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WORKING PAPER SERIES

NO 1036 / MARCH 2009

SEARCH IN THE  
PRODUCT MARKET  
AND THE REAL  
BUSINESS CYCLE

by Thomas Y. Mathä  
and Olivier Pierrard



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# SEARCH IN THE PRODUCT MARKET AND THE REAL BUSINESS CYCLE<sup>1</sup>

by Thomas Y. Mathä  
and Olivier Pierrard<sup>2</sup>

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## Wage Dynamics Network

This paper contains research conducted within the Wage Dynamics Network (WDN). The WDN is a research network consisting of economists from the European Central Bank (ECB) and the national central banks (NCBs) of the EU countries. The WDN aims at studying in depth the features and sources of wage and labour cost dynamics and their implications for monetary policy. The specific objectives of the network are: i) identifying the sources and features of wage and labour cost dynamics that are most relevant for monetary policy and ii) clarifying the relationship between wages, labour costs and prices both at the firm and macro-economic level.

The WDN is chaired by Frank Smets (ECB). Giuseppe Bertola (Università di Torino) and Julian Messina (Universitat de Girona) act as external consultants and Ana Lamo (ECB) as Secretary.

The refereeing process of this paper has been co-ordinated by a team composed of Gabriel Fagan (ECB, chairperson), Philip Vermeulen (ECB), Giuseppe Bertola, Julian Messina, Ian Babetskii (CNB), Hervé Le Bihan (Banque de France) and Thomas Mathä (Banque centrale du Luxembourg).

The paper is released in order to make the results of WDN research generally available, in preliminary form, to encourage comments and suggestions prior to final publication. The views expressed in the paper are the author's own and do not necessarily reflect those of the ESCB.

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# CONTENTS

Abstract	4
Non-technical summary	5
1 Introduction	6
2 On firms' business environment	8
Tables and figures	10
3 Model	11
3.1 Households	11
3.2 Wholesale firms	12
3.3 Retail firms	13
3.4 Price formation	14
3.5 Equilibrium definition	15
4 Inefficiency sources	15
5 Calibration	16
6 Simulations	18
7 Welfare cost of inefficiencies	20
8 Conclusion	22
References	25
European Central Bank Working Paper Series	31

## Abstract

We develop a search-matching model, where firms search for customers (e.g. in form of advertising). Firms use long-term contracts and bargain over prices, resulting in a price mark up above marginal cost, which is procyclical and depends on firms' relative bargaining power. Product market frictions decrease the steady state equilibrium, improve the cyclical properties of the model and provide a more realistic picture of firms' business environment. This suggests that product market frictions may well be crucial in explaining business cycle fluctuations. Finally, we also show that welfare costs of price rigidities are negligible relative to welfare costs of frictions.

Keywords: Business cycle, Frictions, Product market, Price bargain

JEL Classification: E10, E31, E32

## Non-technical summary

In the Walrasian real business cycle model (RBC), the product market is perfectly competitive and all adjustments occur without frictions. This may however be considered too simplistic a world. Empirical evidence suggests that most firms operate in imperfectly competitive markets, where they have some pricing power, and form long-term relationships with their customers, which are predominantly other firms. These relationships are typically governed by implicit or explicit contracts. Available evidence also shows that firms produce substantial effort, typically in form of advertising or marketing, to find new customers and sell their products to. For instance, in the US total advertising expenditures have been close to 2.5% of GDP over the last 10 years.

This paper aims to account for those stylized facts and provide a more realistic story of business relationships and the price formation mechanism. To this end, we depart from the Walrasian RBC model in two aspects. First, we replace the perfectly competitive market assumption standard to the RBC model and develop a search-matching model à la Diamond-Mortensen-Pissarides, where firms produce effort (search, advertising) to form long-term contractual relationships and bargain over prices. In our approach, downstream producers act as wholesalers and bargain over prices with upstream retailers who in turn sell to final consumers. Retailers act as intermediaries between producers and consumers; they alleviate the search costs for final consumers. We believe that this is fair characterization of most product markets in industrialized economies. Only in very special markets do producers sell directly to consumers without intermediaries. Second, we introduce rigidities into a price bargaining process. We therefore provide a story how wholesalers and retailers meet in the market and for the subsequent price formation mechanism between them.

Our key findings are as follows: First, the price bargain results in mark up pricing above marginal cost. The mark up is procyclical and depends on the relative bargaining power of the wholesalers and the retailers. The procyclicality of the mark up arises even without price rigidities. Second, introducing frictions in the product market decreases the steady state equilibrium and improves the cyclical properties. More precisely, frictions (i) increase employment volatility, (ii) break the strong correlation between variables observed in the standard RBC model, (iii) increase output persistence, (iv) generate hump-shape impulse response functions for all variables and (v) provide a realistic description of advertising and price behavior. Our frictions in the product market may therefore be crucial (and maybe more crucial than frictions in the labor market or frictions between retailers and consumers) in explaining business cycle fluctuations. Third, price rigidities only have a weak effect on the cyclical properties of other variables, and welfare costs of price rigidities are negligible relative to welfare costs of frictions.

# 1 Introduction

In the standard Walrasian real business cycle model (hereafter RBC, see for instance King and Rebelo (1999) for an in depth exposition), the product market is perfectly competitive and adjustments occur without frictions. However, empirical evidence clearly shows that this may be considered too simplistic a world. Empirical evidence suggests that most firms operate in imperfectly competitive markets, where they have some power of setting prices themselves, and form long-term relationships with their customers, which are predominantly other firms. These relationships are typically governed by implicit or explicit contracts. Available evidence also shows that firms produce substantial effort, typically in form of advertising or marketing, to find new customers and sell their products to. For instance, in the US total advertising expenditures have been close to 2.5% of GDP over the last 10 years. This effort may also cause an economic chain reaction by increasing sales, consumption and employment.

Given the above stylised facts evidence, this paper aims to provide a more realistic story of business relationships and price formation mechanism. We develop a search-matching model, where firms produce effort (search, advertising) to form long-term contractual relationships and bargain over prices with their customers. Our model only departs from the standard RBC model in two aspects. First, we replace the Walrasian product market of the standard business cycle model with a product market with frictions by following Pissarides (2000) and the associated search-matching literature. In our model, downstream producers act as wholesalers and bargain over prices with upstream retailers, who in turn sell to final consumers. Retailers act as intermediaries between producers and consumer; they alleviate the search costs for final consumers. We believe that this is fair characterization of most product markets in industrialized economies. Only in very special markets do producers sell directly to consumers without intermediaries. Second, we introduce rigidities into a price bargaining process.

With respect to the first departure from the RBC model, in the original search environment developed by Pissarides, Merz (1995), Andolfatto (1996) and others, the focus is on the labor market, where firms' and unemployed people's decisions to open vacancies and to search for jobs are used as complementary inputs into an aggregate matching function. In this paper, we follow the same approach, but transfer the frictions into the product market. Wholesalers produce effort (e.g. advertising or marketing) to find retailers to sell their products to. Retailers produce effort (e.g. by employing purchasing managers) to find wholesalers to buy their products from in order to refill their stores and enlarge their selection. The amount of products exchanged therefore depends on their respective search efforts. Moreover, every buyer-seller contact generates a surplus over which the wholesaler and the retailer bargain. We therefore provide a story how wholesalers and retailers meet in the market and for the subsequent price formation mechanism between them. Regarding the second departure from the RBC model,

the empirical evidence summarized in section 2 shows very persuasively that most firms' main business customers are other firms, with whom they engage in long-term relationships, which are often governed by explicit or implicit contracts. In particular, Zbaracki et al. (2004) provide compelling evidence in favor of substantial customer negotiation costs, which are convex in the size of the price adjustment. Still, our model makes use of a simple representation and remains very close to the standard RBC model. We provide an in depth exploration of the RBC and welfare properties, and find that adding frictions and price bargaining in the product market (between wholesalers and retailers) improves correlations between real data and the model, even more so than introducing frictions and bargaining into other markets, instead.

