

**ESTIMATING MARKET POWER IN A DYNAMIC FRAMEWORK: THE  
CASE OF THE ITALIAN PDO CHEESE MARKET**

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# ESTIMATING MARKET POWER IN A DYNAMIC FRAMEWORK: THE CASE OF THE ITALIAN PDO CHEESE MARKET

## *Abstract*

*In this paper, we evaluate the role of market power by retailers within the supply chain of Parmigiano Reggiano and Grana Padano, the two most famous Italian quality cheeses. Market power is analysed in the context of a dynamic imperfect competition model of the supply chain, in which retailers are allowed to exert market power both downstream and upstream. We jointly estimate market power parameters together with supply and demand elasticities, by means of a structural system of demand, supply and price transmission equations, estimated using the Generalised Method of Moments (GMM). We find evidences of downstream market power by retailers (toward final consumers) only for Parmigiano Reggiano, and no evidences of upstream market power (toward processors/ripeners). These results may be justified by the structure of the supply chain and by the peculiar characteristics of the two cheeses.*

**Keywords:** *Market power; Imperfect competition; PDO cheese (J.E.L. Q13)*

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# ESTIMATING MARKET POWER IN A DYNAMIC FRAMEWORK: THE CASE OF THE ITALIAN PDO CHEESE MARKET

## 1. Introduction

The supply chain of the “grana” cheese sector is extremely relevant for the Italian dairy system: about one third of Italian milk production is processed to obtain grana, mainly Grana Padano (GP) and Parmigiano Reggiano (PR), two Protected Denomination of Origin (PDO) cheeses. Their supply chains have very peculiar characteristics: a large number of farms in the production area produce raw milk for the two cheeses; the production process takes a long time, due to a long aging phase; after the minimum aging period, the ripening phase is mainly carried out by specialised ripening firms, not by milk dairies. The two products have a high degree of penetration in households’ consumption, since more than 90% of Italian households regularly consume one of the two cheeses. For all the above reasons, PR and GP are very peculiar PDO products. Given their widespread consumption, they are among the very few PDO products that can be considered mass market goods rather than niche goods. As most generic food products, they reach final consumers mainly through super and hypermarket chains, rather than through specialised channels, and, given their incidence on food retail sales, they are a key element of the assortment of large retailers. For these reasons, it is interesting to explore the retailers’ behaviour with respect to these products, especially in terms of their ability to exert market power both on the wholesale market, toward processors/ripeners, and on the final market, toward consumers.

In this context, the present paper aims to evaluate the role of market power within the supply chain of PR and GP, trying to fill a gap in applied research. In the supply chain, retailers have been progressively playing a major role. In the ‘90s, the Italian food retail sector has undergone a dramatic change, with the market share of the first five buying groups of retailers rapidly increasing and stabilizing at almost 70% in the second half of 2000s. Retailers benefit from high margins in the PR and GP chains: some recent estimates show that they are getting the highest share of the total value added, from 50 to 75% for PR and around 80% for GP. Furthermore, there is a very low degree of implementation of own-brand policies by dairy processors and ripeners, so that retailers are increasingly adopting private label’s strategies for these products.

Market power is analysed in the context of a dynamic imperfect competition model of the supply chain under a conjectural variations approach. The modelling framework adopted in this paper is based on the “sticky price model” presented in Perloff et al. (2007, Chapter 7), which provides a general framework for estimating indexes of market power in a dynamic setting when

only industry-level (rather than firm) data are available. Our paper extends this model in several ways: it considers two outputs (PR and GP) rather than one; it assumes the presence of both oligopoly and oligopsony power at the same time; it adopts a non linear specification of the demand functions. To our knowledge, this is one of the very few attempts of estimating market power in the food industry using a dynamic model. Notable exceptions are Steen and Salvanes (1999), Hannicutt and Aadland (2003) and Shabbar et al. (2003).

Although criticized on the theoretical ground for its dynamic inconsistency (Friedman, 1983; Corts, 1999), empirically the conjectural variation approach has been particularly appealing, often interpreting conjectures as the result of an un-modelled dynamic and imperfectly competitive game (see Bresnahan, 1989, for a review).

Static estimations of market power indexes, involving both the oligopsony and the oligopoly power potentially exerted by intermediate agents, have been available in the literature since the early '80s. Most of these applications refer to the approach originally proposed by Appelbaum (1982) and applied to the food industries by, among others, Azzam and Pagoulatos (1990) and Schroeter and Azzam (1990). The general idea of these models is that firms account for strategic interrelationships by means of conjectural elasticities, which measure the total effect on the market due to firms' choices (the firm's direct effect and the indirect effect following the strategic response of the competing firms). The dynamic version of the model proposed by Perloff et al. (2007) assumes a game with an open-loop equilibrium<sup>1</sup>, in which the strategic interaction among firms takes place only at a single point in time, with a single information set.

The firm behaviour can be extended to a sector framework by aggregating across competing firms. Aggregation is a central issue for evaluating market power when only industry-level data are available. Work on aggregation can be found in the static models by Appelbaum (1982), Azzam and Pagoulatos (1990), Schroeter and Azzam (1990), Wann and Sexton (1992) and Muth and Wohlgenant (1999), based on conditions and/or restrictions on marginal productivity and/or oligopolistic/oligopsonistic behaviour. Such conditions also hold in the dynamic open-loop model of Perloff et al. (2007).

A second important issue is the identification of the relevant model parameters, especially those measuring market power. Specific assumptions on firms' strategic behaviour can simplify the measurement of these parameters (i.e. for example, in a static model, the assumption of Cournot behaviour among firms makes conjectural elasticities at the sector level equal to the Herfindhal

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<sup>1</sup> As explained by Perloff et al. (2007, page 148): "In an open-loop equilibrium to a dynamic game, it is as if firms choose their entire trajectory of future actions at the initial time. Therefore, such assumption renders the dynamic game "strategically static": firms have no incentive to use current decisions to influence future state variables as means of influencing their rivals' future actions". An alternative (more complex) specification would be a Markov Perfect equilibrium game, in which firms are assumed to internalize the sequence of strategic responses by rivals.

concentration index). In this paper, we have chosen to jointly estimate market power and supply/demand structural parameters, following the approach adopted in static models by Schroeter (1988), Hyde and Perloff (1998) and Gohin and Guyomard (2000) and extended to the dynamic setting by Perloff et al. (2007). Since we carry out the estimation at the aggregate level, we cannot claim to identify the “true game” that firms play, but we rather interpret the market power parameters as a measure of the departure from marginal cost pricing, in line with the interpretation originally proposed by Bresnahan (1982) and Hyde and Perloff (1998), which is still valid in a dynamic setting (Perloff et al., 2007).

Our model focuses on the role of the retail sector as an intermediate agent: retailers sell to final consumers and buy from ripeners. The key element of the model is that they are allowed to exert market power both downstream to consumers and upstream to ripeners. Thus, we concentrate only on one step of the supply chain, which is one of the possible approaches suggested by the literature. In fact, one important aspect emerging from the literature is the relevance of the definition of the vertical chain for which market power is measured: some studies focus on the wholesale-retail level (Gohin and Guyomard, 2000), others on the farm-processing level (Suzuki and Kaiser, 1997; Liu et al., 1995), and others consider jointly the processing/retailing phase (Chidmi et al., 2005; Bhuyan and Lopez, 1997; Merel, 2009). Market power can emerge at different levels of the vertical chain and one has to choose the appropriate setting in order to correctly identify the source of imperfectly competitive behaviour.

The paper is organised as follows. Some basic elements of the PR and GP supply chain are presented in section 2, while in the following two sections the theoretical model and its empirical specification are presented. Data and estimation techniques are described in section 5, while in section 6 the estimation results are discussed. Finally, some concluding remarks close the paper.

