unit decrease in the nominal exchange rate. For each bargaining power of foreign retailers η^* , the persistence of the shock is set to $\lambda_e = 0.99$.