Most papers introducing imperfections in the product market assume monopolistic wholesalers, as Blanchard and Giavazzi (2003), Messina (2006) or the recent DSGE literature (see for instance Christiano et al. (2005) or Smets and Wouters (2003)). Alternatively, in Fagnart et al. (2007), wholesalers experience privately observed and uninsured idiosyncratic shocks, which generates a sub-optimal equilibrium. But none of these approaches allow for bilateral relationships and negotiations between wholesalers and retailers. Very recent related approaches that aim at providing better descriptions of customer-firm relationships are those by Hall (2008), Arsenau and Chugh (2007) and Kleshchelski and Vincent (2007). Hall (2008) explores customer search and seller recruiting by adapting principles of the labour market search and matching models to the product market. In his model, producers invest heavily in attracting final customers, as they receive a large share of the surplus. Hall's approach is concerned with retail markets, and there are frictions but no bargaining between customers and sellers. Arsenau and Chugh (2007) extend Hall's model and explore the effects of different bargaining assumptions. They specifically set out to analyse how the distributive role of prices through the notion of fairness affects price dynamics. In Kleshchelski and Vincent (2007), customers incur switching costs. Customers and firms form long-term relationships and idiosyncratic marginal shocks are only incompletely passed through into prices. However, all three approaches are concerned with the relationship between retail firms and final consumers, whereas our model provides a story of firms' relationships and of the price formation process, and compares simulation results to real data.

We acknowledge that the model in this paper can only provide a very simplistic view of what in reality can be considered a rather complex relationship between buyer and seller. Clearly, contracting parties do not only specify prices in their contracts, but also quantities, discounts, after sales services, etc... However, we believe that the agreed price is the most fundamental of these contractual specifications; without it there is no trade of goods, not even in a barter economy. This is precisely why we focus on this particular aspect and abstract from all other product market contractual issues.

Our key findings are as follows: First, the price bargain results in mark up pricing above



marginal cost. The mark up is procyclical and depends on the relative bargaining power of the wholesalers and the retailers. The procyclicality of the mark up arises even without price rigidities. Second, introducing frictions in the product market decreases the steady state equilibrium and improves the cyclical properties. More precisely, frictions (i) increase employment volatility, (ii) break the strong correlation between variables observed in the standard RBC model, (iii) increase output persistence, (iv) generate hump-shaped IRF's for all variables and (v) provide a realistic description of advertising and price behavior. Our frictions in the product market between wholesalers and producers may therefore well be crucial (and maybe more crucial than frictions in the labour market) in explaining business cycle fluctuations. Third, price rigidities only have a weak effect on the cyclical properties of other variables, and welfare costs of price rigidities are negligible relative to welfare costs of frictions.

Section 2 provides some selective evidence on the product market functioning and further motivation of this paper. Sections 3 and 4 develop and discuss the search-matching model with frictions in the product market and price bargain. Sections 5 and 6 present the calibration and some numerical simulations for US data. Section 7 computes the welfare costs of the different inefficiencies and section 8 concludes.

## 2 On firms' business environment

It is widely accepted that most firms operate in markets, which are governed by imperfections or frictions. By providing search effort firms try to overcome market imperfections. This is motivated by recent evidence, in particular from recent firm surveys. Following the lead by Blinder et al. (1998) firm surveys have been conducted for several industrial countries/areas over the last decade, which improved our understanding of firms' business environment and price setting practices.<sup>1</sup> According to those surveys, it seems that a fair characterisation of a typical or representative firm's business environment is that it operates an imperfectly competitive market and uses some form of mark up pricing above marginal cost as its predominant form of price-setting practice, thereby implying that it is able to exert some market power.<sup>2</sup> This firm engages in business-to-business (B2B) rather than business-to-consumer (B2C) relationships, where it typically does most business with repeat customers and forms long-term relationships with them. A long-term relationship, which can also be regarded as one form of an implicit contract based on principles of trust and fairness, is an effective way to reduce search cost, which the firm otherwise would have to bear. Together, these surveys provide a strikingly coherent set of empirical results and a challenge to many modelling assumptions usually

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<sup>1</sup>See Amirault et al. (2004) for Canada, Fabiani et al. (2006, 2007) for 9 euro area (EA) countries, Nakagawa et al. (2000) for Japan, Apel et al. (2005) for Sweden and Hall et al. (2000) for the UK.

<sup>2</sup>For example, 54% of euro area firms answered that they use a mark up pricing strategy. 73% of euro area firms said that their main market is the domestic market. In Canada, the corresponding figure is 81%.

employed in standard Walrasian macroeconomic models.

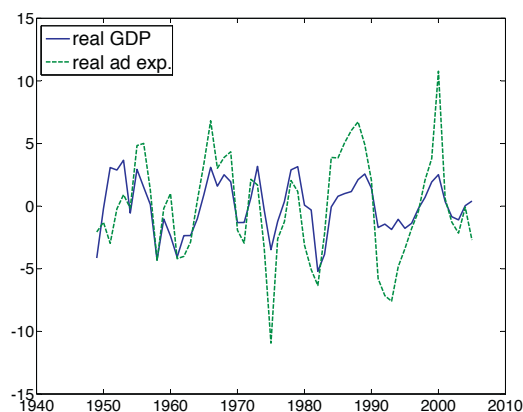
To substantiate the above points, consider that in the US, 85% of firms surveyed by Blinder et al. (1998) indicate that they mainly engage in long-term relationships with their customers. 77% of their main customers are other firms. The corresponding figures for other industrialised economies are of similar magnitudes (EA 70% and Sweden 86% for the share of long-term customers and 75 and 70% for the share of other firms as main customers). Furthermore, these long-term relationships are mainly governed by contracts. 50% of US firms responded that they have 60% or more of their sales covered by explicit or written contracts, which according to Blinder et al. (1998) is estimated to correspond to 38% of US GDP. The predominant share of contracts (75%) set prices; the contracts typically last one year (both the median and the mode are 12 months whereas the average is 20 months). Furthermore 64% of firms indicated that they have implicit contracts with their customers, i.e. an implicit understanding not to raise prices when the market is tight. Given this structure of firms' business relationships, it is therefore not surprising that both explicit and implicit contracts consistently appear among the mostly frequently recognized reasons for not changing prices. Explicit contracts are judged to be an important or very important source of price stickiness by 37% (GDP weighted) of US firms. Furthermore, this theory is of more importance for firms that are primarily engaged in B2B relationships. Surveys for other industrialised countries generally corroborate these findings (see Amirault et al. (2004), Apel et al. (2005) and Fabiani et al. (2006, 2007)).