## **2. The grana cheese sector in Italy**

Parmigiano Reggiano and Grana Padano are two Italian hard cheeses made of raw milk, with a ripening period of at least 12 months for PR and 9 months for GP, although they are usually sold at a longer age (PR is sold up to 28-30 months of aging, GP up to 24 months). They are two regional specialties, which have been granted the PDO status by the European Union (EU). Both the PR and the GP productions have grown steadily in recent years, reaching 116,000 and 163,000 tons, respectively, in 2008.

In the same year, there were about 3,700 dairy farmers producing around 1.8 million tons of milk channelled into the PR supply chain as well as 7,000 farmers producing 2.5 million tons of milk processed into GP. PR processing is carried out by about 420 dairies, mainly farmer cooperatives processing 77% of PR milk; despite a strong concentration process in recent years, dairies are still quite small (the average size is about 3,000 tons). On the contrary, the GP chain is characterised by higher levels of concentration in the production phase (160 dairies), with larger cooperatives, whose share is about 57% of total milk. Furthermore, GP dairies tend to be more flexible, since in periods of market crisis due to over-supply they can use milk to produce other types of hard and semi-hard cheese (Asiago or Provolone) and even soft cheese, thus being less exposed to the potential financial crises deriving by low cheese prices.

After the first 12 months for PR, and 9 months for GP, ripening is mainly carried out by specialised firms: there are about 180 cheese ripeners/wholesalers in the grana cheese market trading either PR or GP or both, and several of them are not involved in production, especially in the PR chain. In fact, while the two chains are separated at the production level, since the two cheeses requires different characteristics of the raw material<sup>2</sup> and different processing methods, ripening requires similar structures and differs only for the length of the period. So the two products compete in ripening space allocation. The top 10 ripening firms cover 33% of the market; hence, concentration in the wholesale market is reasonably strong. Nevertheless, only few traders have adopted adequate marketing strategy to face large modern retailers and/or the export market.

In terms of destination of the final product, around 70% of both PR and GP goes to household domestic consumption, while the remaining 30% goes either to export or to away from home consumption and food industry use.

In 2008, the market value of grana cheese was about 2.5 billion €; retail sales accounted for about 70% of the total. About 76% of total retail sales take place in super/hypermarkets, superettes, and hard discounts, while the share of traditional and specialty shops is declining. In terms of product types, around 60% of grana cheese is still sold as whole natural wheels, freshly cut in the sales outlet (either traditional shops or specialty corners in super/hypermarkets); the remaining 40% is sold with a specific packaging.

In recent years, the market trends of the two cheeses have been strongly different. The GP sales have shown a clear increasing trend in volume terms (+18% from 2002 to 2008), while PR has shown a marked decline (-8% in the same period). This diverging trend has strongly modified the market shares of the two cheeses (43% for PR and 57% for GP in value term in 2008), while in the '90s both cheeses were fluctuating around 50%.

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<sup>2</sup> For example, milk cows cannot be fed with silage.

Price formation along the PR and GP chain is quite complex. At the farm level, milk price for PR is higher than that for GP (on average a 20% price premium), due to more stringent production rules. Given that raw milk has virtually no alternative use in the PR area and cooperatives are the dominant organisational form in the processing sector, the milk price tends to be driven by cooperatives' net revenues. At the wholesale level, prices reflect different levels of aging, since the product is sold at different ripening stages. Thus, prices are sensitive to market expectations, volume of unsold stocks, signals from operators and purchasing policies by large retailers.

Retail prices are likely to be influenced by the increasing bargaining power of retailers in the grana cheese chain and in the whole Italian food system. In fact, thanks to the weaknesses of most of the PR and GP chain actors in setting up a set of coherent marketing strategies, retailers bear the relevant pricing and promotion strategies, also thanks to the increasing role of their private labels in packaged products (vacuum packed pieces, snacks and ready grated cheese), where they account for 25% of the market. The role of promotions is becoming crucial, especially for PR, since the higher PR price (an average 40% price premium) represents an important barrier for consumers, such that a recent survey shows that more than 50% of PR is sold in promotion. This is not surprising, since modern retailers tend to implement massive promotion activities on both grana cheeses, in order to exploit their attractiveness for potential customers and boost retail sales also on other food products.

### **3. Theoretical model**

In order to measure the degree of oligopoly and oligopsony power exerted by retailers in the Italian grana cheese sector, we extend the “sticky price model” presented in Perloff et al. (2007, Chapter 7), emphasising the role of retailers.

As explained earlier, only a few large grana cheese processors carry out both the processing and the ripening phases. Therefore, ripeners normally manage the cheese aging phase but not the processing phase. The supply side of our model considers ripeners as price takers, since the 180 firms acting in the Italian grana cheese market have limited flexibility in deciding when and how to sell their product. In fact, based on the official EU product specifications, the length of the aging phase is fixed: the standard aged GP is sold at 18 months and the standard aged PR is sold at 24 months. Italian consumers can actually find cheese of different ages in the final market, but the range is quite limited (15-20 months for GP and 22-27 months for PR, with some very limited exceptions). Moreover, retailers are increasingly selling products that indicate on their label the exact number of months of the aging phase and consumers are becoming increasingly aware of the

relationship between age and quality of grana cheese. Apart from selling to retailers operating in the domestic market, the main alternative destination of aged PR and GP is export (around 16% of total production for PR and 22% for GP). However, this is possible only for those ripeners that have developed adequate export marketing strategies, and their experience shows that any expansion of the export market requires a considerable amount of time and effort. For these reasons, we believe that the assumption of price-taking behaviour by ripeners may be reasonable.

### 3.1 Consumer demand and ripener supply

The consumer demand of grana cheese is assumed to be the result of a standard utility maximization problem, in which consumers maximize their utility subject to a budget constraint. Thus, at time  $t$ , the market demand of the two grana cheeses takes the following general form:

$$Q_{it}^D = Q_{it}^D(\mathbf{p}_t, \mathbf{d}_t) \quad i = PR, GP \quad (1)$$

where  $\mathbf{p}_t$  is the vector of the two cheese retail prices and  $\mathbf{d}_t$  a vector of demand shifters, including other prices and income.

The ripener supply of cheese is the result of a dynamic maximization problem. This because, in each period  $t$ , the ripener manages his store buying some fresh cheese from processors and selling some ripened cheese to retailers, while his storage cost is a function of the level of inventories and of their composition<sup>3</sup> at time  $t$ . Since inventories at time  $t$  depend on inventories at time  $t-1$ , the management of inventories makes the ripener's optimization problem dynamic<sup>4</sup>.

Thus, we can assume that, for a price-taking ripener, profit at time  $t$  takes the following form:

$$\pi_t^{rip} = \sum_i w_{it} q_{it}^s - \sum_i v_{it} q_{it}^b - C(I_t, \mathbf{q}_t^s, \mathbf{q}_t^b, \mathbf{c}_t) \quad \text{s.t.} \quad I_t = I_{t-1} + \sum_i q_{it}^b - \sum_i q_{it}^s \quad i = PR, GP \quad (2)$$

where  $q_{it}^s$  is the quantity of ripened cheese sold in each period (with  $\mathbf{q}_t^s$  being the vector of the two quantities),  $q_{it}^b$  is the quantity of fresh cheese bought in the same period (with  $\mathbf{q}_t^b$  being the

<sup>3</sup> The composition of the inventories matters in determining the storage cost. In fact, given the nature of the cheese ripening process, managing a store full of fresh cheese is different from managing a store full of ripened cheese, since the ripening operations are different and imply different costs. Since normally we do not have information on the composition of inventories, a simple way of taking this into account is to assume that storage costs depend, in each period, on inventory levels, as well as on the amount of fresh cheese bought and on the amount of ripened cheese sold.

