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Should We Cry over the Spilt Milk? Market Power and Structural Change along Dairy Supply Chains in EU Countries

Daniele Cavicchioli [1], Luca Cacchiarelli [2,*], Alessandro Sorrentino [2] and Roberto Pretolani [1]

[1] Department of Environmental Science and Policy, University of Milan, Via Celoria, 2, 20133 Milan, Italy; daniele.cavicchioli@unimi.it (D.C.); roberto.pretolani@unimi.it (R.P.)
[2] Department of Economics, Engineering, Society and Business Organization, University of Tuscia, Via del Paradiso, 47, 01100 Viterbo, Italy; sorrenti@unitus.it
* Correspondence: cacchiarelli@unitus.it

Abstract: A "first-pass" test on a set of monthly prices index series from 2000 to 2015 was applied to detect market power exertion in the dairy value chain of 25 EU countries. Due to econometric and theoretical restrictions, the test yielded conclusive findings only in 11 over 25 EU Countries. Such results show that in Austria, Portugal, Slovakia, Hungary and Croatia, the downstream sector exerts market power. Other EU countries (Spain, UK, Denmark, Czech Republic, Bulgaria and Sweden) are characterised by perfectly competitive dairy chains. These results were consistent with the findings of previous studies based on structural and mark-up models. Results of the market power test in the subsample of 11 countries have been related to various structural characteristics of the dairy chains. Market power exertion is negatively related to the average farm size. Such variable may be seen as a proxy of the degree of supply concentration provided by Producers Organizations (POs) to increase the bargaining power of the farm sector along the food chain. To test such a hypothesis, comparable data on supply concentration by POs across EU Countries are necessary. On the other hand, the structural change, represented by the increase of average farm size over time and the concentration rate in higher classes (above 250,000 € of Standard Output) is almost unrelated to the perfectly competitive conduct along EU dairy chains.

Keywords: market power; value chain; Common Agricultural Policy

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1. Introduction

The dairy sector represents the second-largest EU agricultural sector in terms of output value after the fruit and vegetable sector, followed by cereals [1]. The European dairy industry is a well-established and organised mature market in terms of product and distribution channels. The price dynamics of raw milk are a decisive driver in this sector [2].

The dairy sector has been subjected to various Common Agricultural Policy (CAP) reforms [3,4]. In the early stages of the CAP, the dairy sector enjoyed price support for its products; the budgetary burden of such measures led to the introduction of milk quotas (in 1984) to limit the maximum amount of milk delivered to dairy products. Later, because of WTO negotiations, the milk quota regime was progressively relaxed and then suppressed in 2015, making EU dairy prices more susceptible to international price movements. Such liberalisation may accrue unbalanced power relationships along the EU dairy chains. Dairy farmers occupy a weak position in the food supply chain, while processors and retailers are highly concentrated [5]. As a result, differences in market power may lead to competition inequalities in EU dairy supply chains.

The last CAP reforms (e.g., Common Market Organisation (CMO) Regulation in 2013 [6], "Milk Package" [7] and the more recent Farm to Fork Strategy [8] aimed to strengthen the role of farmers by fostering supply concentration through Producer Organisations (POs), associations and interbranch organisations, with the objective of balancing power and the distribution of the value-added along the agro-food supply chain.

The "Milk Package", introduced in 2012, was designed to improve the bargaining power of dairy farmers in the supply chain through three main tools: (1) increased transparency in the market; (2) the possibility for farmers to organise into producer organisations (POs) that can negotiate contracts collectively; (3) the opportunity for the Member States to impose written contracts between farmers and dairy processors. The way paved by the Milk Package is prosecuted by the Farm-to-Fork strategy that, among its various targets, will strengthen farmers' position in the supply chain "to capture a fair share of the added value of sustainable production by encouraging the possibilities for cooperation within the common market organisations for agricultural products" [8].

Several studies, using different methodological approaches, focused on oligopolistic and oligopsonistic power exerted within dairy supply chains at the food processing and retail stages to the detriment of farmers (suppliers of raw agricultural inputs) and consumers. Some authors [9–12] have aimed to verify this view by examining the mechanism of price transmission in some EU countries, identifying both short-run and long-run asymmetries as indicators of market power by the downstream sector. Structural models [13–19], the "first-pass" test proposed by Lloyd et al. [20–24] and, recently, the application of stochastic frontier methodology on a mark-up model [25] have been employed to detect market power along EU milk and dairy supply chains, showing, in various cases, market power exertion of processors and retailers. Baráthová et al. [26] and Di Marcantonio et al. [27] found that unfair trading practices frequently occur in the dairy sector in some EU countries.

Antonioli and Santeramo [3] investigated the mechanisms of vertical price transmission in Italian milk supply chains before and after the 2003 policy reform and found that market sluggishness increased in the post-reform period, but the asymmetric dynamics were less evident, identifying that fairness (symmetric price adjustments) may come at the cost of market efficiency (slower price transmission).

While the issue of strengthening the position of dairy farmers in EU supply chains has prompted recent CAP reforms, evidence of the systematic and comparable assessment of market power exertion along EU dairy chains is scant. In particular, while price transmission analyses are easy to implement (relying on consumer and producer prices only) but do not provide conclusive evidence of imperfect competition, structural models yield robust measurement of market power, but being data demanding, are difficult to implement. Given such a shortage of comparable evidence, and to overcome the limitations of both approaches, we apply a "first-pass" test proposed by Lloyd et al. [20] to detect the presence of market power in the dairy chains of 25 EU countries. As a second step, we investigate how structural features of dairy supply chains in EU countries are correlated to the presence of imperfect competition.

This study provides both empirical and methodological contributions to the analysis of EU food supply chains. Firstly, by empirically estimating a "first-pass" test to detect the exertion of market power of processors and retailers in the EU dairy supply chains before the introduction of the last recent CAP reforms (the end of milk quotas and the implementation of the "milk package"). Second, by validating the "first pass" test, comparing its outcomes on market power exertion with those of structural models. Third, it attempts to implicitly assess which structural characteristics across EU-25 food supply chains are correlated to the presence of imperfect competition. Fourth, it implicitly represents an ex-post analysis of the role played by the 2003 CAP reform, which introduced liberalisation of the milk sector by reducing price support and creating direct income support.