Since the product market is necessarily imperfect, there is a need for search of customers, and thus advertising and marketing effort, and a need for search of suppliers. The need for advertising, marketing, promotions, public relations, and sales managers provided almost 600,000 jobs in 2006. Similarly, roughly an equally large number of people were engaged in purchasing and buying occupations (Bureau of Labor Statistics, 2007). This represents almost 0.5% of total US employment for each. And still in the US, total annual expenditures in advertising in all the media represented on average 2.5% of GDP over the last decades. In other words, advertising expenditures amounted to 271 billions US dollars in 2005. Figure 1 also shows that over the economic cycle, advertising expenditures are positively correlated with GDP, have a higher volatility than GDP, especially over the last years, and are very persistent. This figure includes spending for advertising in newspapers, magazines, radio, television, direct mail, billboards and displays, Internet, and other forms, and thus also includes the advertising that is directly targeted towards final consumers, such as car manufacturers' or pharmaceuticals' television adverts.<sup>3</sup> Although producers may directly target consumers, consumers buy via intermediaries and hence advertising towards consumers indirectly affects retailers.

Given the importance of contracts, what are the costs of adjusting prices and how are they

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<sup>3</sup>Source: [www.galbithink.org/ad-spending.htm](http://www.galbithink.org/ad-spending.htm).



Sources: [www.galbithink.org/ad-spending.htm](http://www.galbithink.org/ad-spending.htm). The yearly nominal series are GDP-deflated, logged and HP-filtered ( $\lambda = 100$ ) to extract the business cycle components.

Figure 1: Cyclical fluctuations of real advertising expenditures

negotiated? Here, the most compelling evidence is reported by Zbaracki et al. (2004) for one large US industrial manufacturing firm. They differentiate between physical costs (i.e. menu costs), managerial costs (i.e. information gathering, decision making and internal communication costs) and customer costs (i.e. customer communication and price negotiation costs) and estimate the latter to be 20 times the size of the menu costs, thus accounting for almost 75% of the total price adjustment cost. The required (re-)negotiation of prices with customers, in particular, is reported to be very costly when changing prices, as the negotiations require tailoring to each customer and a substantial time and manpower effort (costs for visiting customers, time spent for the preparing price offers, negotiating prices, actual travel). In case of a price increase it is reported that 60% plus of the key customers require further negotiations. Thus, price negotiations can be regarded the rule rather than the exception; they act as a source of price rigidity. Finally, Zbaracki et al. (2004) report that managerial and customer costs are convex in the size of the price adjustment, while menu costs are not.

This paper aims at providing a story of the price formation mechanism between firms. Given the presented evidence further investigations of these relationships in general and their price formation mechanism in particular seem warranted. In this respect, both the reported importance and the convexity of the negotiation costs is very interesting. It runs somewhat counter to recent evidence on micro consumer prices suggesting very infrequent and sizable price adjustment (see Bils and Klenow (2004); Dhyne et al. (2006)). However, recent evidence on the frequency and the size of individual producer price adjustments points toward comparatively more frequent, but smaller price adjustments (see Vermeulen et al. (2007)), which is consistent with a substantial proportion of adjustment costs being convex, as argued to be the case in Zbaracki et al. (2004).

### 3 Model

There are three types of agents in the economy: households, wholesale firms and retail firms. Goods are produced by wholesale firms and consumed by households. However, conversely to the standard real business cycle literature, we do not assume that products are directly exchanged between producers and consumers; instead we introduce retailers as intermediaries. Retailers buy from producers, who act as wholesalers, and sell to households. Trade frictions are present in the product market between wholesalers and retailers, and we provide an explicit theory of price determination since every wholesaler-retailer contract generates a surplus over which firms bargain. More precisely, the product market consists of a two-sided search market between sellers (wholesale firms) and buyers (retail firms). Let  $T_t$  be the number of contracts between wholesale-retail pairs at period  $t$ , a contract meaning that both parties agree to exchange one unit of output. These contracts terminate and the pairs separate at the exogenous rate  $0 < \chi < 1$ . The contract duration is, thus, on average given by  $d = 1/\chi$ . This results in a continuous depletion of the stock of contracts, and thus trade volume, and consequently a need to refill it. In order to do so, wholesale firms provide a search effort  $S_t$  (marketing or advertising expenditures) to find new buyers; and retail firms provide a search effort  $D_t$  (by purchasing agents) to find new sellers. The number of new matches between sellers and buyers is increasing and concave in the search efforts, and assumed to be generated by a standard Cobb-Douglas matching function:

$$M_t = \bar{m} S_t^\gamma D_t^{1-\gamma}, \quad (1)$$

where  $\bar{m} > 0$  and  $0 < \gamma < 1$ . In analogy to the labour market, the relationship between the search effort of wholesalers and retailers can be regarded as a product market equivalent of the “Beveridge curve”. It has search effort of wholesalers on the vertical axis and search effort of retailers on the horizontal. It slopes downwards as wholesalers produce higher effort (advertising) when retailers are reluctant buying goods. Downward and upward shifts in this curve would signify structural improvements and deteriorations in the efficiency of the matching process, respectively. Movements along the curve, in contrast, imply a cyclical adjustment without alteration of the matching efficiency.

The trade volume evolves according to:

$$T_t = (1 - \chi)T_{t-1} + M_t. \quad (2)$$

#### 3.1 Households

The economy is populated by a large number of infinitively lived households. Their time endowment is normalized to 1 and split between work  $N_t$  and leisure  $1 - N_t$ . Their current utility



is defined as:

$$\mathcal{U}(C_t, 1 - N_t) = \log(C_t) + \frac{\theta}{1 - \eta} \left( (1 - N_t)^{1 - \eta} - 1 \right), \quad (3)$$

where  $C_t$  represents consumption. Utility is assumed to be concave in its arguments and specified as in King and Rebelo (1999):  $\theta \geq 0$  and  $\eta \geq 0$  is the parameter governing the labor supply elasticity. Households receive an income from lending capital to wholesale firms at interest rate  $r_t + \delta$ , and from working at a wage rate  $w_t$ . In each period, they choose the size of the capital investment  $I_t$  and labor supply  $N_t$ , in order to maximize the present discounted value of their life-time utility<sup>4</sup>:

$$W_t^H = \max_{I_t, N_t} \left\{ \mathcal{U}(C_t, 1 - N_t) + \beta W_{t+1}^H \right\}, \quad (4)$$

subject to the constraints:

$$C_t + I_t = w_t N_t + (r_t + \delta) K_t + \Pi_t, \quad (5)$$

$$I_t = K_{t+1} - (1 - \delta) K_t, \quad (6)$$

where  $\beta$  denotes the discount factor. Equation (5) is the budget constraint. Households own both the wholesale and the retail firms and ultimately receive their profits  $\Pi_t$ . Equation (6) is the capital accumulation equation and  $\delta$  denotes the exogenous capital destruction rate. The first order conditions are:

$$\frac{1}{C_t} = \beta(1 + r_{t+1}) \frac{1}{C_{t+1}}, \quad (7)$$

$$\frac{\theta}{(1 - N_t)^\eta} = \frac{w_t}{C_t}. \quad (8)$$

### 3.2 Wholesale firms

The economy is composed of a continuum of identical wholesale firms using capital  $K_t$  and labor  $N_t$  to produce tradable products  $T_t$ , through a Cobb-Douglas production function:

$$T_t = \epsilon_t K_t^\alpha N_t^{1 - \alpha}, \quad (9)$$

where  $\epsilon_t$  is a productivity shock and  $0 < \alpha < 1$ . Given the selling price  $P_t$ , the firms choose their optimal search effort, i.e. level of advertising expenditures  $S_t$  to find new buyers, as well as the optimal capital-labor ratio to produce the output level  $T_t$ . They take as given  $q_t^S$ , the rate at which every effort leads to a new match. The rate is defined as:

$$q_t^S = M_t / S_t. \quad (10)$$

<sup>4</sup>One has to bear in mind that all future variables are actually conditional expectations based on the information available at time  $t$ . For instance,  $Z_{t+j}$  stands for  $E_t(Z_{t+j})$ , where  $Z_t$  may be any variable or combination of variables. Our simplified notation is however easier to read.