<sup>4</sup> In a recent paper, Merel (2009) addresses the issue of market power in the Comté market, a French PDO cheese which is also sold after a long ripening time. In his paper, he recognizes that the strategic role of ripening decisions may bias his results, obtained with a static model of market power.



corresponding vector of the two quantities),  $w_{it}$  is the wholesale price of ripened cheese,  $v_{it}$  is the wholesale price of fresh cheese (with  $\mathbf{w}_t$  and  $\mathbf{v}_t$  being the corresponding price vectors),  $C$  is the ripening cost function,  $I$  is the level of inventories and  $\mathbf{c}_t$  is a vector of storage cost shifters. The constraint in (2) represents the equation of motion of inventories, that generates the dynamics of decision making. The ripener's objective is to maximize the present discounted value of its expected profits:

$$E_t \left[ \sum_{\tau=0}^{\infty} \delta^\tau \pi_{t+\tau}^{rip} \right] \quad (3)$$

where  $\delta$  is the discount rate. This problem can be rewritten as an optimal control problem (Perloff et al., 2007, chapter 7). The ripener's value function  $J(\cdot)$ , that represents the equilibrium value of its payoff, depends on the predetermined endogenous state variable at time  $t$  (the level of inventories at time  $t-I$ ) and on the exogenous variables at time  $t$  (wholesale prices and cost shifters). Thus, the corresponding dynamic programming equation can be written as:

$$J(I_{t-1}, \mathbf{w}_t, \mathbf{v}_t, \mathbf{c}_t) = \max_{q_i^s, q_i^b} E_t \left[ \pi_t^{rip} + \delta J(I_t, \mathbf{w}_{t+1}, \mathbf{v}_{t+1}, \mathbf{c}_{t+1}) \right] \quad (4)$$

As explained in Perloff et al. (2007), this equation states that the equilibrium value of the ripener's payoff in period  $t$  equals the maximized value of the expectation of the sum of current profits and the discounted value of the *continuation profits* (the value function in period  $t+1$ ). Solving the optimal control problem in (4), one can verify that both the supply of ripened PR and GP and the demand of fresh PR and GP depend on exogenous and predetermined variables in two consecutive periods<sup>5</sup>. Thus, since only two periods matter, we can write the following general form for the market supply of ripened cheese:

$$Q_{it}^S = Q_{it}^S(Q_{t-1}^S, \mathbf{w}_t, \mathbf{w}_{t-1}, \mathbf{v}_t, \mathbf{v}_{t-1}, I_{t-1}, \mathbf{c}_t, \mathbf{c}_{t-1}), \quad i = PR, GP \quad (5)$$

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<sup>5</sup> The detailed derivation is not presented here. Actually, it follows exactly the same steps of the derivation of the first order conditions for the "sticky price model" presented in Perloff et al. (2007), but it is much simpler, since we assume that the ripener is a price taker both in the input and in the output market (in fact, the first order conditions simply state that price and marginal cost must equalise in two consecutive periods).

### 3.2 The retailer's problem

As mentioned before, in our model we emphasise the role of retailers, that buy cheese from ripeners and sell it to final consumers, potentially exerting some form of market power both downstream and upstream. We also assume that the supply of ripeners coincides with the demand of final consumers in the same period ( $Q_{it} = Q_{it}^D = Q_{it}^S$ ), since we do not consider any storage activity carried out by retailers<sup>6</sup>. Thus, from equation (1), the inverse demand of the two grana cheeses by final consumers is:

$$p_{it} = p_{it}(\mathbf{Q}_t, \mathbf{d}_t), \quad i = PR, GP \quad (6)$$

with  $\mathbf{Q}_t$  being the vector of market quantities of PR and GP, while, from equation (5), the corresponding inverse supply by ripeners is:

$$w_{it} = w_{it}(\mathbf{Q}_t, \mathbf{Q}_{t-1}, \mathbf{w}_{t-1}, \mathbf{s}_t), \quad i = PR, GP \quad (7)$$

where  $\mathbf{s}_t$  is a vector including all exogenous supply shifters reported in equation (5). The retailer's profit at time  $t$  can be written as

$$\pi_t^{ret} = \sum_i p_{it}(\mathbf{Q}_t, \mathbf{d}_t) q_{it} - \sum_i w_{it}(\mathbf{Q}_t, \mathbf{Q}_{t-1}, \mathbf{w}_{t-1}, \mathbf{s}_t) q_{it} - C\left(\sum_i q_{it}, \mathbf{a}_t\right), \quad i = PR, GP \quad (8)$$

where  $q_{it}$  is the quantity bought/sold by the retailer and  $\mathbf{a}_t$  is a vector of retailing cost shifters. Again, the retailer's optimization problem is dynamic, since the inverse supply function depends on four lagged endogenous variables (lagged supply and lagged wholesale price of both PR and GP), the *state variables* of our model.

In analogy with the ripener's problem, the retailer's objective is to maximize the present discounted value of its expected profits:

$$E_t \left[ \sum_{\tau=0}^{\infty} \delta^\tau \pi_{t+\tau}^{ret} \right] \quad (9)$$

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<sup>6</sup> This assumption seems quite reasonable, since all major retailers are implementing a set of strategies that aim to minimise the average storage time of their products.

and the corresponding dynamic programming equation can be written as:

$$J(\mathbf{Q}_{t-1}, \mathbf{w}_{t-1}, \mathbf{z}_t) = \max_{q_t} E_t \left[ \pi_t^{ret} + \delta J(\mathbf{Q}_t, \mathbf{w}_t, \mathbf{z}_{t+1}) \right] \quad (10)$$

where  $\mathbf{z}_t = (\mathbf{d}_t, \mathbf{s}_t, \mathbf{a}_t)$  is a vector of all demand, supply and retailing cost shifters.

Following Perloff et al. (2007), we use the abbreviations  $J_{w_i}(t) = \partial J(\mathbf{Q}_{t-1}, \mathbf{w}_{t-1}, \mathbf{z}_t) / \partial w_{it-1}$  and  $J_{Q_i}(t) = \partial J(\mathbf{Q}_{t-1}, \mathbf{w}_{t-1}, \mathbf{z}_t) / \partial Q_{it-1}$  to denote the *shadow values* at time  $t$ , i.e. the partial derivatives of the value function with respect to the state variables. For example,  $J_{w_{PR}}(t)$  represents the expected change in the retailer's payoff due to a small change in the lagged wholesale price of PR at time  $t$ .

Assuming an interior solution, the first order conditions (FOCs) for the problem in (10) are:

$$E_t \left[ \begin{array}{l} p_{it} + \frac{\partial p_{it}}{\partial Q_{it}} \frac{\partial Q_{it}}{\partial q_{it}} q_{it} + \frac{\partial p_{it}}{\partial Q_{jt}} \frac{\partial Q_{jt}}{\partial q_{it}} q_{it} + \frac{\partial p_{jt}}{\partial Q_{it}} \frac{\partial Q_{it}}{\partial q_{jt}} q_{jt} + \frac{\partial p_{jt}}{\partial Q_{jt}} \frac{\partial Q_{jt}}{\partial q_{jt}} q_{jt} \\ -w_{it} - \frac{\partial w_{it}}{\partial Q_{it}} \frac{\partial Q_{it}}{\partial q_{it}} q_{it} - \frac{\partial w_{it}}{\partial Q_{jt}} \frac{\partial Q_{jt}}{\partial q_{it}} q_{it} - \frac{\partial w_{jt}}{\partial Q_{it}} \frac{\partial Q_{it}}{\partial q_{jt}} q_{jt} - \frac{\partial w_{jt}}{\partial Q_{jt}} \frac{\partial Q_{jt}}{\partial q_{jt}} q_{jt} - \frac{\partial C_t}{\partial q_{it}} \end{array} \right] + \delta E_t \left[ \begin{array}{l} J_{w_i}(t+1) \left[ \frac{\partial w_{it}}{\partial Q_{it}} \frac{\partial Q_{it}}{\partial q_{it}} + \frac{\partial w_{it}}{\partial Q_{jt}} \frac{\partial Q_{jt}}{\partial q_{it}} \right] + J_{w_j}(t+1) \left[ \frac{\partial w_{jt}}{\partial Q_{it}} \frac{\partial Q_{it}}{\partial q_{it}} + \frac{\partial w_{jt}}{\partial Q_{jt}} \frac{\partial Q_{jt}}{\partial q_{it}} \right] \\ + J_{Q_i}(t+1) \left[ \frac{\partial Q_{it}}{\partial q_{it}} \right] + J_{Q_j}(t+1) \left[ \frac{\partial Q_{jt}}{\partial q_{it}} \right] \end{array} \right] = 0 \quad i, j = PR, GP \quad (11)$$

where  $\partial Q_{it} / \partial q_{it}$  and  $\partial Q_{jt} / \partial q_{it}$  are the (own- and cross-) conjectural parameters, which are used as a base to measure market power.

