Understanding the European Futures Markets on Dairy Products: a Multi-Product Perspective

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Abstract

The European Union has radically reformed its milk policy in the last decades by reducing price support levels and removing production quotas. European dairy operators are now facing volatile milk and dairy prices but can participate in new futures markets. However the liquidity on these markets remains limited so far. This paper develops an original economic framework to understand this apparent puzzle. To implement this framework we first statistically reveal the productive responses of European dairy processors under the milk quota regime with trending dairy prices. Then we find that the production flexibility of dairy processors and the milk price mechanisms are important factors hampering the liquidity of futures market on dairy products. We finally argue that both European dairy processors and milk producers can benefit from efficient futures dairy markets, by expanding their business and saving costs on milk price negotiations.

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Keywords : Futures, Dairy Prices, Europe, risk hedging

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1. Introduction

When the Common Agricultural Policy (CAP) was instituted in the 1960s, the European Union (EU) was not self-sufficient for many products, notably dairy products. By defining a complex price support system, the initial milk Common Market Organization did provide high and stable prices to European dairy producers and processors. The price incentives led to a significant development of European productions and the EU quickly became self-sufficient. In order to limit public expenditures induced by the dairy surplus, milk production quotas were imposed on producers in the mid 1980s and then gradually reduced.

In 1999, a radical reform of this EU milk policy was announced with implementation delayed to 2006. In fact the 2003 CAP Mid Term Review decided to advance and strengthen this reform: the higher reductions of the intervention prices on industrial dairy products (butter and Skimmed Milk Powder, SMP) started in 2004 and up to 2007. Then the CAP Health Check in 2008 implemented the soft landing of milk quotas, from 2008 to 2015. From 2004, direct payments were granted to dairy farmers to compensate the expected decreases of market milk prices. Later reforms of the CAP conditioned these payments on stricter environmental farm practices. Finally a milk package in 2012 defined general guidelines that dairy farmers and processors have to follow when negotiating milk price and volumes.

Following these reforms, the European dairy operators now have to deal with volatile prices. The figure 1 reports the evolution of butter and SMP market and intervention prices from 2001. This figure shows that the market and intervention prices for these two industrial dairy products were close and decreasing up to 2007. Then the market prices became volatile and, most of the time, higher than the intervention prices. From 2007 to 2015, the market prices of butter and SMP were positively correlated. Since 2015 and the complete removal of milk production quotas, the market prices of these two products became negatively correlated. Measured with a yearly coefficient of variation, the volatility of European market prices of industrial dairy products now reach 15%, compared to 2% before the milk reform.

Even if the average market prices of dairy products did not decrease as much as the intervention prices, the significant rise of the price volatility on dairy markets rapidly becomes a major political concern. This issue is obviously critical when the milk and dairy product prices are particularly low, this downside volatility was particularly noticeable during two periods of time over the last ten years (in 2009 and 2016). In both cases, public debates on the efficiency of the European milk reform reopened. Proponents of the reform argue that, with less public intervention on the physical dairy markets, futures markets will emerge and allow operators to efficiently manage their price risks. It is also argued that public intervention should help the initial development of these futures markets (recent examples included the EC, 2017). Some dairy economic actors also welcome these futures market (Eucolait, 2017).

While some futures markets defined on European dairy products (butter, SMP, whey powder and liquid milk) exist for some years now, the liquidity of these markets remain very limited, with very limited open positions and daily traded volume. The central question of this paper is to understand this apparent puzzle. With a rather similar price volatility, the futures markets on European cereals are now significantly liquid. In the United States (US) and New Zealand, the futures markets on dairy products are also operational and liquid, albeit much less than grain markets. So what is different so far for the European dairy case?

This paper contributes to understand this puzzle by measuring two potential factors behind the current poor liquidity of dairy futures markets. The first factor is given by the behavior of dairy processors in terms of production of dairy products. As the figure 2 shows, the European productions of butter, SMP and Whole Milk Powder (WMP) significantly decrease in the 2000s while the total milk delivered to dairy processors was rather stable. This implies that the dairy processors on average modify their production portfolio away from less valuable industrial dairy products and towards less price-volatile products (in particular cheese and fresh dairy products). From the end of the 2000s and the soft landing of milk quotas, the productions of the industrial dairy products increase, in line with the increase of milk delivered to the dairy factories. This simple visual analysis of European dairy productions suggests that the dairy processors adapt their production portfolio to their economic environment (or to the long term changes of their environment), which may impact their hedging needs or at least hedging practices (on the long term) and hence the liquidity of the futures markets on dairy products. The second factor is given by the transmission of dairy product prices to the milk prices paid to dairy farmers. As the figure 3 shows, the milk price decreases smoothly from 2001 to 2007 in line with the price reductions of industrial dairy products[1]. Since 2007, the world and European market prices of these industrial dairy products became very volatile. The European milk prices also became volatile but slightly less than the milk price equivalent (their coefficients of variation amount to 0.11 and 0.19 respectively). In particular, the milk prices paid by dairy processors in 2007 and 2013/2014 were high but lower than the milk price equivalent. Conversely, the milk prices paid by dairy processors in 2009 and 2015 were low but higher than the milk price equivalent. In these four periods, the