Hence, the problem faced by each firm can be summarized by the following dynamic programming problem:

$$W_t^W = \max_{S_t, N_t} \left\{ P_t T_t - w_t N_t - (r_t + \delta) K_t - \kappa \frac{S_t^2}{2} - \phi \frac{(P_t - P_{t-1})^2}{2} T_t + \beta_t W_{t+1}^W \right\}, \quad (11)$$

subject to the constraints (2), (9) and (10).  $w_t$  and  $r_t + \delta$  are respectively the labor and the capital costs. We impose a quadratic search cost with  $\kappa \geq 0$ <sup>5</sup> and a quadratic price adjustment cost with  $\phi \geq 0$ <sup>6</sup>. The discount factor  $\beta_t$  is compatible with the pricing kernel of the consumers-shareholders:

$$\beta_t = \beta \frac{U_{C_{t+1}}}{U_{C_t}}. \quad (12)$$

The first order condition for the search intensity is:

$$\frac{\kappa S_t}{q_t^S} = P_t - \Lambda_t - \phi \frac{(P_t - P_{t-1})^2}{2} + \beta_t (1 - \chi) \frac{\kappa S_{t+1}}{q_{t+1}^S}, \quad (13)$$

where  $\Lambda_t$  is the real marginal cost and given by:

$$\Lambda_t = \frac{1}{\epsilon_t} \left( \frac{w_t}{1 - \alpha} \right)^{1-\alpha} \left( \frac{r_t + \delta}{\alpha} \right)^\alpha. \quad (14)$$

The optimal capital-labor ratio is:

$$\frac{K_t}{N_t} = \frac{\alpha}{1 - \alpha} \frac{w_t}{r_t + \delta}. \quad (15)$$

### 3.3 Retail firms

The economy is also composed of a continuum of identical retail firms buying tradable products  $T_t$ , and selling them to households. At given buying price  $P_t$ , the firms choose their optimal search effort  $D_t$ , i.e. by setting aside the necessary number of purchasing and buying employees, to find and bargain with new wholesalers. They take as given  $q_t^D$ , the rate at which every effort leads to a new match. The rate is defined as:

$$q_t^D = M_t / D_t. \quad (16)$$

Hence the problem faced by each firm can be summarized by the following dynamic programming problem:

$$W_t^R = \max_{D_t} \left\{ T_t - P_t T_t - \kappa \frac{D_t^2}{2} - \phi \frac{(P_t - P_{t-1})^2}{2} T_t + \beta_t W_{t+1}^R \right\}, \quad (17)$$

<sup>5</sup>See Merz (1995) for a similar approach in a business cycle model with frictions in the labor market.

<sup>6</sup>We here follow the elegant approach of Rotemberg (1982, 1983) and introduce price rigidities through convex price adjustment costs. This approach is justified in section 2. An alternative would be to introduce price rigidities through Taylor (1999) or Calvo (1983) contracts. At the macro level, both approaches are however equivalent.

subject to the constraints (2) and (16). We impose the same quadratic search cost as for wholesale firms with  $\kappa \geq 0$ , and the same quadratic price adjustment cost as for wholesale firms with  $\phi \geq 0$ . The discount factor  $\beta_t$  is still defined by (12). The first order condition for the search intensity is:

$$\frac{\kappa D_t}{q_t^D} = 1 - P_t - \phi \frac{(P_t - P_{t-1})^2}{2} + \beta_t(1 - \chi) \frac{\kappa D_{t+1}}{q_{t+1}^D}. \quad (18)$$

### 3.4 Price formation

Each product market match yields pure economic rents equal to the expected search costs for wholesalers and retailers (including foregone profits). The agreed price is such that these rents are shared and in addition each party is compensated for its incurred costs of forming the match. We follow the labour market literature (see for instance Pissarides (2000)) and assume that the rent sharing is a solution to a Nash (1950) bargaining problem. More precisely, prices are (re-)negotiated between wholesalers and retailers at the beginning of every period through a Nash bargain over the surplus resulting from the match. Because all firms are identical, the price is the same throughout the economy:

$$\max_{P_t} \left( \frac{\partial W_t^W}{\partial T_t} \right)^{1-\lambda} \left( \frac{\partial W_t^R}{\partial T_t} \right)^\lambda, \quad (19)$$

where  $0 \leq \lambda \leq 1$  is the retailer bargaining power. This gives:

$$\lambda \frac{\partial W_t^W}{\partial T_t} \frac{\partial^2 W_t^R}{\partial P_t \partial T_t} + (1 - \lambda) \frac{\partial W_t^R}{\partial T_t} \frac{\partial^2 W_t^W}{\partial P_t \partial T_t} = 0, \quad (20)$$

where, from equations (11) and (17), the marginal values are respectively:

$$\frac{\partial W_t^W}{\partial T_t} = P_t - \Lambda_t - \phi \frac{(P_t - P_{t-1})^2}{2} + \beta_t(1 - \chi) \frac{\partial W_{t+1}^W}{\partial T_{t+1}}, \quad (21)$$

$$\frac{\partial W_t^R}{\partial T_t} = 1 - P_t - \phi \frac{(P_t - P_{t-1})^2}{2} + \beta_t(1 - \chi) \frac{\partial W_{t+1}^R}{\partial T_{t+1}}, \quad (22)$$

$$\frac{\partial^2 W_t^W}{\partial P_t \partial T_t} = 1 + \phi (P_{t-1} - P_t + \beta_t(1 - \chi)(P_{t+1} - P_t)), \quad (23)$$

$$\frac{\partial^2 W_t^R}{\partial P_t \partial T_t} = -1 + \phi (P_{t-1} - P_t + \beta_t(1 - \chi)(P_{t+1} - P_t)). \quad (24)$$

If we have no price adjustment cost ( $\phi = 0$ ), then equation (20) simplifies to:

$$\lambda \frac{\partial W_t^W}{\partial T_t} = (1 - \lambda) \frac{\partial W_t^R}{\partial T_t}, \quad (25)$$

which gives, using equations (21) and (22):

$$P_t = \lambda \Lambda_t + (1 - \lambda). \quad (26)$$

Prices are therefore a weighted average of the marginal cost and 1, and increasing (resp. decreasing) in the bargaining power of the wholesalers (resp. retailers). If wholesalers have no bargaining power, the price is equal to their marginal cost. In all other cases, prices are a mark up over marginal cost with the size of the mark up depending on firms' relative bargaining power.<sup>7</sup> Also, we obtain that the mark up is procyclical, and this procyclicality would obviously increase with price rigidities.