In order to obtain an estimable version of this FOCs, we need to get rid of the endogenous (and unknown) shadow values, such that the equilibrium condition involves only the primitive demand, supply and retailing cost parameters. To do so, we need to make the following assumptions:

- (a) the game takes the form of an open-loop equilibrium, such that a change in the state variables does not affect the rivals' response (Perloff et al., 2007);
- (b) the demand, supply and retailing cost parameters, as well as the conjectural parameters, are not random.

The above two assumptions are sufficient to obtain an estimable version of the FOC's, but its mathematical form is extremely untransparent and messy<sup>7</sup>. Thus, in order to obtain a more transparent and interpretable version of the FOCs, we need to make the following additional assumptions:

- (c) the cross-conjectural parameters are equal to 0;
- (d) the own-conjectural parameters are constant over time (i.e.  $\frac{\partial Q_{it}}{\partial q_{it}} = \frac{\partial Q_{it+1}}{\partial q_{it+1}} = \frac{\partial Q_i}{\partial q_i}$ );
- (e) the functional form of the supply function is linear, such that the supply parameters are also constant over time;
- (f) the supply-side conjectural elasticities, those related to the retailers-ripeners relationship, are the same for both PR and GP  $\left( \text{i.e. } \frac{\partial Q_i^S}{\partial q_i} \frac{q_i}{Q_i^S} = \frac{\partial Q_j^S}{\partial q_j} \frac{q_j}{Q_j^S} \right)$ .

Assumption (c) is rather common in multiproduct market power studies, as the interpretation of the cross-conjectural parameters is not straightforward, since it has to do with the strategic impact of firm decisions on output/input  $i$  on the market supply/demand of output  $j$ . Assumptions (d) and (e) are also rather common in similar studies (see for example Steen and Salvanes, 1999 and Hannicutt and Aadland, 2003), mainly because they facilitate convergence in highly non-linear estimations, but they are certainly suitable in our study, since we work on monthly data that cover a rather short period of time. Finally, assumption (f) is motivated by the fact that most ripeners manage both PR and GP in their stores and the contracts between retailers and ripeners often involve both cheeses. Thus, in setting the quantities to be purchased, retailers are likely to exert the same degree of market power for both cheeses.

These additional assumptions allow us to obtain the following elasticity form of the FOCs:

$$\begin{aligned}
& p_{it} + f_{iit}\theta_{ii}p_{it} + f_{jit}\theta_{ii}p_{jt} \frac{q_{jt}}{q_{it}} - w_{it} - g_{iit}\phi w_{it} - g_{jit}\phi w_{jt} \frac{q_{jt}}{q_{it}} - \frac{\partial C_t}{\partial q_{it}} \\
& - \delta \frac{\phi}{q_{it}} [q_{it+1}A1 - q_{jt+1}A2] \\
& + \delta \left[ p_{it+1} + f_{iit+1}\theta_{ii}p_{it+1} + f_{jit+1}\theta_{ii}p_{jt+1} \frac{q_{jt+1}}{q_{it+1}} - w_{it+1} - g_{iit+1}\phi w_{it+1} - g_{jit+1}\phi w_{jt+1} \frac{q_{jt+1}}{q_{it+1}} - \frac{\partial C_{t+1}}{\partial q_{it+1}} \right] \left[ \frac{A2 * B3 - A1 * B2}{B1 * B2 - B3 * B4} \right] \\
& + \delta \frac{q_{jt}}{q_{it}} \left[ p_{jt+1} + f_{ijt+1}\theta_{jj}p_{it+1} \frac{q_{it+1}}{q_{jt+1}} + f_{jjt+1}\theta_{jj}p_{jt+1} - w_{jt+1} - g_{jjt+1}\phi w_{it+1} \frac{q_{it+1}}{q_{jt+1}} - g_{jjt+1}\phi w_{jt+1} - \frac{\partial C_{t+1}}{\partial q_{jt+1}} \right] \left[ \frac{A1 * B4 - A2 * B1}{B1 * B2 - B3 * B4} \right] = 0 \\
& i, j = PR, GP
\end{aligned} \tag{12}$$

<sup>7</sup> This mathematical derivation, as well as the further manipulations to obtain equation (12), are available from the authors upon request.

where  $A1, A2, B1, B2, B3$  and  $B4$  are combinations of supply parameters and elasticities<sup>8</sup>, while elasticities and flexibilities are defined as follows:

$$\begin{aligned}
f_{iit} &= \frac{\partial p_{it}}{\partial Q_{it}} \frac{Q_{it}}{p_{it}} & f_{jii} &= \frac{\partial p_{jt}}{\partial Q_{it}} \frac{Q_{it}}{p_{jt}} & g_{iit} &= \frac{\partial w_i}{\partial Q_i} \frac{Q_{it}}{w_{it}} & g_{jii} &= \frac{\partial w_j}{\partial Q_i} \frac{Q_{it}}{w_{jt}} \\
\theta_{ii} &= \frac{\partial Q_i^D}{\partial q_i} \frac{q_i}{Q_i^D} & \phi &= \frac{\partial Q_i^S}{\partial q_i} \frac{q_i}{Q_i^S} = \frac{\partial Q_j^S}{\partial q_j} \frac{q_j}{Q_j^S}
\end{aligned} \tag{13}$$

$$\begin{aligned}
f_{iit+1} &= \frac{\partial p_{it+1}}{\partial Q_{it+1}} \frac{Q_{it+1}}{p_{it+1}} & f_{jii+1} &= \frac{\partial p_{jt+1}}{\partial Q_{it+1}} \frac{Q_{it+1}}{p_{jt+1}} & g_{iit+1} &= \frac{\partial w_i}{\partial Q_i} \frac{Q_{it+1}}{w_{it+1}} & g_{jii+1} &= \frac{\partial w_j}{\partial Q_i} \frac{Q_{it+1}}{w_{jt+1}} \\
f_{ijt+1} &= \frac{\partial p_{it+1}}{\partial Q_{jt+1}} \frac{Q_{jt+1}}{p_{it+1}} & f_{jii+1} &= \frac{\partial p_{jt+1}}{\partial Q_{jt+1}} \frac{Q_{jt+1}}{p_{jt+1}} & g_{ijt+1} &= \frac{\partial w_i}{\partial Q_j} \frac{Q_{jt+1}}{w_{it+1}} & g_{jii+1} &= \frac{\partial w_j}{\partial Q_j} \frac{Q_{jt+1}}{w_{jt+1}} \quad i, j = PR, GP
\end{aligned}$$

From the point of view of analysing market power, the key parameters of the above FOCs are the conjectural elasticities  $\theta_{ii}$  and  $\phi$ . In fact, on both sides of the supply chain, when their value is zero we have the perfect competition case, while when their value is one we have the monopoly/monopsony case. Values between zero and one reflect different levels of the retailers' market power on both the final market and the wholesale market.