The remainder of the paper is organised as follows: Section 2 provides a reasoned literature review on the tools used to analyse imperfect competition along food supply chains. Such a section motivates the use of the empirical model adopted and reports the relevant literature on price transmission and imperfect competition analysis in the dairy sector. Section 3 explains the choice of the model adopted to isolate imperfect competition along EU dairy chains, the data and econometric tools used for its empirical application, and some relevant characteristics of the supply chains examined. Section 3 presents the results of the market power test and how the structural characteristics of the national dairy supply chain are related. Section 4 concludes.

2. A Reasoned Literature Review on Tools for Analysing Imperfect Competition along Food Supply Chains

This section aims to motivate the use of the empirical approach adopted in this article to detect the presence of imperfect competition in EU dairy chains. As briefly mentioned in the introduction, imperfect competition in agri-food markets has been investigated using two methodologies: Asymmetric price transmission and structural models, presented in the two sub-sections. Such tools require different kinds of data, operate at different levels and present advantages and disadvantages. Based on such pros and cons, the last sub-section motivates the use of the market power test adopted in this article. In each sub-section, the relevant literature applied to the dairy sector is listed. A more in-depth comparison of price transmission and market power analysis models is provided by Cavicchioli [21].

2.1. Asymmetric Price Transmission (APT) Analyses

Such models examine the speed, timing and extent to which prices are transmitted both spatially (among markets of the same product) and vertically, from input to retail market [28]. Focusing on vertically related markets (especially food supply chains), the incomplete transmission of price changes from the farm to consumer stage are usually attributed to imperfect competition [28]. From the empirical viewpoint, APT analyses use time series of producer (wholesale) and retail prices, in level or as indexes, by testing their asymmetric movements using various time series econometrics tools. Given the availability of data required, APT studies are quite popular in the literature on agri-food markets. The explanations of the causes of APT are various and contrasting [29], even if market power in one or more stages of the supply chain is pointed among the causes. This is the case with various APT analyses in the dairy sector [12,30–35]. The weak points of APT studies are their lack of theoretical foundations and, consequently, their inability to demonstrate a clear causal relationship between imperfect competition and price asymmetries along the food chains [36–38]. The nexus between imperfect competition and APT has been investigated widely. Peltzman [39] examined price transmission in a wide range of vertically related markets, putting the results in comparison with a proxy of market power for each market. The weakness of this analysis is to use a market concentration index (Hirschmann-Herfindahl) as a proxy for the exercise of market power. This approach (like all those based on the Structure-Conduct-Performance paradigm) suffers from the endogeneity of market structure and simultaneity bias [40–42]. Along the same line, Bakucs et al. [10] carried out a meta-analysis on the relationship between the structure of agricultural markets and price transmission. It emerged that high degrees of concentration approximate only the potential for market power exertion and not necessarily an actual anti-competitive behaviour. In addition, in this case, the causal nexus between imperfect competition and ATP has been questioned.

On the theoretical side, Gardner [43] developed a farm–retail supply chain equilibrium displacement model, assuming perfect competition in the intermediate stage and constant return to scale; the model indicates a higher effect of food demand shifters compared to farm supply shifters on the marketing margin. Following the Gardner framework, McCorriston et al. [44,45] have shown that market power can reduce price transmission elasticity, but different conditions in the elasticity of substitution and returns to scale may either offset or amplify the market power effect. This implies that even with imperfectly competitive processing and retailing markets, certain technology and cost conditions (high elasticity of substitution and increasing returns to scale) can compensate for the market power effect, yielding symmetric price transmission along the marketing chain. In this case, the presence of APT would not be a viable tool for detecting the exertion of market power along food chains.

In addition to the previous criticisms, the literature provides other causes of ATP different from market power, such as policy intervention in farm prices [30], inflation [46], inventory costs [47] and menu-repricing costs [48,49].

To summarize what has been reported so far, the APT approach presents the advantage of using easily available data on farm and consumer price movements to examine and gain insights into the dynamics of the whole food supply chain. In so doing, all the vertically related stages within the marketing (farming, processing, wholesaling and retailing) chain are analysed. However, for a number of theoretical and empirical reasons, the presence of APT cannot represent conclusive evidence of market power exertion in one or more stages of the marketing chain analysed.

2.2. Structural Models

The present subsection draws on the contributions of Perloff et al. [50] and Perekhozhuk et al. [51], to which reference should be made for a more detailed discussion.

The broad category of structural models, also known as new empirical industrial organization (NEIO) models, was born to overcome the limitations of the structure–conduct–performance paradigm [42]. In their simpler versions, NEIO models are usually aimed at testing for the presence of market power exertion or estimating its extent at the market level and not along the entire food chain. A notable exception and evolution is represented by multi-stage market power models, discussed later. NEIO models differ according to the side of the market analysed (product supply or factor demand, measuring, respectively, oligopolistic or oligopsonistic power), the kind of product examined (homogeneous vs. differentiated), the estimation strategy adopted (parametric vs. non-parametric model) and the repetition of interactions among economic agents (static vs. dynamic models).

Oligopolistic power in a static, parametric and homogeneous product setting is exerted when sellers increase product prices above the marginal cost (MC). Firms' marginal costs are difficult to observe but can be estimated by exploiting the different revenue functions of firms under different market structures. In fact, under perfect competition, a firm's selling price (P) equals its marginal revenue (MR), whereas, under monopoly, the single seller represents the entire market supply, and therefore, its marginal revenue decreases as product quantity (Q) increases: $MR = P + Q(dP/dQ)$, where dP/dQ is the amount of the price decrease for an additional unit of product sold on the market. Both the previous expressions can be generalized in a single revenue function: $MR = P + \theta\, Q(dP/dQ)$, where θ represents a conduct parameter ranging from 0 to 1, measuring the extent of oligopolistic power. There is perfect competition when $\theta = 0$ or monopoly when $\theta = 1$; more generally, $\theta > 0$ indicates the exertion of oligopolistic power. Note that a symmetric explanation may be provided for oligopsonistic power exerted on the demand side for raw agricultural products. In empirical terms, θ and the marginal cost are estimated using a simultaneous equation model composed of optimality conditions (by equating MR and MC functions) and the market demand function [50]. To set up such a model, data on product price and quantity, demand shifters (i.e., consumer income, price of substitutes) and supply shifters (i.e., factor prices) are needed. Note that such a procedure allows estimation of the degree of market power only on one side (supply) of one stage within a supply chain.