### 3.5 Equilibrium definition

Given initial conditions on  $K_t$ , an equilibrium of this economy is a sequence of prices  $\{\mathcal{P}_t^r\}_{t=0}^\infty = \{r_t, w_t, P_t\}_{t=0}^\infty$  and a sequence of quantities  $\{Q_t\}_{t=0}^\infty = \{C_t, K_{t+1}, S_t, N_t, D_t\}_{t=0}^\infty$  such that:

- given a sequence of prices  $\{\mathcal{P}_t^r\}_{t=0}^\infty, \{C_t, K_{t+1}\}_{t=0}^\infty$  are solutions to the household solution (7) and the product market law of motion (2)
- given a sequence of prices  $\{\mathcal{P}_t^r\}_{t=0}^\infty, \{S_t, N_t\}_{t=0}^\infty$  are solutions to the wholesaler solutions (13) and (15)
- given a sequence of prices  $\{\mathcal{P}_t^r\}_{t=0}^\infty, \{D_t\}_{t=0}^\infty$  is solution to the retailer solution (18)
- given a sequence of quantities  $\{Q_t\}_{t=0}^\infty, \{r_t, w_t\}_{t=0}^\infty$  clear the capital market (5) and the labour market (8)
- the price  $\{P_t\}_{t=0}^\infty$  is set according to the Nash bargain solution (20)

## 4 Inefficiency sources

The economy we describe is characterised by three sources of inefficiency. The first source is search costs that induce an inefficiently low level of output. Proposition 1 shows that when search costs disappear, the steady state tends to the Walrasian steady state: labor and capital are priced at their respective marginal productivity, firms make no profit and output is maximised<sup>8</sup>.

### Proposition 1 (*Search costs and Walrasian output*)

When  $\kappa \rightarrow 0$  (no search costs), the steady state solution tends to the Walrasian one.

<sup>7</sup>Note that  $P_t$  represents a real producer price (price of final/consumer products are still normalized to 1 as in a standard real business cycle model). The mark up  $= \frac{P_t}{\Lambda_t} = \lambda + \frac{1-\lambda}{\Lambda_t}$  and, following the terminology of Goodfriend and King (1997), the marginal mark up is equal to the average mark up because all wages are (re-)negotiated every period.

<sup>8</sup>Although the steady state tends to the Walrasian one, still the dynamics are different from the dynamics of a standard Walrasian real business cycle.



**Proof.** When  $\kappa \rightarrow 0$ , first order conditions (13) and (18) simplify to  $P = \Lambda$  and  $P = 1$ . Combining  $\Lambda = 1$  with equations (14) and (15), we obtain  $w = (1 - \alpha)\epsilon(K/N)^\alpha$  and  $r + \delta = \alpha\epsilon(K/N)^{\alpha-1}$ . This means that prices are normalized to 1, wages are equal to the marginal productivity of labor and interest rates (incl. depreciation) are equal to the marginal productivity of capital. Moreover, by replacing  $P$ ,  $w$ ,  $r + \delta$  in equations (11) and (17) and using (9), we see that profits of wholesalers and retailers are equal to zero. This solution is therefore equivalent to the Walrasian one. ■

The second source of inefficiency results from the search externalities. In a decentralized economy, search process exhibits externalities, and in most cases, the decentralized equilibrium is different from the social planner's equilibrium. With search frictions in the labor market, Hosios (1990), in a static environment, and Merz (1995), in a dynamic environment, show that an efficiency condition (workers' bargaining power equal to unemployed's elasticity in the matching function) exists such that the externalities are internalized and the decentralized outcome is strictly equivalent to the social planner's outcome. In proposition 2, we show that a similar condition exists when the search frictions are in the product market.

**Proposition 2** (*Externalities in the decentralized economy*)

We assume  $\phi = 0$  (no price adjustment costs). When  $\lambda = 1 - \gamma$ , the decentralized equilibrium is strictly equivalent to the social planner's problem.

**Proof.** The social planner's problem is solved in Appendix A and the equivalence between the two solutions is proved. ■

As an immediate result, the decentralised equilibrium with price rigidities ( $\phi > 0$ ) is always suboptimal. The third source of inefficiency is therefore the price adjustment costs. It is worth mentioning that the first two inefficiencies exist both in the short and the long run, whereas the third inefficiency only exists in the short run (price adjustment costs do not affect the steady state). In section 7, we quantify the size of these respective inefficiencies.

## 5 Calibration

The technology shock is the exogenous driving force and is assumed to be AR(1):

$$\log(\epsilon_t) = \rho \log(\epsilon_{t-1}) + u_t^\epsilon, \tag{27}$$

where  $\rho$  is the autoregressive parameter and  $u_t^\epsilon \sim N(0, \sigma_\epsilon^2)$ . We consider two versions of the model. We first remove all the frictions in the product market to obtain a standard Walrasian real business cycle model, where labor and capital are priced at their respective marginal productivity and prices are normalized to 1 (the standard Walrasian real business cycle is presented in Appendix B). We then add frictions. In this case, labor and capital are priced below

their respective marginal productivity, prices are endogenous and lower than unity, firms make profits, and total output is lower than in the Walrasian case.

We calibrate our model on quarterly data to reproduce some stylized facts for the US economy. We follow King and Rebelo (1999) to calibrate the standard business cycle parameters  $\{\beta, \delta, \alpha, \theta, \eta, \rho, \sigma\}$ . The discount factor is calibrated to yield an average return to capital of 6.5% per annum:  $\beta = 1/(1 + 0.065/4)$ . The annual rate of capital depreciation set to 10%, which gives  $\delta = 0.1/4$ . We set  $\alpha = 1/3$ , which is the standard value for the long run capital income share. We assume that  $\eta = 1$  in order to obtain a double log utility function:  $\mathcal{U}(C_t, 1 - N_t) = \log(C_t) + \theta \log(1 - N_t)$ . We choose  $\theta = 3.3$  to match  $N = 0.20$ , which means that 20% of total available time is used for work. Finally, still as in King and Rebelo (1999), we set  $\rho = 0.979$  and  $\sigma_\epsilon = 0.0072$ .

The other parameters  $\{\lambda, \gamma, \chi, \kappa, \bar{m}, \phi\}$  are specific to the model with search frictions and price rigidities. If retailers (wholesalers) have no bargaining power, *i.e.* no market power, the wholesaler (retailer) appropriates all rents from the contractual relationship. In reality, the bargaining power of retailers and wholesalers is in-between these extreme cases. It may also vary across markets and depend for instance on the relative size of buyers and sellers (and for example whether firm-specific investments have to be undertaken, which gives rise to the classic hold up problem). Since we do not have any priors and data on “economy-wide” bargaining power, we assume that wholesalers and retailers have the same bargaining power:  $\lambda = 1 - \lambda = 0.5$ . In order to have a Pareto optimal outcome (see proposition 2), we impose  $\gamma = 1 - \lambda = 0.5$ .<sup>9</sup> Each wholesaler-retailer pair may separate with an exogenous probability. We set this probability to  $\chi = 0.2$ , meaning that the average duration of a pair is 5 quarters. This average duration of a contract seems plausible with regard to empirical evidence (see section 2). We assume that advertising expenditures ( $\kappa S^2/2$ ) represent 2.2% of GDP as observed in data (see section 2), and that the probability for a wholesaler to find a retailer is 85%, which results in  $\kappa = 1.2$  and  $\bar{m} = 0.8$ . Finally, depending on the simulations, we assume that  $\phi = 0$  (no price adjustment costs) or  $\phi = 50$  (price adjustment costs). This price adjustment cost represents on average 0.005% of GDP, *i.e.* is about 500 times lower than advertising expenditures.

The parameters are displayed in table 1. The parameters in the first line are common to both models, with and without frictions. The parameters in the second line are specific to the model with frictions.

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<sup>9</sup>The calibration to obtain the Pareto outcome in a decentralized economy is standard in the matching literature. See for instance Merz (1995) and Andolfatto (1996) for such a calibration in a similar model but with frictions in the labor market.