The FOCs in (12) are an extension of those derived by Perloff et al. (2007) for the single-output dynamic oligopoly case (equation (7.20), pag. 157). In analogy with that simpler model, only two periods matter in determining the optimal retailers' choices and, in the absence of market power ( $\theta_{ii} = 0$  and  $\phi = 0$ ), equation (12) is satisfied when output price equals marginal cost in each period, the well-known necessary conditions for a competitive equilibrium.

As in most studies of this type, we work with aggregate data; thus aggregation over the retailing firms is required in order to obtain an estimable form of (12). Thus, in each period, we replace  $q_i$  and  $q_j$  with the corresponding market quantities  $Q_i$  and  $Q_j$ , but we assume non-linear aggregation of industry output, such that marginal costs can differ across retailing firms of different size.<sup>9</sup> Since we allow this differentiation, the estimated  $\theta_{ii}$  and  $\phi$  cannot be interpreted as the common conjectural elasticities of all firms in the industry, but simply as a measure of the departure

<sup>8</sup> The definitions of these terms are reported in the Appendix.

<sup>9</sup> Linear aggregation of output over firms (i.e.  $Q_i = \sum q_i$ ) requires that firm-level cost functions are quasi-homothetic. This implies that technical differences across firms are restricted to the level of fixed costs, while marginal costs are constant and identical across firms. This is of course a very restrictive assumption, that can be relaxed assuming some more general form of nonlinear aggregation of output (i.e.  $Q_i = f(q_i^1, \dots, q_i^K)$  where  $K$  is the number of retailing firms) (Chambers, 1988, Chapter 5).

from marginal cost pricing, in line with the interpretations originally proposed by Bresnahan (1982) and Hyde and Perloff (1998), which are still valid in a dynamic setting (Perloff et al., 2007).<sup>10</sup>

The two inverse demand equations in (6), the two inverse supply equations in (7) and the two FOCs in (12) define the six-equation system to be estimated.

#### 4. Empirical specification

In order to obtain the empirical version of our model, we need to specify the functional forms for the demand functions, the supply functions and the marginal cost of retailing. Although the quantity-setting dynamic model presented in section 3 is based on inverse demands and supplies, we believe that, for the grana cheese market, the most suitable specifications are the direct (quantity-dependent) demands and supplies, since inverse specifications are normally considered appropriate for the case of fresh highly perishable products.

The demand side of our model considers home consumption of PR and GP by Italian households, which represents the main use of the two grana cheeses (around 70% of total aged production for both PR and GP). To model final consumption, we adopt the well-known Almost Ideal Demand System (AIDS) conditional specification (Deaton and Muellbauer, 1980), assuming multistage budgeting and weak separability between the two grana cheeses and all the other purchased goods:

$$w_{it} = \alpha_i + \sum_{j=1}^N \gamma_{ij} \ln p_{jt} + \beta_i \ln(X_t / P_t) + \tau_i \ln T_t \quad i = PR, GP \quad (14)$$

where  $w_{it} = p_{it}Q_{it} / X_t$  is the budget share of the  $i^{th}$  good,  $X_t$  the total consumer expenditure on grana cheeses and  $T_t$  a yearly linear time trend, while  $\alpha_i$ ,  $\beta_i$ ,  $\gamma_{ij}$  and  $\tau_i$  are parameters to be estimated.  $P_t$  is a general price index that in the so-called ‘‘Linear Version’’ of the AIDS (LAIDS) is approximated by the Stone price index  $\left( \ln P_t = \sum_i w_{it} \ln p_{it} \right)$ <sup>11</sup>. In order to avoid the unit of measurement problem

<sup>10</sup> This assumption is also needed if we want to distinguish between  $\theta_{ii}$  from  $\phi$ . In fact, as explained in Gohin and Guyomard (2000), under fixed proportions and constant marginal costs across retail firms, we have that  $\theta_{ii} = \phi$ . On the contrary, under our assumption, we allow different degrees of market power on the wholesale and retail market.

<sup>11</sup> The theoretical properties of homogeneity, symmetry and adding-up can be maintained through the following parametric restrictions  $\gamma_{ij} = \gamma_{ji}$ ,  $\sum_i \gamma_{ij} = \sum_j \gamma_{ij} = \sum_i \beta_i = \sum_i \tau_i = 0$ ,  $\sum_i \alpha_i = 1$ .

implied by this last index, we scale retail prices and total expenditure at their sample mean (Moschini, 1995). Since in the FOCs in (12) we have the demand flexibilities defined in equation (13) ( $f_{iit}$ ,  $f_{ijt}$ ,  $f_{iit+1}$ ,  $f_{jit+1}$ ,  $f_{ijt+1}$  and  $f_{jtt+1}$ ), their parametric form is obtained inverting the Marshallian price elasticity matrix of the AIDS model (Anderson, 1980) and then substituted in equation (12)<sup>12</sup>.

On the ripeners' side, we employ a standard (quantity-dependent) linear supply function, in coherence with assumption (e) discussed in the previous section, where the key explanatory variables are those specified in (5), that are derived from the ripeners' optimization problem:

$$Q_{it} = \lambda_0 + \sum_j \lambda_{ij} Q_{jt-1} + \sum_j \omega_{ij} w_{jt} + \sum_j \varphi_{ij} w_{jt-1} + \sum_j \eta_{ij} v_{jt} + \sum_j \mu_{ij} v_{jt-1} + \sum_j \rho_{ij} I_{jt-1} + \tau_i \ln T_t \quad i, j = PR, GP \quad (15)$$

Again, since in the FOCs in (12) we have the supply flexibilities ( $g_{iit}$ ,  $g_{ijt}$ ,  $g_{iit+1}$ ,  $g_{jit+1}$ ,  $g_{ijt+1}$  and  $g_{jtt+1}$ ), their parametric form is obtained inverting the corresponding direct price elasticity matrix and then substituted in equation (12)<sup>13</sup>.

Given the seasonality of both consumption and production of grana cheese, we also added a set of monthly intercept dummies to the two demand equations in (14) and a set of intercept and slope<sup>14</sup> quarterly dummies to the two supply equations in (15).

On the FOCs side, given the nature of the retailing activity, the retailers' marginal cost is assumed to be the same for both PR and GP and dependent on the sum of the marketed quantities of the two cheeses:

$$\frac{\partial C_t}{\partial Q_{it}} = \frac{\partial C_t}{\partial Q_{jt}} = \mu_0 + \mu_1 lab_t + \mu_2 (Q_{it} + Q_{jt}) \quad (16)$$

where  $lab_t$  is the wage index for the retail sector. We also allow the conjectural elasticities to vary over time defining:

$$\begin{aligned} \theta_{ii} &= \theta_{ii}^1 + \theta_{ii}^{t>1} \ln T_t \\ \phi &= \phi^1 + \phi^{t>1} \ln T_t \end{aligned} \quad (17)$$

in order to capture changes on the quantity setting behaviour by retailers. Thus, the price transmission equations between wholesale and retail prices of PR and GP are derived from the

<sup>12</sup> Note that our demand specification is similar to that of Hyde and Perloff (1998), but they adopt a simple inverse of each LAIDS elasticity as parametric form of the corresponding flexibility.

<sup>13</sup> In order to maintain homogeneity, all prices in (15) are normalised using as numeraire the wage index of the dairy industry, since labour represents one of the main cost components for ripeners.

<sup>14</sup> The slope quarterly dummies act only on the own-price supply parameters.