In their more complex versions, NEIO models analyse the extent of oligopolistic and oligopsonistic power on more stages of the marketing chain [52,53], estimating market power for each stage of the supply chain, but presumably at the cost of increasing demand for data and econometric sophistication.

There are various contributions using NEIO models to estimate market power in the dairy markets, such as those of Grau an Hockmann [13]; Zavelberg et al. [14]; Sckokai et al. [54]; Salhofer et al. [15], Hockmann and Voneki [16], De Mello and Brandao [17] and Perekhozhuk et al. [19].

To overcome the methodological shortcomings of NEIO models, Kumbhakar et al. [55] and De Loecker and Warzynski [56] developed an approach to estimate the mark-up price over marginal costs ($[P - MC]/MC$) and the Lerner index using stochastic frontier analysis. Such a methodology requires firm microdata and, therefore, has the same data limitations as structural models. Nevertheless, there are some notable applications in EU dairy processing (Čechura et al. [25]; Koppenberg and Hirsch [57]; and Lee and Van Cayseele [58].

As NEIO models are rooted in economic theory, findings on the extent of market power exertion derived from their use are more conclusive and reliable than those of APT studies [36], even if there are some criticisms regarding their accuracy [59,60]; however, their requirements in terms of the quantity and quality of data and econometric efforts increase with model complexity (single-stage vs. multi-stage).

2.3. The "First Pass" Test to Detect Market Power Exertion along Food Supply Chains

The two groups of models (APT and NEIO) share, in some way, the same objective—to test or estimate market power exertion, even if the results of APT models are not conclusive; however, they operate at different levels, use different types of data, and provide different findings. To make the detection of market power exertion in agri-food systems more effective for competition policy purposes, it is desirable to integrate such approaches [36]. As previously stated, such an objective requires a methodology that unifies the advantages and addresses the limitations of the APT and NEIO models to conclusively test the exertion of market power along the entire food supply chain. The search for such a methodology should begin with the first model, which explicitly describes the functioning of a vertically related supply chain [44], even assuming perfect competition in the intermediate stage. McCorriston et al. [44,45] adapted the model, allowing for market power exertion within the marketing chain, variable elasticity of substitution, and nonconstant returns to scale to derive the elasticity of price transmission under different conditions. Lloyd et al. [20,61] built on this framework and developed (and applied) a theoretical model capable of detecting market power exertion along the food chain.

Such contributions are not unique; indeed, Holloway [62] modified the Gardner model, relaxing the assumption of perfectly competitive behaviour to test its effect on the farm-retail price spread (and then check for market power exertion). Both approaches use conduct parameters to allow for imperfect competition along the food chain; however, only the latter explicitly consider the entrance of new firms. However, the method used by Holloway [62] is more demanding in terms of data for the empirical application, as it requires time series data for prices and quantities (of raw agricultural products), whereas the "first pass" test of Lloyd et al. needs time series of prices (or price indices) supplemented by other easily available data (proxies of marketing costs, demand and supply shifters). From the perspective of data requirements, the latter approach is preferable when data on product quantities are not readily available. Therefore, this methodology has been employed in many countries [11,21,22,63–67]. Recently, Kinnucan and Tadjon [68] developed a framework to test for perfect competition, claiming its advantages over those of Lloyd et al. (2009). Unfortunately, this approach requires absolute farm and retail prices and often, only index prices are available in many countries.

3. Materials and Methods

3.1. The Model

The method of detecting market power exertion along the food supply chain is represented by the theoretical model introduced by McCorriston [44] and adapted by Lloyd et al. [20,61] for empirical applications to some food supply chains. The authors built a theoretical model by modifying the Gardner model [43] and assuming perfectly competitive markets. This theoretical framework considers the food supply chain by focusing on farm and marketing levels, while for simplicity, the intermediate stage is considered as an aggregate of the food processing and retail sectors. Specifically, retailers face the following demand function for the processed product:

$$x = D(Px, N) \tag{1}$$

where Px is the retail price of the good and N is the general demand shifter. The supply function of the agricultural raw material is given in the inverse form as follows:

$$Pa = k(A, W) \tag{2}$$

where A is the quantity of agricultural products supplied by farmers to retailers and resold by retailers to consumers, and W is the exogenous shifter in the farm supply equation. The source of power in the food chain is given to be at the retail level in the form both of oligopsony power "θ" (versus suppliers) and of oligopoly power "μ" (versus consumers). Although these parameters are widely employed in NEIO to estimate the extent of market power, in this case, they are used as instruments to signal anti-competitive behaviour.

Furthermore, the model considers a representative, retail firm with the following profit function:

$$\pi_i = Px(x)x_i - Pa(a)a_i - C_i(x_i) \tag{3}$$

where C_i is the other cost and, assuming a fixed proportion technology, $x_i = a_i/\rho$, where ρ is the input-output coefficient. Then, constant returns to scale in the distribution are assumed even if, as demonstrated by McCorriston et al. [43], the release of this assumption would not affect the significance of the market power test.

According to Lloyd et al. [20,61], for further details on the theoretical structure of the model, it delivers a quasi-reduced-form equation aimed at estimating the possible presence of market power as follows:

$$Px = \beta_0 + \beta_1 Pa + \beta_2 M + \beta_3 N + \beta_4 W \tag{4}$$

Under perfect competition along the food chain ($\theta = \mu = 0$), none of the shifters (N and W) affects the margin, and the associated parameters are not expected to be significantly different from zero. An additional prerequisite, consistent with economic theory and the theoretical model, is that the retail price must be positively related to both the producer price ($\beta_1 > 0$) and marketing cost ($\beta_2 > 0$) in the long term, and the associated parameter estimates should be positive and statistically significant. Thus, perfect competition can be tested as follows.

$$H_{0\ pc} : \beta_1 \succ 0; \beta_2 \succ 0; \beta_3 = \beta_4 = 0 \tag{5}$$

Note that, by failing to reject the null hypothesis, we can conclude that the supply chain is perfectly competitive, and rejection of the null hypothesis is not a sufficient condition to deduce the exertion of market power (although in conventional hypothesis testing, this would be the case). To reach this conclusion, some additional conditions are required: first, both parameters have to be significantly different from zero ($\beta_3 \neq 0$; $\beta_4 \neq 0$), and second, the parameter of the exogenous shifter N has to be positive ($\beta_3 > 0$), while the parameter of W has to be negative ($\beta_4 < 0$). Similarly, the market power exertion along the food chain was tested under the following null hypothesis:

$$H_{0mp} : \beta_1 \succ 0, \beta_2 \succ 0; \beta_3 \succ 0; \beta_4 \prec 0 \tag{6}$$

In the interpretation here (which differs slightly from the version of the authors who developed and implemented the model), only empirical results that fail to reject H_{0pc} (perfect competition) or H_{0mp} (market power exertion) are plausible and conclusive. Alternative hypotheses (only one of the shifters is significant and not signed according to model prescriptions) would yield ambiguous and inconclusive results.