$\beta$	$\delta$	$\alpha$	$\theta$	$\eta$	$\rho$	$\sigma_\epsilon$
0.984	0.025	0.33	3.3	1	0.979	0.0072
$\lambda$	$\gamma$	$\chi$	$\kappa$	$\bar{m}$	$\phi$	
0.5	0.5	0.2	1.5	0.6	0/50	

Table 1: Parameter values

## 6 Simulations

We use an autoregressive productivity shock and simulate two different models: (i) the model with frictions in the product market presented in section 3 (with no price adjustment costs) and (ii) the same model but without frictions. This second model is therefore a standard Walrasian real business cycle model, as presented in King and Rebelo (1999) (see Appendix B for an exposition of the equations). We use the same calibration for both models and compare results to the business cycle characteristics of US data (see Appendix C). The simulation results as well as the US statistics are reported in table 2 and figure 2.

As already stated in proposition 1, the introduction of frictions reduces the steady state of both the quantity variables and the price variables (at the exception of the interest rate  $r_t$  which is only determined by the discount factor). In our calibration, total search costs only represent 4.4% of GDP, but removing these costs would increase GDP by almost 40%.

Table 2 and figure 2 also show that the Walrasian RBC model does a good job in reproducing consumption and investment behaviour but suffers from some weaknesses: (i) employment is not volatile enough, (ii) there is no strong endogenous persistence mechanism and (iii) there are no smooth impulse responses (except for consumption and wages). The introduction of frictions improves the statistics along all these dimensions. Because of the sluggish process to create new matches, we increase persistence in output, which in turn increases the volatility of all variables, and especially of employment (see table 2). It is therefore worth noting that employment volatility is mainly due to the search and matching approach, rather than to the price formation mechanism. As displayed in figure 2, quite remarkably we obtain a hump-shaped reaction for all variables. The very reason is that we have frictions between wholesalers and retailers and these frictions therefore directly affect not only output but also all inputs in production. With frictions in the labour market instead, we would be able to generate hump-shaped

	steady state		relative standard deviation		
	RBC	frictions	US data	RBC	frictions
$P_t$		0.84	0.59		0.84
$ad_t$		0.01	2.57		4.93
$GDP_t$	0.57	0.41	1.00	1.00	1.00
$C_t$	0.45	0.36	0.81	0.44	0.60
$I_t$	0.12	0.07	3.41	3.38	4.16
$N_t$	0.20	0.18	1.00	0.49	0.94
$w_t$	1.90	1.36	0.64	0.54	0.57
$r_t$	0.02	0.02	0.31	0.03	0.03

	first-order autocorrelation			contemporaneous correlation with output		
	US data	RBC	frictions	US data	RBC	frictions
$P_t$	0.80		0.51	-0.17		-0.12
$ad_t$	0.88		0.55	0.77		0.27
$GDP_t$	0.88	0.72	0.91	1.00	1.00	1.00
$C_t$	0.88	0.79	0.73	0.86	0.94	0.70
$I_t$	0.92	0.71	0.70	0.94	0.99	0.88
$N_t$	0.94	0.71	0.41	0.83	0.97	0.42
$w_t$	0.81	0.76	0.88	0.24	0.98	0.90
$r_t$	0.55	0.71	0.67	-0.06	0.96	0.87

All variables have been logged (with the exception of the real interest rate) and detrended with the HP filter. US data: see Appendix C; RBC: standard Walrasian real business cycle model *à la* King and Rebelo (1999) presented in Appendix B; frictions: model with frictions in the product market presented in section 3.  $P_t$  : real producer price,  $ad_t = \kappa S_t^2/2$  : advertising expenditures,  $GDP_t = C_t + I_t$  : gross domestic product,  $C_t$  : consumption,  $I_t$  : investment,  $N_t$  : employment,  $w_t$  : wage,  $r_t$  : interest rate.

Table 2: Steady state and cyclical properties

reactions for employment but neither for investment nor output (it would be possible but by adding further frictions as capital adjustment costs). This suggests that frictions in the product market might be more crucial than frictions in the labour market in explaining business cycle fluctuations. Finally, we are able to reproduce statistical properties of real producer prices (less volatile than output and slightly countercyclical) and advertising expenditures (more volatile than output and procyclical) observed in data, suggesting that search is an interesting representation of the product market.

### *Price adjustment costs*

In the baseline setup, prices are bargained every period without any cost ( $\phi = 0$ ), that generates a strong - negative - reaction of prices. However, prices may be subject to adjustment costs which need to be born by the firms (convex price adjustment costs *à la* Rotemberg in our case). Figure 2 shows that adding price adjustment costs ( $\phi = 50$ ) smooths the price reaction and stimulates advertising expenditures and the economy (consumption - investment - employment). The quantitative effects of price adjustment costs are however weak (and we show in the next section that the welfare costs of price rigidities are almost negligible).

## 7 Welfare cost of inefficiencies

To compute the welfare cost of the different inefficiencies presented in section 4, we follow Lucas (1987) and calculate the welfare cost as a fraction of the consumption a household would agree to give up each period in return for moving to the efficient situation. We define the expected welfare of an agent in the efficient situation as:

$$W_t^e = \log(C_t^e) + \theta \log(1 - N_t^e) + \beta W_{t+1}^e. \quad (28)$$

Similarly, we define the expected welfare of an agent in the inefficient situation as:

$$W_t^i = \log(C_t^i) + \theta \log(1 - N_t^i) + \beta W_{t+1}^i. \quad (29)$$

If the welfare cost of living in the inefficient economy is  $\psi$ , equation (29) can be rewritten as:

$$W_t^i = \log((1 - \psi)C_t^e) + \theta \log(1 - N_t^e) + \beta W_{t+1}^i. \quad (30)$$

By subtracting equation (28) from equation (30), we obtain the welfare cost of the inefficiency:

$$\psi = 1 - \exp((1 - \beta)(W_t^i - W_t^e)). \quad (31)$$

We use a second order approximation of equation (31) to avoid the certainty equivalence property. We first consider the search cost inefficiency. The efficient situation  $W_t^e$  is considered when the search cost parameter  $\kappa$  is equal to zero (Walrasian steady state, see proposition 1). We then