FOCs in (12), substituting the quantity-dependent specification of the marginal cost in (15)<sup>15</sup> and the definition of the conjectural parameters in (17):

$$\begin{aligned}
& p_{it} + f_{iit} (\theta_i^1 + \theta_i^{t>1} \ln T) p_{it} + f_{jit} (\theta_j^1 + \theta_j^{t>1} \ln T) p_{jt} \frac{q_{jt}}{q_{it}} \\
& - w_{it} - g_{iit} (\phi^1 + \phi^{t>1} \ln T) w_{it} - g_{jit} (\phi^1 + \phi^{t>1} \ln T) w_{jt} \frac{q_{jt}}{q_{it}} - [\mu_0 + \mu_1 m_t + \mu_2 (Q_{it} + Q_{jt})] \\
& - \delta \frac{(\phi^1 + \phi^{t>1} \ln T)}{q_{it}} [q_{it+1} A1 - q_{jt+1} A2] \\
& + \delta \left[ \begin{aligned} & p_{it+1} + f_{iit+1} (\theta_i^1 + \theta_i^{t>1} \ln T) p_{it+1} + f_{jit+1} (\theta_j^1 + \theta_j^{t>1} \ln T) p_{jt+1} \frac{q_{jt+1}}{q_{it+1}} \\ & - w_{it+1} - g_{iit+1} (\phi^1 + \phi^{t>1} \ln T) w_{it+1} - g_{jit+1} (\phi^1 + \phi^{t>1} \ln T) w_{jt+1} \frac{q_{jt+1}}{q_{it+1}} - [\mu_0 + \mu_1 m_{t+1} + \mu_2 (Q_{it+1} + Q_{jt+1})] \end{aligned} \right] \left[ \frac{A2 * B3 - A1 * B2}{B1 * B2 - B3 * B4} \right] \\
& + \delta \frac{q_{jt}}{q_{it}} \left[ \begin{aligned} & p_{jt+1} + f_{jtt+1} (\theta_j^1 + \theta_j^{t>1} \ln T) p_{jt+1} + f_{iit+1} (\theta_i^1 + \theta_i^{t>1} \ln T) p_{it+1} \frac{q_{it+1}}{q_{jt+1}} \\ & - w_{jt+1} - g_{jtt+1} (\phi^1 + \phi^{t>1} \ln T) w_{jt+1} - g_{iit+1} (\phi^1 + \phi^{t>1} \ln T) w_{it+1} \frac{q_{it+1}}{q_{jt+1}} - [\mu_0 + \mu_1 m_{t+1} + \mu_2 (Q_{it+1} + Q_{jt+1})] \end{aligned} \right] \left[ \frac{A1 * B4 - A2 * B1}{B1 * B2 - B3 * B4} \right] = 0
\end{aligned} \tag{18}$$

$i, j = PR, GP$

Appending an error term to the two demand equations in (14), the two supply equations in (15) and the two price transmission equations in (18) we obtain a six-equation system with six endogenous variables: the two retail prices, the two wholesale prices and two quantities exchanged of PR and GP. This system can be estimated simultaneously, since all parameters are identified.

## 5. Data and estimation

All of the data required to estimate the empirical version of the model are available on a monthly frequency for the period January 2002 - December 2008 (84 observations). The short period of time (7 years) allows to work on a set of relatively homogeneous data from the point of view of estimating market power parameters. In fact, in the 2002-08 period, the structure of the food retail sector has been relatively stable, since most of the big mergers and acquisitions took place at the end of the '90s. The same can be said on the structure of the grana cheese ripeners/wholesalers, since most of the major players, both among cooperatives and among private firms, have maintained their market shares during the period. Thus, any direction of changes of market power over time should be related to a change in retailers' conducts and should be captured by the definition of the parameters in equation (17).

Information on PR and GP home consumption has been retrieved from a representative panel of 6,000 consumers managed by CRPA-SIPR (2009). This survey collects domestic consumption data

<sup>15</sup> A quantity-dependent marginal cost is consistent with non-linear aggregation of industry output (see footnote 7).



(that is consumption at home through purchases at the retail level) both in value and in quantity terms, such that monthly average retail prices can be obtained taking the ratio between the corresponding values and quantities. The value of consumption already includes sales in promotion. Hence, promotions are implicitly included in the monthly average retail prices of the two cheeses. The wholesale prices of the two grana cheese are regularly collected by public institutions such as the local Chambers of Commerce. Data on input prices (wage index in both the retail and the dairy industries) are available from the National Institute of Statistics (ISTAT). Data on private stocks of PR and GP are regularly collected, since grana cheese enjoyed a special payment for private storage in the context of the Common Agricultural Policy (CAP), which has now been abolished after the “Health Check” dairy policy reform. As a measure of the fixed rate of discount  $\delta$ , we have used the difference between the average return of short-term treasury bonds and the average inflation rate in the sample period, taken from the Central European Bank official statistics; this should approximate the real interest rate.

The system is estimated using the Generalised Method of Moments (GMM). The advantage of GMM over traditional estimation methods, such as maximum likelihood, is that GMM does not require strong assumptions on the underlying data generating process and has the ability to generate heteroscedasticity and autocorrelation robust standard errors<sup>16</sup>. The method is based on a set of  $M$  moment conditions used to estimate the  $K$  parameters of the model, with  $M \geq K$  (Greene, 2003). We adopt a standard set of instrumental variable moment conditions, where the instruments are assumed to be orthogonal to the residuals in each equation. Thus, since we adopt the same set of  $L$  instruments for each equation, in our case the number of moment conditions is  $M=hL$ , where  $h$  is the number of equations to be estimated.

The estimated version of the model includes five equations: one of the two demand share equations<sup>17</sup> in (14), the two supply equations in (15) and the two price transmission equations in (18). The final set of instruments include all the exogenous variables in the system (the constant, eleven monthly dummies, three quarterly dummies, a time trend, final expenditure on grana cheeses, wage index in the retail sector, wage index in the dairy industry, contemporary and lagged prices of fresh PR and GP, lagged stocks of PR and GP) and all the predetermined variables (lagged and leaded wholesale prices, retail prices and marketed quantities of both PR and GP).

Since the model is highly non-linear and convergence is difficult to achieve, starting values for GMM estimation have been constructed in three stages: first estimating the demand share equation

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<sup>16</sup> Many popular estimation methods (non linear least squares, instrumental variables, maximum likelihood) can be interpreted as special cases of GMM, depending upon the number and type of moment conditions considered, as well as the form of the weighting matrix used in the criterion function (Greene, 2003).

<sup>17</sup> The second share equation is omitted in order to avoid singularity of the system.

only, then the two supply equations only and finally the two price transmission equation, holding the supply and demand parameters constant at the values estimated in the first two stages. The covariance matrix of the moment conditions was then constructed from these starting values, and during the estimation procedure was iterated in order to obtain its optimal form. This optimal matrix was constructed taking into account the presence of serial correlation, since we are using monthly time series data. For the same reason, standard errors are also computed correcting for serial correlation.

To see whether the structure of the model is correct, we use a  $J$ -test of overidentifying restrictions. If there are  $M=hL$  moment conditions and  $K$  parameters, there are  $M-K$  over-identifying restrictions and it can be shown that the corresponding Sargan statistics has a  $\chi^2_{M-K}$  distribution (Greene, 2003). The null hypothesis of the  $J$ -test is that the over-identifying restrictions hold and then the structure of the model is correct. The set of instruments described above was not rejected by the test<sup>18</sup>.

## 6. Results and discussion

Parameter estimates of the simultaneous system of five equations are reported in Table 1. Since the model is non-linear in the endogenous variables, it has been estimated in its implicit form as written in (14), (15) and (18). Thus, goodness-of-fit statistics, such as  $R^2$ , could not be computed. However, statistically significant parameters are present in all equations, and this is a signal that the GMM estimation technique performed well. Table 2 also shows the Marshallian elasticity estimates for the demand and supply equations at the mean point of the sample.