3.2. Data

Table 1 shows the available data collected from the Eurostat public database, covering partially or totally from January 2000 to June 2016 for 25 EU countries. All data are monthly or quarterly time series in index form (rescaled, when necessary, to the base year 2010 and monthly). Consumer price corresponds to the harmonised price index of milk, cheese, and eggs purchased by consumers in the selected EU markets. Agricultural production price refers to the nominal and real price indices of milk, milk, cheese, eggs and whole milk sold by EU dairy farmers. To proxy for marketing costs, we used various time series, such as labour, transport, and energy cost indexes at the retail level. The real and nominal price indices of all goods and services purchased by farmers incorporated agricultural supply-side shocks (W). Finally, the demand shifter (N) is represented by the harmonised consumer price index for food, food and non-alcoholic beverages.

Since one of our objectives is to implicitly assess whether structural characteristics across EU-25 food supply chains are correlated to the presence of imperfect competition, Table 2 reports the main structural characteristics of the dairy sector in the EU 25 countries. The first two columns, which report the value of dairy production and its percentage of total agricultural production, indicate that the dairy sector, weighing between 15 and 30%, plays a relevant role in EU agriculture. Although in almost all countries, national farmers supply most dairy products employed in the next stages of the national dairy supply chains, the dairy industry and retailers in other countries buy a relevant share of raw materials.

Table 2 reports the average size, measured in terms of "standard output", of the dairy farms, which range from 6000 euros in Bulgaria to 435,000 euros in Denmark, showing the heterogeneity of agricultural production among EU countries. Table 2 also reports changes (%) in dairy farm size between 2005 and 2013 to capture agricultural structural change. Finally, we include the concentration rate of standard output in dairy farms larger than 250,000 euros and of the first five buyers in food retailing (CR5). The results indicate that the concentration level is decidedly higher in the retail stage than in agricultural production.

Table 1. Description of variables used for the test on market power.

Variable Category	Typology/Group of Product	Description of the Variable	Abbreviation	Frequency of Data	Time Coverage	Country Coverage	Base Year of the Index	Data Transformation
Retail price	Milk, cheese and eggs	Harmonized index of consumer price	rp1	monthly	2000M01–2016M06	ALL EU (25)	2005 = 100	Rescaled from 2005 to 2010;
Retail price	Milk, cheese and eggs	Consumer Price—Food Price Monitoring Tool	rp2	monthly	2005M01–2016M03	ALL EU (25)	2010 = 100	
Agricultural price (farmer price)	Milk	Farm price index of milk, nominal index	fp1	quarterly	2000M01–2016M06 (11 Countries)	17 countries 2005–2016	2010 = 100	from quarterly to monthly
Agricultural price (farmer price)	Milk	Farm price index of milk, real index	fp2	quarterly	2000M01–2016M06 (11 Countries)	17 countries 2005–2016	2010 = 100	from quarterly to monthly
Agricultural price (farmer price)	Milk, cheese and eggs	Agricultural Commodity price—Food Price Monitoring Tool	fp3	monthly	2005M01–2015M06 (20 Countries)	20 Counties 2005–2015	2010 = 100	
Agricultural price (farmer price)	Whole milk	Agricultural Commodity price—Food Price Monitoring Tool	fp4	monthly	2005M01–2015M06 (20 Countries)	20 Counties 2005–2015	2010 = 100	
Producer price (dairy processor gate)	Manifacture of Dairy products	Producer pricein Industry, domestic data, manufacture of dairy products	mp1	monthly	2000M01–2016M06	11 Countries	2010 = 100	
Producer price (dairy processor gate)	Operation of Dairies and Cheese making	Producer price in Industry, domestic data, operation of dairies and cheese making	mp2	monthly	2000M01–2016M06	11 countries	2010 = 100	
Producer price (dairy processor gate)	Milk, cheese and eggs	Producer price—Food Price Monitoring Tool	mp3	monthly	2005M01–2016M05 (5 countries)	5 countries	2010 = 100	
Marketing cost	Manifacturing	Labor Cost Index—Wages and salaries (total)—Calendar and seasonally adjusted data	Lcman	quarterly	2000Q1–2016Q1	24 Countries (no Croatia)	2012 = 100	Rescaled from 2012 to 2010; from quarterly to monthly
Marketing cost	Wholesale and Retail trade	Labor Cost Index—Wages and salaries (total)—Calendar and seasonally adjusted data	lcwr	quarterly	2000Q1–2016Q1	24 Countries (no Croatia)	2012 = 100	Rescaled from 2012 to 2010; from quarterly to monthly
Marketing cost	Transport and storage	Labor Cost Index—Wages and salaries (total)—Calendar and seasonally adjusted data	lcts	quarterly	2000Q1–2016Q1	24 Countries (no Croatia)	2012 = 100	Rescaled from 2012 to 2010; from quarterly to monthly
Marketing cost	Energy	Producer price index of energy in domestic market—unadjusted data	encost1	monthly	2000M1–2016M6	19 Countries	2010 = 100	
Marketing cost	Energy	Harmonized Index of Consumer Prices	encost2	monthly	2000M01–2016M06	19 Countries	2015 = 100	Rescaled from 2015 to 2010;

