CAHIER D'ÉTUDES
WORKING PAPER

N° 32

SEARCH IN THE PRODUCT MARKET AND THE REAL BUSINESS CYCLE

Thomas Y. Mathä and Olivier Pierrard

JULY 2008

BANQUE CENTRALE DU LUXEMBOURG
EUROSYSTÈME
1998 - 2008
10 ANS

Contents

Search in the Product Market and the Real Business Cycle*

Thomas Y. Mathä[†] and Olivier Pierrard[‡]

1 July 2008

Abstract

This paper develops a search-matching model, where producers provide effort to find customers (e.g. in form of advertising and marketing expenditures). Firms form long-term contractual relationships and bargain over prices. The price bargain results in mark up pricing above marginal cost. The size of the mark up is procyclical and depends on the relative bargaining power of producers and customers. Introducing frictions in the product market decreases the steady state equilibrium, improves the cyclical properties of the model and provides a more realistic picture of firms' business environment, which includes effort in form of advertising and price fluctuations. 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

*The views expressed in this paper are personal views of the authors and do not necessarily reflect those of the Banque centrale du Luxembourg or the Eurosystem. We would like to thank our colleagues at the BCL and in the Eurosystem Wage Dynamics Network for their comments and remarks on earlier drafts of the paper.

[†]Banque centrale du Luxembourg, Email: thomas.mathae@bcl.lu.

[‡]Banque centrale du Luxembourg and Université catholique de Louvain, Email: olivier.pierrard@bcl.lu.

Résumé non-technique

Dans le modèle de cycles réels standard (RBC: real business cycle), le marché des biens est parfaitement compétitif et donc tous les ajustements sont instantanés. Les observations empiriques suggèrent plutôt que la plupart des firmes opèrent dans un marché des biens non compétitif, dans lequel elles créent des relations de long terme et ont un certain pouvoir pour fixer les prix. Les observations montrent également que la plupart des firmes doivent fournir des efforts substantiels, par exemple en terme de publicité ou de marketing, afin de trouver de nouveaux débouchés/clients.

Dans cette étude, nous essayons de prendre en compte ces faits afin de proposer un modèle RBC avec une représentation du marché des biens plus réaliste. Pour ce faire, nous remplaçons le marché des biens compétitif que l'on trouve dans un modèle RBC standard par un marché des biens avec recherche et appariement ("search and matching model") *à la* Diamond - Mortensen - Pissarides. Dans ce marché non compétitif, les firmes (producteurs) doivent fournir un effort (publicité, marketing) afin de trouver de nouveaux clients (détaillants), et les clients doivent fournir un effort (département des achats) afin de trouver de nouveaux producteurs. Les producteurs et les détaillants négocient ensuite le prix et nous introduisons la possibilité de rigidités dans cette formation de prix. Nous pensons que cette représentation du marché des biens entre producteurs et détaillants est assez réaliste pour les pays industrialisés. En effet, hormis quelques cas particuliers, il est rare de voir les producteurs vendre directement aux consommateurs et donc le rôle des détaillants est primordial. Et s'il est vrai qu'une partie de la publicité faite par les producteurs est directement adressée aux consommateurs, ceux-ci la répercutent ensuite sur les détaillants à travers l'augmentation de leur demande.

Nos principaux résultats sont les suivants. Premièrement, le prix négocié est supérieur au coût marginal de production et la marge pour le producteur dépend de son pouvoir relatif (par rapport à celui du détaillant) de négociation. Cette marge est également procyclique. Deuxièmement, l'introduction de frictions sur le marché des biens diminue le niveau d'équilibre de long terme (production, consommation, emploi, salaire, ...) et améliore les propriétés dynamiques du modèle.[1] Plus précisément, les frictions (i) augmentent la volatilité de l'emploi, (ii) diminuent la forte corrélation entre variables que l'on a dans les modèles RBC standards, (iii) augmentent la persistance de la production, (iv) génèrent des réactions aux chocs progressives pour toutes les variables et (v) décrivent de manière réaliste les comportements des prix et des efforts de recherche. Les imperfections sur le marché des biens entre producteurs et détaillants semblent donc cruciales (et peut-être même plus cruciales que les imperfections sur le marché du travail ou les frictions sur le marché des biens entre détaillants et consommateurs) pour expliquer les fluctuations conjoncturelles. Enfin, troisièmement, les rigidités sur les prix

[1] Les propriétés dynamiques du modèle sont comparées aux propriétés dynamiques des données réelles.

ont un effet assez faible sur les propriétés dynamiques du modèle, et la perte de bien être liée à ces rigidités est négligeable par rapport à la perte de bien être liées aux 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 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.