The two demand functions are well-behaved and both own-price and expenditure elasticities have the expected signs. Both PR and GP have inelastic demand with own-price elasticities that are close in absolute value. The two cheese differ in expenditure elasticities, with the demand for PR that is relatively more sensitive to the amount spent by consumers in this cheese category (1.19 for PR vs. 0.85 for GP). Since we are evaluating conditional elasticities, it is incorrect to classify PR as a luxury, but for sure it is more sensitive to a change in consumer income as compared to GP. In fact, GP demand is inelastic with respect to total expenditure, thus it can be classified as a necessity, since for food items income elasticity is normally lower than group expenditure elasticity. This seems to confirm the competitive position of the two PDO cheeses, with PR targeted to a “premium” use and GP playing the role of “mass product”.

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<sup>18</sup> The P-value of our J-test is 0.92 with 115 degrees of freedom.

Looking at cross-price effects, both cross-price elasticities are not significantly different from zero. Thus, in the last few years it seems that the degree of substitutability between the two PDO cheeses has been quite low, at least for home consumption. This may imply some degree of loyalty of groups of Italian consumer to each of the two PDO cheeses, while the level of consumption strongly depends on own-price and consumer income.

Another important element of the analysis is the significant negative trend parameter for PR (to which, by construction, corresponds a positive trend for GP), which confirms the long-term trend observed in recent years. The trend parameter captures structural change in tastes as well as other factors that are not considered in the model. On the demand side, the PR negative trend is likely due to a shift in consumers' preferences, that tend to use GP more often for home dish preparations, leaving PR to higher quality preparations and "stand alone" consumption.

Marginal costs of retailing are positively related to the retail labour wage index, while they turn out to be negatively related to the marketed quantities of the two cheese. This seems to suggest that retailers have still to exploit some economies of scale.

The supply of grana cheese by ripeners is more difficult to interpret, given the dynamics, the number of estimated parameters and the role of the dummy variables. The own-price elasticities at the mean point of the sample are not significantly different from zero, while the supply variability is mainly explained by the quarterly dummies acting on the intercept of the supply function and by the (input) price of fresh grana cheese. In fact, the fresh PR price is statistically significant and seems to drive the ripeners' decisions, decreasing the quantity supplied of both PR and GP. However, both supply functions do not provide fully satisfactory results, and this might reflect a problem either in the data or in their empirical specification<sup>19</sup>.

The key results of our analysis are of course the estimated conjectural parameters included in the price transmission equations. Parameters are significantly different from zero on the consumer side, and the trend effect plays a role for both products and in different directions: for PR the departure from perfect competition seems to increase over time, while it reduces for GP. This may be coherent with the fact that GP, as lower quality cheese, is increasingly used by retailers for promotion activities<sup>20</sup>. Therefore, the estimated parameters confirm the existence of a departure from perfect competition by retailers toward final consumers, while on the ripeners' side the conjectural parameters are not significantly different from zero and the market appears to be

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<sup>19</sup> We tried several alternative linear specifications of the supply functions, but the results did not change substantially. One of the problem might be the stock variable that we use. As mentioned in section 5, this variable refers to the private stocks that were entitled to receive the CAP private storage payment, that is cheese in a specific phase of the ripening process. So, it gives only a partial indication of the whole amount of PR and GP cheese under ripening. Unfortunately, no better information about stocks is available.

<sup>20</sup> Unfortunately, no data about the intensity of promotions are available, thus a more specific analysis of the role of promotions cannot be carried out in this context.

competitive. Of course, this last result should be interpreted with caution given the estimation problems of the supply functions. Table 3 shows the conjectural elasticity values at the mean point of the sample, that are significant only for PR, with a value of 0.25.

In order to measure the oligopoly total price distortion, Table 3 also shows the computed Lerner's type index (Schroeter and Azzam, 1990):

$$D_i = \frac{p_i - w_i - \frac{\partial C_i}{\partial Q_{it}}}{p_i - w_i} \quad i = PR, GP. \quad (19)$$

This index simply measures, for each product, the incidence of the market power distortion on the observed price margin. Over the sample period,  $D_{PR}$  and  $D_{GP}$  have an average value, respectively, of 0.68 and 0.59 with low standard deviations, indicating a limited variability of the price distortion over time. However, the indexes computed at the mean point of the sample show a significant impact of market power, on the oligopoly side only for PR.

The interpretation of this result is not straightforward. The fact that market power is only exerted for PR may suggest that the different reputation of the two grana cheeses, which reflects in different demand characteristics, might play a role: PR is in fact perceived as the highest quality grana cheese by Italian consumers, with a higher retail price premium, a stronger reputation and lower marketed volumes. Moreover, the results concerning the wholesale market do not seem to reflect a common claim by PR and GP processors/ripeners, that often highlight the strong market power exerted by retailers. This might reflect problems in the estimation phase, but one has also to consider that both collective PDO brands (PR and GP) are very well known to Italian consumers and have a high stock of goodwill, such that all Italian retail chains must have grana cheese in their assortment. Thus, this may reduce the possibilities of a quantity setting behaviour toward ripeners.

## 7. Concluding remarks

In this paper, we have evaluated the role of market power by retailers within the supply chain of Parmigiano Reggiano (PR) and Grana Padano (GP), the two most famous Italian PDO cheeses. We focus on the role of retailers, because they are becoming increasingly important in the grana cheese supply chain. This is because PR and GP are very peculiar PDO products. Given their widespread consumption, they are among the very few PDO products that can be considered mass market goods rather than niche goods. Thus, as most generic food products, they reach final consumers mainly through super and hypermarket chains, rather than through specialised channels, and, given their incidence on food retail sales, they are a key element of the assortment of large retailers.

Market power is analysed in the context of a dynamic imperfect competition model of the supply chain, under a quantity setting approach. The modelling framework draws from the “sticky price model” presented in Perloff et al. (2007, Chapter 7), extending this model in several ways: considering two outputs (PR and GP) rather than one; assuming the presence of both oligopoly and oligopsony power at the same time; adopting a non linear specification of the demand functions.

The model has been estimated on industry-level data and the GMM estimation performed well, showing significant parameters in all the equations, although some unsatisfactory results are still present in the supply equations.

We find evidences of downstream market power by retailers (i.e. toward final consumers) only for PR and no evidences of upstream market power toward processors/ripeners. Thus, these results do not confirm the frequent claim by PR and GP processors/ripeners that often highlight their low bargaining power toward retailers. Such results may be related to the established reputation of the two PDO brands among Italian consumers, that may make more difficult for retailers to exercise their market power.

Starting from the results of this paper, further improvements of the model may lead to more conclusive evidences. The modelling framework would need further sophistications in the modelling of the dynamic behaviour of the ripeners’ supply, but this finds limitations both in the complexity of the model and in the availability of data. To pursue this objective one has to face the difficulties in estimating a simultaneous highly nonlinear system of equations, which make any extension of the model quite challenging. Moreover, the lack of detailed data on stocks limits the possible alternatives in interpreting this key aspect of the supply side.

The interpretation of the empirical results is also limited by the quantity setting approach. As in many of these models, one can find evidences of departure from perfect competition but little can be said about the strategic game behind this result. This is evident from the comments provided in the results section, where new hypotheses and alternative explanations are suggested that would require further investigation under alternative settings and data. In perspective, it would be interesting to support and compare the results of this study with other studies based on other approaches. For example, one may emphasise the bargaining relationships between suppliers and retailers, or, as suggested by one referee, one may estimate a multi-stage vertical chain model, assuming that ripeners can also exert market power.