Table 1. *Cont.*

Variable Category	Typology/Group of Product	Description of the Variable	Abbreviation	Frequency of Data	Time Coverage	Country Coverage	Base Year of the Index	Data Transformation
Marketing cost	Manifacture of food products	Gross wages and salaries—seasonally and calendar adjusted data	lc4	monthly	2000M01–2016M04 (7 Countries)	7 countries	2010 = 100	
Demand shifter	HICP—All items	Harmonized Index of Consumer Prices	ds1	monthly	2000M01–2016M06	ALL EU (25)	2005 = 100	Rescaled from 2015 to 2010;
Demand shifter	HICP -Overall excluding seasonal food	Harmonized Index of Consumer Prices	ds2	monthly	2001M01–2016M06	24 Countries (Croatia 2004–2016)	2005 = 100	Rescaled from 2015 to 2010;
Demand shifter	HICP—food and nonalcholic beverages	Harmonized Index of Consumer Prices	ds3	monthly	2000M01–2016M06	ALL EU (25)	2005 = 100	Rescaled from 2015 to 2010;
Demand shifter	HICP—food	Harmonized Index of Consumer Prices	ds4	monthly	2001M01–2016M06	24 Countries (Croatia 2004–2016)	2005 = 100	Rescaled from 2015 to 2010;
Supply shifter	Price index of the means of agricultural production—Goods and services currently consumed in agriculture	Nominal Index	ss1	quarterly	2000Q1–2016Q1	14 countries–23 countries 2005–2016	2010 = 100	from quarterly to monthly
Supply shifter	Price index of the means of agricultural production—Goods and services currently consumed in agriculture	Real Index	ss2	quarterly	2000Q1–2016Q1	14 countries–23 countries 2005–2016	2010 = 100	from quarterly to monthly

Source: Eurostat.

Table 2. Structural characteristics of the dairy sector in EU 25 Countries (average 2005–2015).

Country	Value of Dairy Production (mln €)	% of Dairy on Total Agricultural Production	Import of Dairy Product (mln €)	Share of Import on Domestic Production (Dairy)	Share of Trade on Domestic (imp + exp) on Domestic Production (Dairy)	Average Size of Dairy Farms (000 € Standard Output)	Change (%) in Dairy Farm Size between 2005 and 2013 (%)	Concentration Rate (%) of Standard Output in Dairy Farms Bigger than 250,000 €	Concentration Rate (%) of First 5 Buyers in Food Retailing (CR5) (2009 or Later)
Austria	1232	21	625	0.51	1.30	42	67	31	94
Belgium	1175	15	2618	2.23	4.42	167	83	6	71
Bulgaria	588	17	125	0.21	0.38	6	128	19	67
Croatia	368	15	111	0.30	0.41	21	117	31	48
Czech Republic	887	21	439	0.49	1.15	198	161	76	46
Denmark	1744	19	501	0.29	1.35	435	115	57	89
Estonia	201	30	50	0.25	0.97	84	316	70	79
Finland	1181	31	275	0.23	0.58	99	90	11	92
France	9415	15	2688	0.29	0.86	120	63	4	65
Germany	10,368	22	5636	0.54	1.24	155	49	26	89
Greece	1692	17	762	0.45	0.65	63	60	17	50
Hungary	700	11	299	0.43	0.76	69	71	69	68
Ireland	1662	27	475	0.29	1.19	106	54	7	65
Italy	6105	14	3405	0.56	0.88	126	36	33	40
Latvia	246	26	97	0.39	1.07	12	181	25	77
Lithuania	458	21	147	0.32	1.26	9	105	19	92
Netherlands	4836	22	2878	0.60	1.87	248	59	15	65
Poland	4151	21	437	0.11	0.45	20	145	36	48
Portugal	849	14	488	0.57	0.91	79	113	22	65
Romania	3128	22	209	0.07	0.09	4	66	10	23
Slovakia	368	19	245	0.67	1.36	32	182	73	48
Slovenia	200	18	113	0.56	1.15	30	99	31	82
Spain	3835	10	1707	0.45	0.69	89	81	22	70
Sweden	1219	25	669	0.55	0.81	228	80	28	95
UK	5020	21	2800	0.56	0.81	278	92	33	78
EU 25	61,629	18	27,801	0.80	1.02	66	76	24	

Source: Eurostat; CR5: Consumers International, 2012; Mortimer, 2014; Mesic, 2015.

3.3. Preliminary Analysis

To estimate the parameters of Equation (4), a preliminary step is to test the order of integration and stationarity properties of the univariate time series involved in the model. Following Lloyd et al. [20,61], it is appropriate to apply empirical analysis to a vector autoregressive (VAR) framework. However, the estimation of the parameters of the VAR models requires that the variables are covariance stationary. If the time series are not covariance stationary, but their first differences are, a vector error-correction model (VECM) can be used [69].

A VAR model, written with exogenous variables, is given by:

$$xt = \phi 1xt - 1 + \phi 2xt - 2 + \ldots + \phi pxt - p + \Psi Dt + \varepsilon t \quad (7)$$

where xt is a $(m \times 1)$ vector of jointly determined $I(1)$ variables, Dt is a $(q \times 1)$ vector of deterministic and/or exogenous variables and each ϕi $(i = 1, \ldots, p)$ and Ψ are $(m \times m)$ and $(m \times q)$ matrices of coefficients to be estimated by Johansen's [70] maximum likelihood procedure. Finally, εt is a vector of the n.i.d. disturbances with zero mean.

The vector error correction model (VECM) representation of (X) is given by

$$\Delta xt = \alpha\beta\prime xt - p + \sum_{i=1}^{p-1} \Gamma \Delta xt - I + \Psi Dt + \varepsilon t \quad (8)$$

where attention is focused on the $(m \times r)$ matrix of cointegrating vectors β that quantifies the long-run relationships between the time series in the system and the $(m \times r)$ matrix of error correction coefficients, α, the elements of which load deviations from equilibrium into Δxt for correction. The Γi coefficients estimate the short-run effect of shock on Δxt, allowing the short- and long-run responses to differ.

Consequently, before we run the VAR or VECM models, we investigate the stationarity and cointegration of the employed time series. All the time series in each dataset were tested for stationarity in level and first differences, looking for their order of integration. Stationarity was tested using the augmented Dickey–Fuller (ADF) test [71], which takes nonstationarity (the presence of a unit root) as the null hypothesis against the alternative of stationarity. In each test, an underlying data-generating process was assumed with the variable having intercept and time trend, and intercept only. Judgments about the order of integration of each variable were made by comparing t-statistics (for ADF) with critical values for each distribution (at 1%, 5% and 10%).