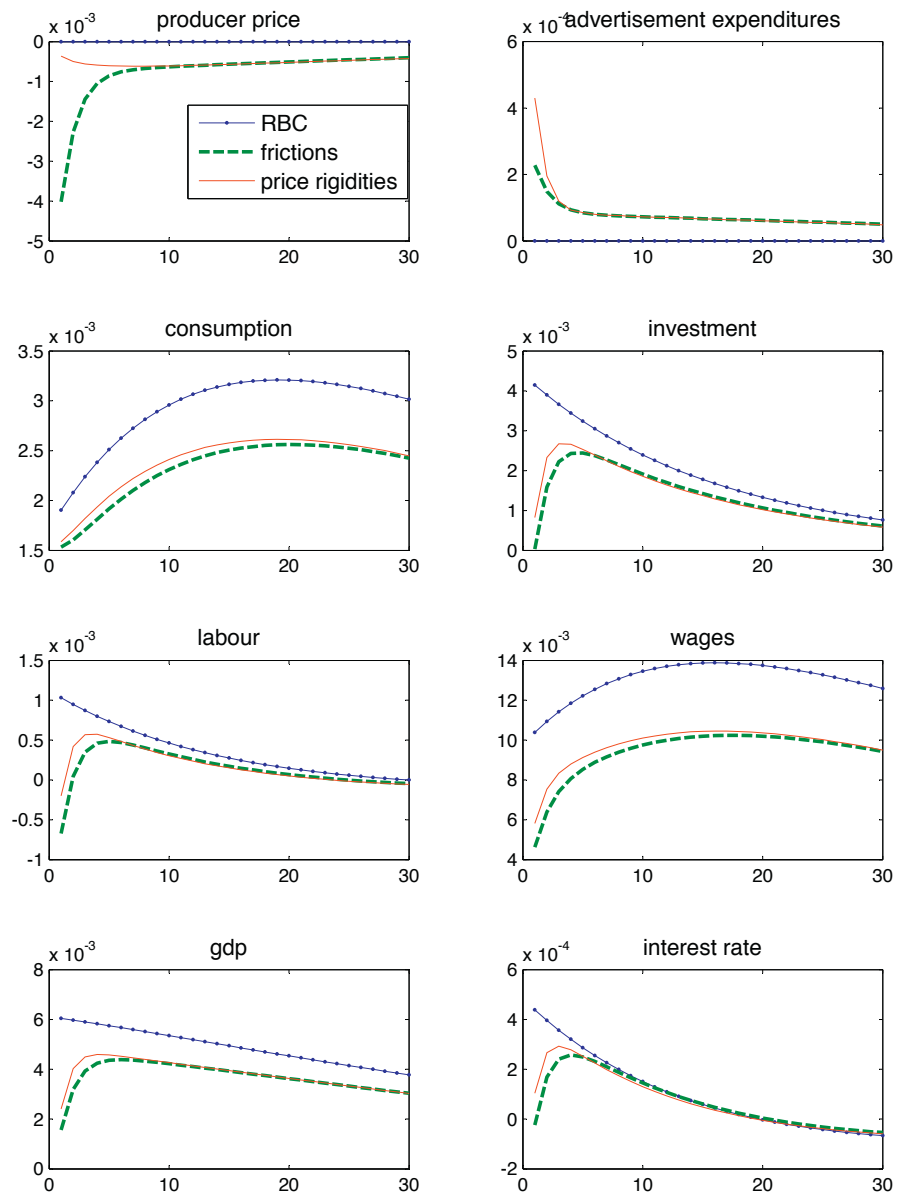


Figure 2: Impulse response functions to a productivity shock

increase  $\kappa$  and compute  $W_t^i$  for each value of  $\kappa$ . The function  $\psi(\kappa)$  increases in  $\kappa$ , as displayed in figure 3. With our calibration ( $\kappa = 1.5$ , see table 1), an household would be willing to give up 3% of her consumption each quarter to live in the efficient/Walrasian world.

We then consider the search externality inefficiency. We show in proposition 2 that when the retailer's bargaining power  $\lambda$  is equal to her search elasticity  $1 - \gamma$  in the matching function, the decentralised solution is equivalent to the social planner's solution. This is our efficient solution  $W_t^e$ . We then move the bargaining power  $\lambda$  from 0.1 to 0.9 and compute  $W_t^i$  for each value of  $\lambda$ . We obtain  $\psi(\lambda)$ , as displayed in figure 4. We see that  $\psi(\lambda) = 0$  when  $\lambda = 1 - \gamma = 0.5$  (see calibration in table 1). The welfare cost increases when the distance between the bargaining power and the matching elasticity increases. For instance, with a bargaining power of 0.2 or 0.8, an household would be willing to give up 2% of her consumption each quarter to live in the social planner's world.

We finally consider the price rigidity inefficiency. When  $\phi = 0$ , prices are fully flexible; this is our efficient economy  $W_t^e$ . We then increase  $\phi$  and compute  $W_t^i$ . We see in figure 5 that the welfare cost increases with the price rigidities. However, the cost is quite low - if price rigidities are high, a household would only agree to give up 0.01% of her consumption each quarter to live in a world with flexible prices. This welfare cost is therefore negligible relative to the welfare cost of the search externalities and relative to the welfare cost of the search costs.

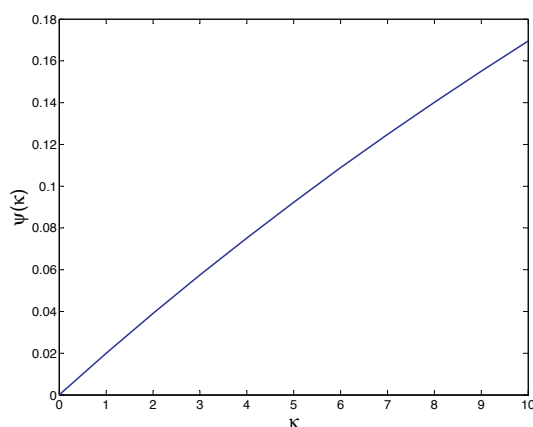


Figure 3: Welfare cost of search frictions

## 8 Conclusion

This paper develops a theoretical model, where both wholesale and retail firms provide search effort, i.e via advertising expenditures and employment of sales and purchasing managers) to

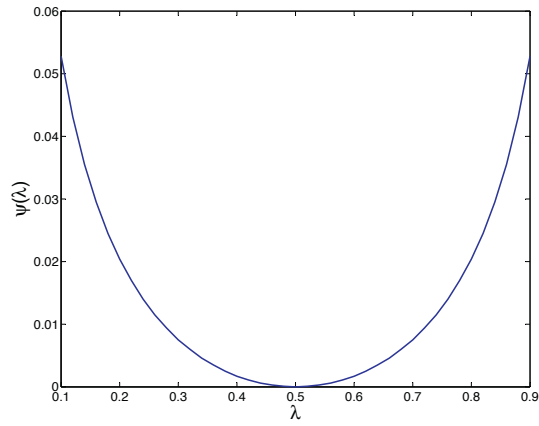


Figure 4: Welfare cost of matching externalities

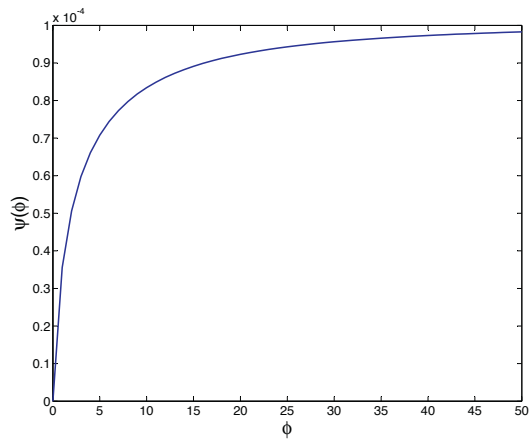


Figure 5: Welfare cost of adjusting prices



meet their customers in the product market. Firms form long-term contractual relationships and bargain over prices. Our model departs from a standard RBC and makes two alterations. First, we replace the Walrasian product market of the standard business cycle model by a product market with search frictions and matching. Second, we introduce rigidities into the price bargaining process. Downstream producers or wholesalers bargain over prices with upstream retailers, who in turn sell to the final consumers. Introducing these frictions in the product market affects both the steady state equilibrium and the cyclical properties, such that the higher the frictions, the lower the steady state quantities and prices. Moreover, frictions break the strong correlation between variables in the standard RBC model, increase output persistence, increase the volatility of employment and generate hump-shaped reactions for all variables. Second, the model reproduces quite nicely the behaviour of prices and advertising expenditures. Third, price rigidities have almost no effect on the cyclical properties of the real variables and a negligible welfare cost. Frictions between wholesalers and retailers seem therefore crucial to understand business cycle fluctuations.