Other 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. We believe that price bargaining and contractual negotiations are a crucial feature of firms' relationships with each other. In fact, our model remains close to the monopolistic representation used in Blanchard and Giavazzi (2003) or in recent DSGE models (see for instance Christiano et al. (2005) or Smets and Wouters (2003)) but provides a more realistic story, because we escape from an unilateral decision of wholesalers to allow for bilateral relationships and negotiations between wholesalers and retailers.

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 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 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.

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.[2] 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 exert some market power.[3] 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 modeling assumptions usually 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

[2]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.

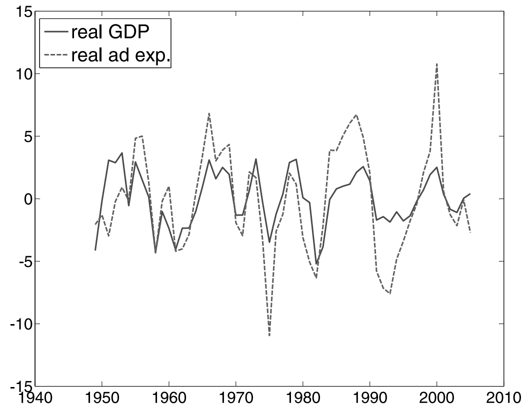
[3]For example, 54% of euro area firms answered that they use a mark up pricing strategy. 73% of euro area firms said that their main market is the domestic market. In Canada, the corresponding figure is 81%.

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.[4] 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 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

[4]Source: www.galbithink.org/ad-spending.htm.



Sources: 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

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 cont(r)act 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. 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:

$$M_t = \bar{m} S_t^{\gamma} D_t^{1-\gamma}, \tag{1}$$

where $\bar{m} > 0$ and $0 < \gamma < 1$. The trade volume evolves according to:

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

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:

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

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[5]:

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

subject to the constraints:

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

[5]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.

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

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

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

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

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:

$$T_t = \epsilon_t K_t^\alpha N_t^{1-\alpha}, \tag{9}$$

where ϵ_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:

$$q_t^S = M_t / S_t. \tag{10}$$

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

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

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 $\kappa \geq 0$ [6] and a quadratic price adjustment cost with $\phi \geq 0$ [7]. The discount factor β_t is compatible with the pricing kernel of the consumers-shareholders:

$$\beta_t = \beta\frac{\mathcal{U}_{C_{t+1}}}{\mathcal{U}_{C_t}}. \tag{12}$$

The first order condition for the search intensity is:

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

[6] See Merz (1995) for a similar approach in a business cycle model with frictions in the labor market.

[7] 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.

where Λ_t is the real marginal cost and given by:

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

The optimal capital-labor ratio is:

$$\frac{K_t}{N_t} = \frac{\alpha}{1-\alpha} \; \frac{w_t}{r_t + \delta}. \tag{15}$$

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:

$$q_t^D = M_t / D_t. \tag{16}$$

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

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

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 β_t is still defined by (12). The first order condition for the search intensity is:

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

3.4 Price formation

Each period, prices are (re-)negotiated between wholesale and retail firms. Prices are determined by the following Nash product problem:

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

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

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

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

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

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

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

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

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.[8] Also, we obtain that the mark up is procyclical, even without price rigidities.[9]

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 $\{\mathcal{Q}_t\}_{t=0}^{\infty} = \{C_t, K_{t+1}, S_t, N_t, D_t\}_{t=0}^{\infty}$ 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 $\{\mathcal{Q}_t\}_{t=0}^{\infty}$, $\{r_t, w_t\}_{t=0}^{\infty}$ 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)

[8]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).

[9]Without price rigidities, the mark up $= \frac{P_t}{\Lambda_t} = \lambda + \frac{1-\lambda}{\Lambda_t}$.

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[10].

Proposition 1 *(Search costs and Walrasian output)*
When $\kappa \longrightarrow 0$ (no search costs), the steady state solution tends to the Walrasian one.