Furthermore, because there may exist up to $m - 1$ cointegrating relations among m variables in xt, the precise number is evaluated by Johansen's trace test statistic [70]. In this test, the null hypothesis is that there are at least r co-integrating relationships. Where a single cointegrating relationship among variables included in econometric equations is detected, our goal is to verify the significance of the supply and demand shocks in the VECM estimations to investigate whether market power is present along the selected food chain.

Therefore, our strategy is to check those combinations of variables showing one cointegrating vector under one or more of the aforementioned assumptions and proceed to the VECM estimates of the more parsimonious models.

4. Results and Discussion

4.1. The Presence of Market Power in EU Dairy Supply Chain

The analysis to detect the exertion of market power described in Section 2.1 was applied to the dairy chains of 25 selected EU countries using the variables listed in Table 1. Table 3 presents the results, which are also summarized in Figure 1a.

Table 3. Results of market power test on dairy supply chains in EU-25 Countries.

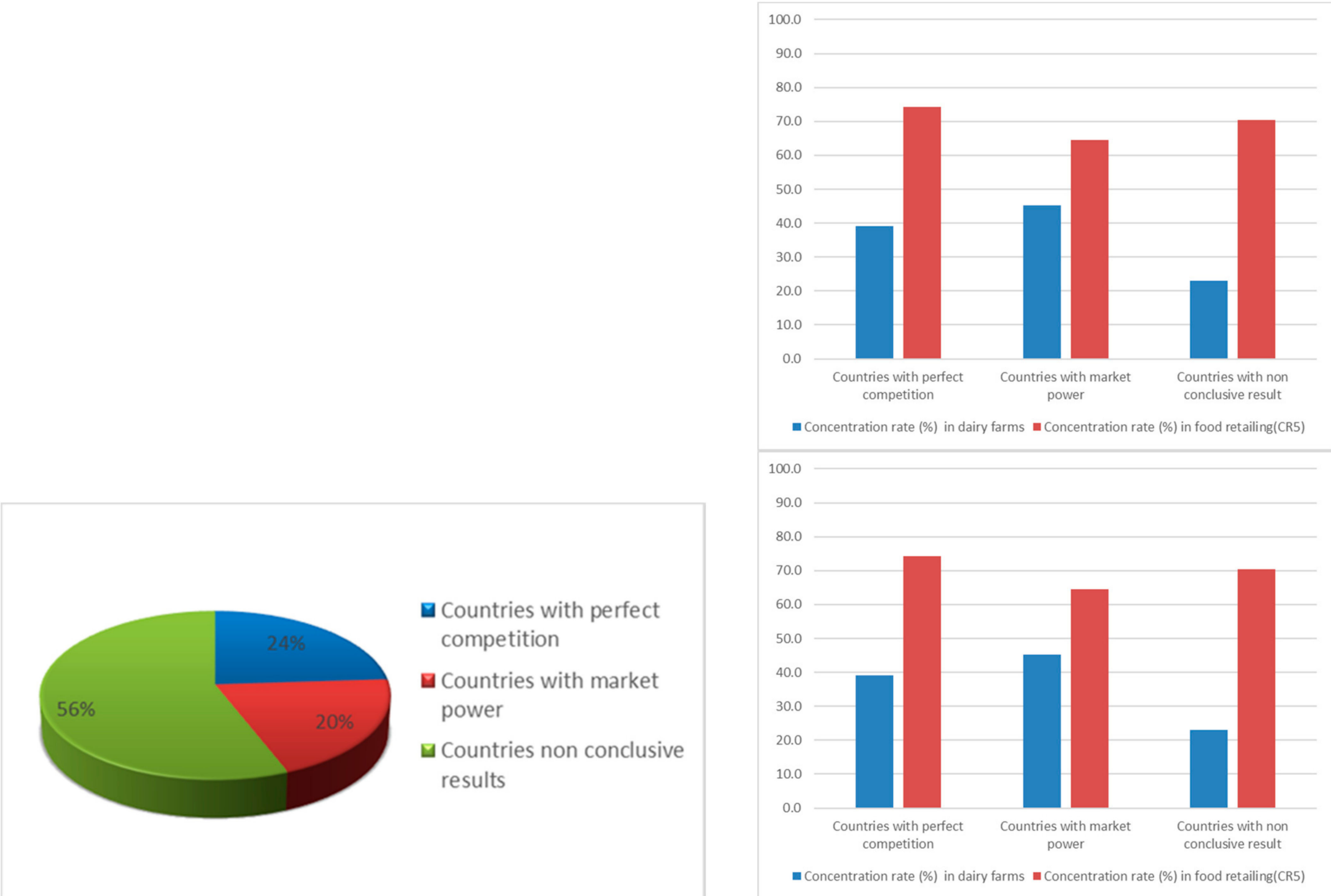
Country	Results of the Market Power on the Dairy Supply Chain	Country	Results of the Market Power on the Dairy Supply Chain
Austria	Market power	Italy	Non conclusive
Belgium	Non conclusive	Latvia	Non conclusive
Bulgaria	Perfect competition	Lithuania	Non conclusive
Croatia	Market power	Netherlands	Non conclusive
Czech Republic	Perfect competition	Poland	Non conclusive
Denmark	Perfect competition	Portugal	Market power
Estonia	Non conclusive	Romania	Perfect competition
Finland	Non conclusive	Slovakia	Market power
France	Non conclusive	Slovenia	Non conclusive
Germany	Non conclusive	Spain	Perfect competition
Greece	Non conclusive	Sweden	Perfect competition
Hungary	Market power	UK	Perfect competition
Ireland	Non conclusive		
Conclusive results = 11			
Non conclusive results = 14			
% conclusive/total cases = 44%			

Source: own elaboration.

As explained in the previous section, the market power test may yield non-conclusive results because of the strict requirements to be fulfilled on both the econometric estimation side (Section 3.3) and the theoretical model (Section 3.1). The former requires that all the variables involved in the estimation (retail price, producer price, marketing cost, demand, and supply shifters) be cointegrated to estimate their long-run relationships. The latter suggests that, in the estimated Equation (4), parameters associated with farmer price and marketing cost should exert a positive effect on retail prices (β_1 and $\beta_2 > 0$). In contrast to the model prerequisites, all estimated equations lacking these conditions were not considered. The remaining combinations of variables have been considered conclusive exclusively in the following cases:

(i) perfect competition along the dairy chain if both shifter parameters are not significantly different from zero;

(ii) market power exertion along the dairy chain when both shifter parameters are different from zero, with the demand shifter parameter positive ($\beta_3 > 0$) and, at the same time, the supply shifter parameter negative ($\beta_4 < 0$).