**Table 1: GMM estimated parameters of the 5-equation system**

Variable	Parameter	Coefficient	t-stat	Coefficient	t-stat
<b>Demand</b>		<b>PR</b>			
	Constant	$\alpha_i$	0.48168***	50.604	
$p_{it}$	PR price	$\gamma_{ii}$	0.07460	0.975	
$\ln(X_t/P_t)$	Total expenditure	$\beta_i$	0.08601***	2.689	
$T_t$	Trend	$\tau_i$	-0.03505***	-7.414	
dm1	Monthly dummy		0.02384**	2.377	
dm2			0.00395	0.452	
dm3			-0.01591**	-2.046	
dm4			0.01716	1.305	
dm5			0.00265	0.216	
dm6			-0.01355	-1.568	
dm7			-0.01242	-0.845	
dm8			-0.00405	-0.268	
dm9			-0.03257***	-3.930	
dm10			0.03307***	2.718	
dm11			0.03726***	4.205	
<b>Marginal costs</b>					
	Constant	$\mu_0$	-3.71869	-1.328	
$lab_t$	Wage index	$\mu_1$	0.04802***	2.684	
$Q_{PRt}, Q_{Gpt}$	Marketed quantities	$\mu_2$	-0.00002***	-2.718	
<b>Conjectural parameters</b>		$\phi^1$	-0.00047	-0.270	
		$\phi^{t>1}$	0.00020	0.262	
			<b>PR</b>	<b>GP</b>	
		$\theta_{ii}^1$	0.16876	1.446	0.27525*
		$\theta_{ii}^{t>1}$	0.05910***	2.627	-0.04399**
			<b>PR</b>	<b>GP</b>	
	Constant	$\lambda_0$	3562.6**	1.879	5480.7
$Q_{PRt-1}$	PR quantity	$\lambda_{ii}$	0.11415	0.998	-0.01036
$Q_{Gpt-1}$	GP quantity	$\lambda_{ij}$	-0.20496***	-2.744	-0.30415**
$W_{PRt}$	PR wholesale price (ripened)	$\omega_{ii}$	-12815.5	-0.477	24323.0
$W_{Gpt}$	GP wholesale price (ripened)	$\omega_{ij}$	146953.0**	1.905	350637.0**
$W_{PRt-1}$	PR wholesale price (ripened)	$\phi_{ii}$	1790.6	0.530	-2296.8
$W_{Gpt-1}$	GP wholesale price (ripened)	$\phi_{ij}$	1897.5	0.372	-543.0
$V_{PRt}$	PR wholesale price (fresh)	$\eta_{ii}$	-87791.3*	-1.718	-236255.0**
$V_{Gpt}$	GP wholesale price (fresh)	$\eta_{ij}$	33825.2	0.398	-35954.7
$V_{PRt-1}$	PR wholesale price (fresh)	$\mu_{ii}$	59989.3	1.187	202161.0*
$V_{Gpt-1}$	GP wholesale price (fresh)	$\mu_{ij}$	-46627.6	-0.577	-179386.0
$I_{PRt-1}$	PR stocks	$\rho_{ii}$	-0.01581	-1.277	-0.03310
$I_{Gpt-1}$	GP stocks	$\rho_{ij}$	-0.01196	-1.296	-0.01179
$T_t$	Trend	$\tau_i$	-404.6***	-2.903	456.1
dq1	Quarterly dummy		5877.6*	1.745	15168.3*
dq2			7912.2***	3.205	14495.7***
dq3			6637.4**	2.249	14612.2**
dq1	Quarterly dummy * $W_{PRt}$		34738.0	1.058	77078.3
dq2			2886.5	0.107	13174.7
dq3			6479.6	0.221	24453.9
dq1	Quarterly dummy * $W_{Gpt}$		-158263.0*	-1.715	-385172.0
dq2			-161526.0**	-2.251	-294545.0*
dq3			-152372.0**	-2.046	-315565.0**

Note: \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels.

Table 2: Demand and supply elasticities at the mean point of the sample<sup>(a)</sup>

	p1	p2	y
<i>Demand</i>			
Parmigiano Reggiano (q1)	-0.917*** (-5.048)	-0.278 (-1.627)	1.195*** (16.493)
Grana Padano (q2)	-0.066 (-0.456)	-0.780*** (-5.783)	0.846*** (14.766)
<i>Supply</i>			
Parmigiano Reggiano (q1)	-0.029 (-0.168)	0.322 (1.241)	
Grana Padano (q2)	0.490* (1.686)	0.644 (1.440)	

Note: \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels.  
<sup>(a)</sup>asymptotic t-statistics in parenthesis

Table 3: Market power parameters at the mean point of the sample<sup>(a)</sup>

	Parmigiano Reggiano	Grana Padano
<i>Conjectural elasticities</i>		
$\theta_{i,i}$	0.25070** (2.082)	0.21426 (1.303)
$\phi$	-0.00019 (-0.264)	
<i>Index of oligopoly total price distortion</i>		
$D_i$	0.687** (2.029)	0.598 (1.381)
<i>average values over the sample period</i>		
$D_i$	0.677	0.593
Standard Dev.	0.053	0.097

Note: \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels.  
<sup>(a)</sup>asymptotic t-statistics in parenthesis



## Appendix

In equation (12), the following definitions hold:

$$A1 = \left[ g_{iit} w_{it} \frac{\partial w_{it}}{\partial w_{it-1}} + g_{jit} w_{jt} \frac{\partial w_{it}}{\partial w_{jt-1}} + h_{iit+1} w_{it+1} \right]$$

$$A2 = \left[ g_{iit} w_{it} \frac{\partial w_{jt}}{\partial w_{it-1}} + g_{jit} w_{jt} \frac{\partial w_{jt}}{\partial w_{jt-1}} + h_{jii+1} w_{jt+1} \right]$$

$$B1 = \left\{ g_{iit} w_{it} + \left[ \frac{h_{iit+1} w_{it+1} \frac{\partial w_{jt}}{\partial w_{jt-1}} - h_{jii+1} w_{jt+1} \frac{\partial w_{it}}{\partial w_{jt-1}}}{\frac{\partial w_{it}}{\partial w_{it-1}} \frac{\partial w_{jt}}{\partial w_{jt-1}} - \frac{\partial w_{it}}{\partial w_{jt-1}} \frac{\partial w_{jt}}{\partial w_{it-1}}} \right] \right\}$$

$$B2 = \left\{ g_{jit} w_{jt} + \left[ \frac{h_{jii+1} w_{jt+1} \frac{\partial w_{it}}{\partial w_{it-1}} - h_{iit+1} w_{it+1} \frac{\partial w_{jt}}{\partial w_{it-1}}}{\frac{\partial w_{it}}{\partial w_{it-1}} \frac{\partial w_{jt}}{\partial w_{jt-1}} - \frac{\partial w_{it}}{\partial w_{jt-1}} \frac{\partial w_{jt}}{\partial w_{it-1}}} \right] \right\}$$

$$B3 = \left\{ g_{iit} w_{it} + \left[ \frac{h_{jii+1} w_{it+1} \frac{\partial w_{jt}}{\partial w_{jt-1}} - h_{iit+1} w_{jt+1} \frac{\partial w_{it}}{\partial w_{jt-1}}}{\frac{\partial w_{it}}{\partial w_{it-1}} \frac{\partial w_{jt}}{\partial w_{jt-1}} - \frac{\partial w_{it}}{\partial w_{jt-1}} \frac{\partial w_{jt}}{\partial w_{it-1}}} \right] \right\}$$

$$B4 = \left\{ g_{jit} w_{jt} + \left[ \frac{h_{iit+1} w_{jt+1} \frac{\partial w_{it}}{\partial w_{it-1}} - h_{jii+1} w_{it+1} \frac{\partial w_{jt}}{\partial w_{it-1}}}{\frac{\partial w_{it}}{\partial w_{it-1}} \frac{\partial w_{jt}}{\partial w_{jt-1}} - \frac{\partial w_{it}}{\partial w_{jt-1}} \frac{\partial w_{jt}}{\partial w_{it-1}}} \right] \right\}$$

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