Proof. When $\kappa \longrightarrow 0$, 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

[10] Although the steady state tends to the Walrasian one, the dynamics is still different from the dynamics of a standard Walrasian real business cycle.

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 ρ 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. 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 $\gamma = 1 - \lambda = 0.5$.[11] 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

[11] 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.

adjustment costs) or $\phi = 50$ (price adjustment costs).

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.

β	δ	α	θ	η	ρ	σ_ϵ
0.984	0.025	0.33	3.3	1	0.979	0.0072
λ	γ	χ	κ	$\bar{m}$	ϕ	
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 volatil-

	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

ity of all variables, and especially of employment (see table 2). As displayed in figure 2, we also remarkably obtain hump-shape 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.[12] 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:

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

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

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

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

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

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

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

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

[12]With frictions between retailers and consumers or frictions in the labour market, instead, we would not be able to generate hump-shape reactions for all variables.

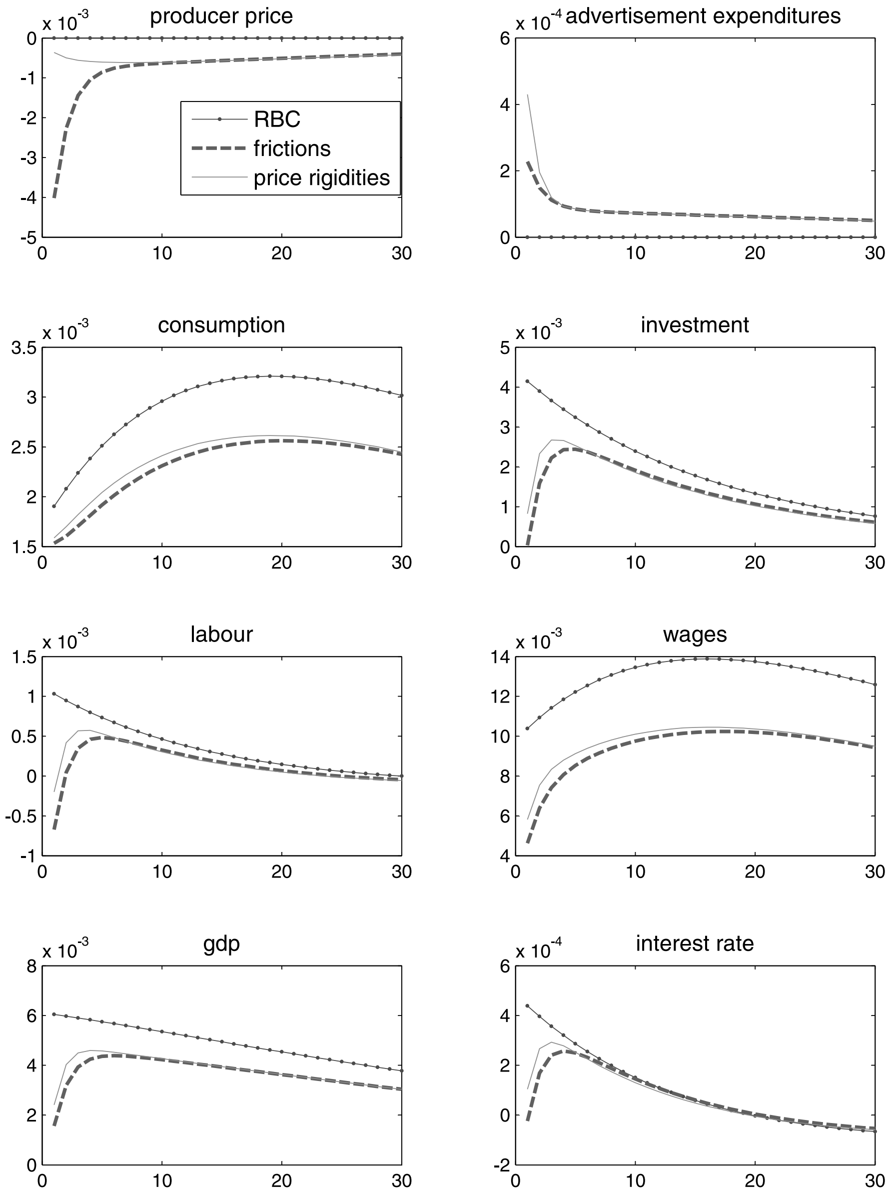


Figure 2: Impulse response functions to a productivity shock

the search cost parameter κ is equal to zero (Walrasian steady state, see proposition 1). We then increase κ and compute W_t^i for each value of κ. The function $\psi(\kappa)$ increases in κ, 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 λ 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 λ from 0.1 to 0.9 and compute W_t^i for each value of λ. 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 ϕ 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.