(**a**) (**b**)

Figure 1. Main results of the market power test. (**a**) Results of market power test on EU-25 dairy chains (%). (**b**) Results of market power test on EU-25 dairy chains (%). Source: own elaboration.

All other combinations of variables with different signs and significance in the shifter parameters were considered meaningless for the market power test. The test has been conclusive in 11 countries and non-conclusive in 14 countries, with a share of 44% (Table 3).

4.2. *Market Power and Structural Characteristics of the EU Dairy Chains*

To better understand the possible causes that may influence the discriminant power of the test, we correlated our results (using a dummy variable on test conclusiveness: 1 = conclusive, 0 = non-conclusive) with the main features of European dairy chains, as reported in Table 2. The results of these correlations are presented in Table 4.

Table 4. Correlation between conclusiveness of the market power test and structural characteristics of dairy supply chains.

	Value of Dairy Production (mln €)	% of Dairy on Total Agricultural Production	Share of Import on Domestic Production (Dairy)	Share of Trade on Domestic (imp + exp) on Domestic Production (Dairy)	Average Size of Dairy Farms (000 € Standard Output)	Change (%) in Dairy Farm Size between 2005 and 2013	Concentration Rate (%) of Standard Output in Dairy Farms Bigger than 250,000 €	Concentration Rate (%) of First 5 Buyers in Food Retailing (CR5)
Correlation with conclusiveness (1 = conclusive, 0 = non conclusive)	−0.302	−0.365	−0.044	−0.183	0.221	0.079	0.464 *	0.075

Source: own elaboration. * Significant at the 5% level.

The discriminant power of the test is negatively related to the economic dimension of the dairy sector in the country, in both absolute and relative terms. Surprisingly, the relative importance of trade with respect to domestic production is weakly correlated with test performance, although we expected higher values because the underlying model does not incorporate the effect of trade on imperfect competition. However, this result could be interpreted as a negligible impact of trade on national dynamics along the dairy supply chain. The change in the average farm size and the concentration rate of the top five food retailers did not correlate with the performance of the test. Finally, the success of the market power test is positively related at 22% to the average farm size and 46% (statistically significant at 5% level) to the farm concentration rate.

Figure 1b shows the degree of concentration rate in food retailing and in dairy farms by countries (with perfect competition, market power or non-conclusive results). Results seem counterintuitive, as the concentration rate in food retailing is higher in countries with market power while the concentration rate in dairy farms is slightly lower in countries with perfect competition. Such sketched relationships are analysed and discussed in more detail using correlation analysis between the market power test and structural features of dairy chains (Table 5).

Moving on to the conclusive results of the test (Table 5), among 11 cases in which the test was conclusive, we found six countries in which markets are perfectly competitive, while the remaining countries show the presence of market power at the retail level. Perfect competition characterizes countries such as Spain and the UK, whose dairy supply chains are relevant in absolute terms; Denmark, which presents, on average, bigger farms; and the Czech Republic, which shows high concentration rates in the largest dairy farms. The exercise of market power, instead, is observed in Austria, where the retail industry shows a remarkable consolidation, but also in Portugal, whose retailers are less concentrated, and in some of EU-13 (Slovakia and Hungary), where the concentration at the farm level is slightly higher than that at the retail stage.

For validation purposes, results of the market power test have been compared with those of structural models and mark-up models when available. Interestingly, our results are consistent with those yielded by those models. For instance, Cechura et al. [25] found that processors in Bulgaria, UK and Sweden exercise a lower degree of non-competitive behaviour (close to perfect competition), on average, as compared to processors in Austria, Hungary, and Portugal. Koppenberg and Hirsch [57] find small average deviations from perfect competition in Spain. Moreover, Salhofer et al. [15] showed market power exertion at the retail level in Austria and by Hockmann and Vöneki [16] and De Mello and Brandao [17] at the industry level in Hungary and Portugal, respectively.

Overall, the results in the second column of Table 5 do not clearly show which determinants seem to be associated with the exercise of market power. For this reason, we examined the relationship between perfectly competitive conduct (or market power) and the structural characteristics of the dairy chain (Table 5).

Table 5. Conclusive results of market power test and correlation with structural features of dairy supply chains in EU Countries.

Country	Test	Result of Market Power Test	Evidence of Previous Analysis	Value of Dairy Production (mln €)	% of dairy on Total Agricultural Production	Share of Import on Domestic Production (Dairy)	Share of Trade on Domestic (imp + exp) on Domestic Production (Dairy)	Average Size of Dairy Farms (000 € Standard Output)	Change (%) in Dairy Farm Size between 2005 and 2013	Concentration Rate (%) of Standard Output in Dairy Farms Bigger than 250,000 €	Concentration Rate (%) of First 5 Buyers in Food Retailing (CR5)
Austria	1	Market power	Salhofer et al. (2012); Cechura et al. (2015)	1232	21	0.51	1.30	42	67	31	94
Bulgaria	0	Perfect competition	Cechura et al. (2015)	588	17	0.21	0.38	6	128	19	67
Croatia	1	Market power		368	15	0.30	0.41	21	117	31	48
Czech Republic	0	Perfect competition		887	21	0.49	1.15	198	161	76	46
Denmark	0	Perfect competition		1744	19	0.29	1.35	435	115	57	89
Hungary	1	Market power	Hockmann and Vöneki (2009); Cechura et al. (2015)	700	11	0.43	0.76	69	71	69	68
Portugal	1	Market power	De Mello and Brandao (1999); Cechura et al. (2015)	849	14	0.57	0.91	79	113	22	65
Slovakia	1	Market power		368	19	0.67	1.36	32	182	73	48
Spain	0	Perfect competition	Koppenberg and Hirsch, 2021	3835	10	0.45	0.69	89	81	22	70
Sweden	0	Perfect competition	Cechura et al. (2015)	1219	25	0.55	0.81	228	80	28	95
UK	0	Perfect competition	Cechura et al. (2015)	5020	21	0.56	0.81	278	92	33	78
Correlation with market power test (0 = perfect competition)				−0.522 *	−0.326	0.267	0.125	−0.609 **	0.004	0.145	−0.279

Source: own elaboration. ** Significant at the 5% level; * Significant at the 10% level.