The model could still be extended further. Taylor or Calvo contracts are likely to be more intuitive given the micro evidence on price adjustments which are lumpy and sizable. A monetary dimension (see Smets and Wouters (2003) or Christiano et al. (2005)) and other real frictions as imperfect labour market (see Merz (1995) or Andolfatto (1996)) are currently not included in this model. Introducing these dimensions and comparing with the standard monopolistic competition New Keynesian set up would be an exciting research programme. Moreover, the aim of this paper is rather analytic (introduction of product market frictions and effects) but so far nothing is said on the normative implications of our findings. For instance, given the strong adverse effects of search frictions in the product market, policies aiming at reducing these imperfections (lower entry barriers, role of subsidies, taxation, trade associations, ...) might prove powerful. On the other hand, based again on our results, lowering price rigidities seems less important. Finally, we could use this setup to discriminate between product market and labour market regulations (see for instance Messina (2006) or Fang and Rogerson (2007) for models with monopolistic competition). We leave these extensions to future research.

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## A The social planners's problem

*Social planner*

The social planner's maximization problem is:

$$W_t = \max_{C_t, S_t, D_t} \left\{ \log(C_t) + \frac{\theta}{1-\eta} \left( (1-N_t)^{1-\eta} - 1 \right) \right\},$$

subject to the constraints:

$$T_t = C_t + K_{t+1} - (1-\delta)K_t + \kappa \frac{S_t^2}{2} + \kappa \frac{D_t^2}{2},$$

$$T_t = F(K_t, N_t) = \epsilon_t K_t^\alpha N_t^{1-\alpha},$$

$$T_t = (1-\chi)T_{t-1} + M(S_t, D_t).$$

The three first order conditions are:

$$\frac{1}{C_t} = \beta \left[ \frac{1-\delta}{C_{t+1}} + \frac{\theta}{(1-N_{t+1})^\eta} \frac{\alpha}{1-\alpha} \frac{N_{t+1}}{K_{t+1}} \right], \quad (P1)$$

$$\frac{\kappa S_t}{C_t} \frac{1}{M_{S_t}} = \frac{1}{C_t} - \frac{\theta}{(1-N_t)^\eta} \frac{1}{F_{N_t}} + \beta(1-\chi) \frac{\kappa S_{t+1}}{C_{t+1}} \frac{1}{M_{S_{t+1}}}, \quad (P2)$$

$$\frac{\kappa D_t}{C_t} \frac{1}{M_{D_t}} = \frac{1}{C_t} - \frac{\theta}{(1-N_t)^\eta} \frac{1}{F_{N_t}} + \beta(1-\chi) \frac{\kappa D_{t+1}}{C_{t+1}} \frac{1}{M_{D_{t+1}}}. \quad (P3)$$

*Decentralised equilibrium*

In section 3, the three similar first order conditions are:

$$\frac{1}{C_t} = \beta(1+r_{t+1}) \frac{1}{C_{t+1}}, \quad (D1)$$

$$\frac{\kappa S_t}{q_t^S} = P_t - \frac{w_t}{F_{N_t}} + \beta_t(1-\chi) \frac{\kappa S_{t+1}}{q_{t+1}^S}, \quad (D2)$$

$$\frac{\kappa D_t}{q_t^D} = 1 - P_t + \beta_t(1-\chi) \frac{\kappa D_{t+1}}{q_{t+1}^D}. \quad (D3)$$

Using equations (8) and (15), we can rewrite equation (D1) as:

$$\frac{1}{C_t} = \beta \left[ \frac{1-\delta}{C_{t+1}} + \frac{\theta}{(1-N_{t+1})^\eta} \frac{\alpha}{1-\alpha} \frac{N_{t+1}}{K_{t+1}} \right]. \quad (D4)$$

Using equations (10), (12), (8) and (26), we can rewrite equation (D2) as:

$$\frac{\kappa S_t \gamma}{M_{S_t}} = (1-\lambda) \left( 1 - \frac{C_t \theta}{(1-N_t)^\eta} \frac{1}{F_{N_t}} \right) + \beta \frac{C_t}{C_{t+1}} (1-\chi) \frac{\kappa S_{t+1} \gamma}{M_{S_{t+1}}}. \quad (D5)$$

Using equations (16), (12), (8) and (26), we can rewrite equation (D3) as:

$$\frac{\kappa D_t (1-\gamma)}{M_{D_t}} = \lambda \left( 1 - \frac{C_t \theta}{(1-N_t)^\eta} \frac{1}{F_{N_t}} \right) + \beta \frac{C_t}{C_{t+1}} (1-\chi) \frac{\kappa D_{t+1} (1-\gamma)}{M_{D_{t+1}}}. \quad (D6)$$

## Equivalence

The central planner's equilibrium is equivalent to the decentralized equilibrium if and only if the first order conditions (P1)-(P2)-(P3) are equivalent to the first order conditions (D4)-(D5)-(D6). We see that equations (P1) and (D4) are always identical. We also see that  $\gamma = 1 - \lambda$  is a sufficient and necessary condition to ensure that the system of equations (P2)-(P3) is equivalent to the system of equations (D5)-(D6).

## B The standard Walrasian real business cycle model

The equations of the standard Walrasian real business cycle model are:

$$\begin{aligned}\frac{1}{C_t} &= \beta(1 + r_{t+1})\frac{1}{C_{t+1}}, \\ \frac{\theta}{(1 - N_t)^\eta} &= \frac{w_t}{C_t}, \\ \epsilon_t K_t^\alpha N_t^{1-\alpha} &= C_t + K_{t+1} - (1 - \delta)K_t, \\ w_t &= \epsilon_t(1 - \alpha) \left(\frac{K_t}{N_t}\right)^\alpha, \\ r_t + \delta &= \epsilon_t \alpha \left(\frac{K_t}{N_t}\right)^{\alpha-1}.\end{aligned}$$

## C Quarterly US data

From 1971:q1 to 2006:q1.

Real producer price: Monthly PPI deflated by the monthly CPI. The monthly data are transformed into quarterly ones. Source: BLS. Logged and HP-filtered with a 1600 smoothing weight.

Advertising expenditures: Sum of quarterly advertising expenditures in newspaper (source: <http://www.naa.org/>, seasonally adjusted using X12) and quarterly advertising expenditures in internet (source: [http://www.iab.net/resources/ad\\_revenue.asp](http://www.iab.net/resources/ad_revenue.asp)). The sum is GDP-deflated, logged and HP-filtered with a 1600 smoothing weight.

GDP: Quarterly gross domestic product. Source: BEA. Logged and HP-filtered with a 1600 smoothing weight.

Consumption: Quarterly total private consumption. Source: BEA. Logged and HP-filtered

with a 1600 smoothing weight.

Investment: Quarterly total private investment. Source: BEA. Logged and HP-filtered with a 1600 smoothing weight.

Employment: Quarterly employment in the non farm business sector. Source: BLS. Logged and HP-filtered with a 1600 smoothing weight.

Wages: Quarterly hourly compensation in the non farm business sector. Source: BLS. Logged and HP-filtered with a 1600 smoothing weight.

Interest rate: Monthly 3-month Treasury bill nominal rate. Nominal rates are deflated by the realized 3-month inflation rate. The monthly data are transformed into quarterly ones. Source: Federales Reserve Bank of St Louis. HP-filtered with a 1600 smoothing weight.

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