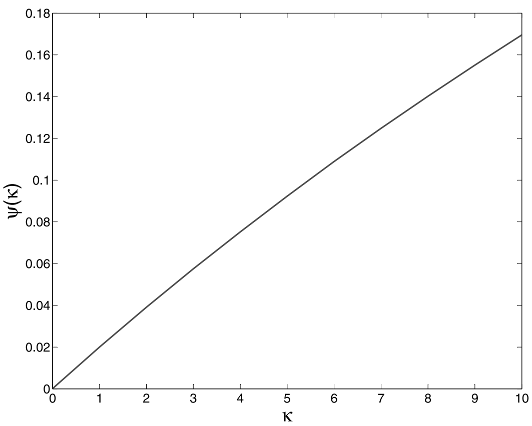


Figure 3: Welfare cost of search frictions

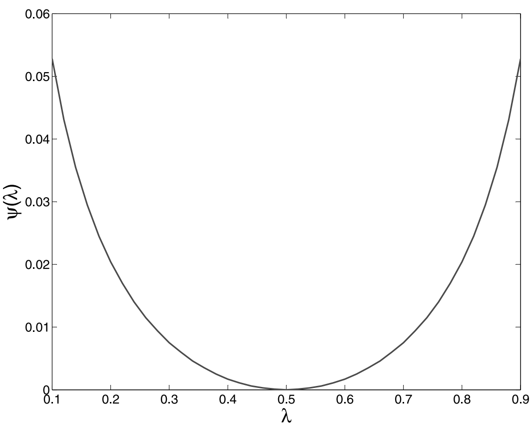


Figure 4: Welfare cost of matching externalities

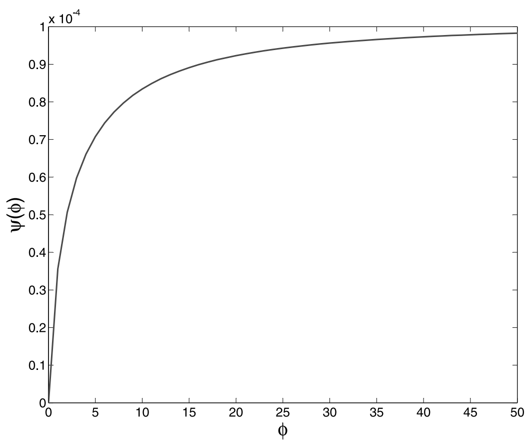


Figure 5: Welfare cost of adjusting prices

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 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-shape 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. Finally, we could use this setup to analyze the respective effects of 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.

References

Amirault, D., C. Kwan, and G. Wilkinson (2004). A survey of the price-setting behaviour of Canadian companies. *Bank of Canada Review Winter 2004-2005*, 29–40.

Andolfatto, D. (1996). Business cycles and labor-market search. *American Economic Review 86*(1), 112–132.

Apel, M., R. Friberg, and K. Hallsten (2005). Microfoundations of macroeconomic price adjustment: Survey evidence from Swedish firms. *Journal of Money, Credit and Banking 37*(2), 313–338.

Arsenau, D. and S. Chugh (2007). Bargaining, fairness, and price rigidity in a DSGE environment. International Finance Discussion Papers, No. 900, Board of Governors of the Federal Reserve System.

Bils, M. and P. Klenow (2004). Some evidence on the importance of sticky prices. *Journal of Political Economy 112*(4), 947–985.

Blanchard, O. and F. Giavazzi (2003). Macroeconomic effects of regulation and deregulation in goods and labor markets. *Quarterly Journal of Economics 118*(3), 879–907.

Blinder, A., E. Canetti, D. Lebow, and J. Rudd (1998). *Asking About Prices: A New Approach to Understanding Price Stickiness*. Russell Sage Foundation: New York.

Bureau of Labor Statistics (2007). Occupational employment and wages, 2006. http://www.bls.gov/oes.