The use of correlations rather than regression analysis (using the results of the market power test as a dependent variable) is due to the simultaneous nature of the relationships among structure, conduct, and performance. For this reason, even if the use of the binary conduct variable (market power or perfect competition) as a dependent variable and the structural characteristics of the dairy chain as explanatory variables seem useful for exploring the determinants of imperfect competition, the estimated relationship would be biased toward the above-mentioned endogenous relationships [42]. For this reason, we limited our analysis to correlation, leaving a causal analysis for future development. Before commenting on such results, it is worth pointing out that the correlations presented are computed on a subsample of countries on which the market power test has provided a result. Unfortunately, it does not include some countries whose dairy supply chains are relevant, both in absolute terms (Germany, France and Italy) and relative terms (Finland, Estonia, Ireland). Consequently, the validity of the following results and subsequent discussions is limited to the subsample examined.

The variables with the highest (>50%) inverse correlation with market power exertion are the value of dairy production in a country (−52%) and the average size of dairy farms (−61%) with statistical significance levels, respectively, at 10% and 5%. The former result might indicate that the greater the importance of the sector in a country, the better the organisation and efficiency of the supply chain, in which private entities such as producer organisations and inter-branch organisations play a relevant role. The latter result is of particular interest for the relationship between structural change and imperfect competition. According to such evidence, farm size and imperfect competition along the chain are inversely related, while no or limited relationships are observed with the change in average farm size over time and with the concentration rate of farms (in terms of production value). These three results are of particular interest. A possible explanation (remembering that correlation is not necessarily causation) may be that in countries with larger farms, it is easier to implement all those tools to foster supply concentration (POs, cooperatives), balancing the power relationships along the dairy chain [72]. If this hypothesis is true, the inverse relationship between market power and farm size may reflect the concentration in dairy farm supply. Moreover, various studies have investigated the efficiencies generated by PO in terms of increasing productivity, raising farmers' welfare, and ensuring reasonable consumer prices (e.g., Van Herck [73]). The internationalisation of PO activities might improve their performance, especially in smaller countries where POs face a smaller domestic market [72]. Confirming these hypotheses would provide useful data on the concentration of dairy cooperatives in EU countries; unfortunately, such data are not homogeneous and comparable to those on farm size and concentration. In any case, the hypothesis of farm size-supply concentration is, in part, indirectly confirmed by the lack of correlation between market power, change in farm size, and concentration rate of farms. Both the increase in farm size concentration and the increase in farm size over time are not related to perfect competition in the chain. This may be explained in terms of supply concentration; both features may be seen as alternatives to supply concentration in counterbalancing market power along the chain. However, the relevance of this finding requires further investigation. Finally, the relationship between imperfect competition in the chain and the concentration rate of the top five food retailers is unexpected, even though it is neither strong (−28%) nor statistically significant. As the absolute value of such a correlation is lower than 50%, the two variables are weakly related; nevertheless, the sign of the correlation is quite surprising as it points to a (weak) negative association between retailers' concentration and market power. However, if the dairy value chain is considered a homogenous product upstream market followed by a downstream market with differentiated products [13], retailers' behaviour might be considered a strategy to increase their market share by offering lower prices, especially in times of economic crisis. However, retailers have developed marketing strategies such as private labels to gain further control over price transmission [74].

5. Conclusions

Although the literature on market power along the dairy supply chain includes various studies [11,13–16], this work represents one of the first attempts to empirically estimate market power exertion along EU-25 dairy chains, linking such evidence to the observable structural characteristics of the different stages of supply chains in the countries examined and the last CAP reforms (the 2003 CAP reform, the end of milk quotas and the implementation of the "milk package").

An econometric analysis was conducted in which we found consistent conclusions on the conduct (market power or perfect competition) of 11 dairy chains over the 25 examined with a discriminant power of 44%. This result is lower than those of similar analyses and indicates an improvement in the discriminant power of the test adopted to detect imperfect competition along food chains. The results show that, in some EU countries (Austria, Portugal, Slovakia, Hungary and Croatia), the downstream sector exerts market power. In contrast, other EU countries (Spain, UK, Denmark, Czech Republic, Bulgaria and Sweden) are characterised by perfectly competitive markets. These results are consistent with those of the previous studies [15–17,25,57]. This empirical estimation implicitly represents an ex-post analysis of the role played by the 2003 CAP reform, which introduced the liberalisation of the milk sector by reducing price support and creating direct income support. Empirical results indicate that only 20% of the countries considered the test indicates the presence of market power in the dairy supply chain for the period 2000–2015. This might point out that

CAP reform, by introducing completely decoupled support to farmers, no longer linked to levels or type of production, might have played a significant role in the relationship between farmers and processors [3,9]. Further analysis should estimate whether the introduction of the last recent CAP reforms, such as the end of milk quotas and the implementation of the "milk package" has caused a structural break in processors' and retailers' behaviour in the EU dairy supply chain.

Moreover, in the sub-sample of countries where the test concluded, the presence or absence of market power was related to various structural features of the dairy chain. Even if the correlation analysis does not reveal causal relationships, some meaningful results are worth highlighting. In particular, the significant inverse correlation between average farm size and market power and, at the same time, the lack of correlation between farm size increase and farm concentration rate may be explained by the (unobserved) role played by farm supply concentration, probably through the various kinds of organisations (POs, APOs and cooperative) supported by the recent CAP reforms. In fact, without falling into the causality trap, the greater the average farm size in a country, the easier it would be to implement organizations aimed to foster supply concentration. The alternative (to POs, APOs and cooperatives) to counterbalance power relationships along the food chain may be provided by structural change: increased average farm size over time and increased concentration rate in higher classes (above 250,000 € of Standard Output). However, the latter indicators are almost uncorrelated with perfect competition along dairy chains, while average farm size (that is a proxy of supply concentration provided by POs) is inversely correlated with market power exertion. This hypothesis and the relationship between farm structure, supply concentration and market power along food chains deserve to be examined in greater depth. In this context, gathering comparable data on dairy supply concentration in European countries would shed light on these relationships, allowing us to test the effectiveness of this category of EU policy intervention to strengthen the position of farmers within the EU supply chains.

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