Calvo, G. (1983). Staggered prices in a utility maximizing framework. *Journal of Monetary Economics 12*, 383–398.

Christiano, L., M. Eichenbaum, and C. Evans (2005). Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy 113*(1-45), 346–353.

Dhyne, E., L. Alvarez, H. L. Bihan, G. Veronese, D. Dias, J. Hoffmann, N. Jonker, P. Lünnemann, F. Rumler, and J. Vilmunen (2006). Price changes in the Euro Area and the United States: Some stylized facts from individual consumer price data. *Journal of Economic Perspectives 20*(2).

Fabiani, S., M. Druant, I. Hernando, C. Kwapil, B. Landau, C. Loupias, F. Martins, T. Mathä, R. Sabbatini, H. Stahl, and A. Stokman (2006). What firms' surveys tell us about price-setting behavior in the Euro Area. *International Journal of Central Banking 2*(3), 3–47.

Fabiani, S., C. Loupias, F. Martins, and R. Sabbatini (2007). *Pricing Decisions in the Euro Area: How Firms Set Prices and Why*. New York: Oxford University Press.

Fang, L. and R. Rogerson (2007). Product market regulation and market work: A benchmark analysis. NBER Discussion Paper 12981.

Hall, R. (2008). General equilibrium with customer relationships: A dynamic analysis of rent-seeking. mimeo.

Hall, S., M. Walsh, and A. Yates (2000). Are UK companies' prices sticky? *Oxford Economic Papers 52*(3), 425–446.

Hosios, A. (1990). On the efficiency of matching and related models of search and unemployment. *Review of Economic Studies 57*, 279–298.

King, R. and S. Rebelo (1999). Resuscitating real business cycles. In J. Taylor and M. Woodford (Eds.), *Handbook of Macroeconomics*, Volume I B, Chapter 14. Amsterdam: North-Holland.

Kleshchelski, I. and N. Vincent (2007). Market share and price rigidity. manuscript.

Lucas, R. (1987). *Models of Business Cycles*. Basil Blackwood: Oxford.

Merz, M. (1995). Search in the labor market and the real business cycle. *Journal of Monetary Economics 36*, 269–300.

Messina, J. (2006). The role of product market regulations in the process of structural changes. *European Economic Review 50*(7), 1863–1890.

Nakagawa, S., R. Hattori, and I. Tagagawa (2000). Price setting behaviour of Japanese companies. Bank of Japan Working Paper.

Pissarides, C. (2000). *Equilibrium Unemployment Theory*. The MIT Press: Cambridge.

Rotemberg, J. (1982). Monopolistic price adjustment and aggregate output. *The Review of Economic Studies 49*(4), 517–531.

Rotemberg, J. (1983). Aggregate consequences of fixed costs of price adjustment. *The American Economic Review 73*(3), 433–436.

Smets, F. and R. Wouters (2003). An estimated dynamic stochastic general equilibrium model of the euro area. *Journal of the European Economic Association 1*(5), 1123–1175.

Taylor, J. (1999). Staggered price and wage setting in macroeconomics. In J. Taylor and M. Woodford (Eds.), *Handbook of Macroeconomics*. Amsterdam: North-Holland.

Vermeulen, P., D. Dias, M. Dossche, E. Gautier, I. Hernando, R. Sabbatini, and H. Stahl (2007). Price setting in the Euro Area: Some stylised facts from individual producer price data. ECB Working Paper 727.

Zbaracki, M., M. Ritson, D. Levy, S. Dutta, and M. Bergen (2004). Managerial and customer costs of price adjustment: Direct evidence from industrial markets. *Review of Economics and Statistics 86*(2), 514–533.

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:

$$\begin{aligned} T_t &= C_t + K_{t+1} - (1-\delta)K_t + \kappa \frac{S_t^2}{2} + \kappa \frac{D_t^2}{2}, \\ T_t &= F(K_t, N_t) \; = \; \epsilon_t K_t^{\alpha} N_t^{1-\alpha}, \\ T_t &= (1-\chi)T_{t-1} + M(S_t, D_t). \end{aligned}$$

The three first order conditions are:

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

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

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

Decentralised equilibrium

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

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

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

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

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

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

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

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

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

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

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). 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: Federale Reserve Bank of St Louis. HP-filtered with a 1600 smoothing weight.