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[1] The milk price equivalent is computed using the formula given by Jongenel et al., 2001, p. 152 and the monthly prices of industrial dairy products, see our equation 13 below.

dairy processors retain part of the consequences of the price volatility of industrial dairy products. From 2016 onwards, both milk prices have the same degree of volatility (as measured by the coefficient of variations). The degree of price transmissions among dairy product prices influences the margin risks faced by the dairy processors. This is likely to be another factor impacting the hedging needs of dairy processors and thus the liquidity of futures markets on dairy products. This paper intends to go beyond these intuitions and visual analyses, by developing a structural modelling approach to quantify these two factors.

This paper is organized as follows. The first section provides a synthesis of the main insights of the large economic and financial literature that analyses the success and failure of futures markets. We also report the main insights of papers analyzing the futures on dairy products. The second section develops a new economic simulation model allowing to measure the importance of our two factors. Our new economic model features two main original contributions. First this is a multi-product model accounting for the complex substitution relationships between the different dairy products that can be obtained by dairy processors. Second this model encompasses and investigate the economic consequences of the institutional arrangements between milk farmers and processors on milk price and volumes. In order to implement this simulation model, the third section develops original statistical analyses using available information from the EU milk market observatory. The econometric results confirm that dairy processors adapt their production portfolio to cope with price developments on the long-term. The fourth section is devoted to simulations to understand the hedging demands of dairy processors on futures markets, as well as assessing the usefulness of these markets. The simulation results reveal that the production flexibility on the long term of dairy processors and the milk price mechanisms on the short term are important factors limiting the development of dairy futures market. Section five concludes.

2. Literature review

The first organized futures markets date back from the 1850's. Since that time, many new futures market on agricultural and food products have been launched. But only one third of them lasts many years and the other two thirds fail rapidly. A large economic and financial literature analyses the conditions of success of these markets. This literature is always active, with recent papers analyzing new specific cases and/or developing new methods. For instance, Bekkerman and Tejeda (2017) developed an original multi-commodity analysis upon which we elaborate below. These authors found that that the viability of new futures contract for commodities that are jointly produced with other commodities is impacted by the position of economic agents on related futures contract.

We offer a synthesis of this literature, supported with illustrative references on dairy products. In a general way, the factors of success of futures markets already identified by Brorsen and Fofana (2001) remain relevant in the recent studies. Some of these factors are related to the characteristics of the physical markets. In particular the spot price must be sufficiently volatile so that price hedging brings value to participants. Pennings and Meulenberg (1998) analyzed the usefulness of futures contracts on European milk production rights, because their prices can be much more volatile than the milk prices. The higher is the risk aversion of economic agents, the higher is the potential liquidity. But risk aversion is not a necessary condition for the existence of futures markets (Williams, 1987). On the other hand, other solutions, such as the credit market, can be mobilize to manage price risks. In this respect, Loughrey et al. (2018) evaluated different tools, including fiscal policies, to manage price/income volatility at the dairy farm level in Ireland and found, as expected, that fiscal policies matter.

Some other factors behind the success/failure of futures markets are directly related to the characteristics of these futures markets. This includes the price convergence at settlement between spot and futures prices. The basis risk is analysed by Bialkowski and Koeman (2017) for the US and New Zealand case, by O'Connor et al. (2015) and Weber (2017) in the European case. This last author concluded that the European futures market on dairy products (butter, SMP and whey powder) efficiently fulfill their functions. Besides, the liquidity on futures markets is enhanced with lower "transaction" costs. The transaction costs differ according to the contract settlement (delivery/cash), the product homogeneity (involved grading system for differentiated commodities), the trading system (such as electronic). Finally the presence of market makers/scalpers, at least in the initial phase, is often advanced.

More generally, a futures market can develop if there is no market price manipulation due to the market power by some participants. A futures market can disappear if a "similar" futures market already exist (for instance, in a close country). And, not least, the public policy on both the physical and futures markets should be predictable and does not crowd out private incentives. Newton et al. (2014) provided an example showing the interaction between the complex US milk policy and participation in futures markets (for both inputs and outputs).

This predictability of public policies is very difficult to assess but can be invoked in the European dairy case. The different CAP reforms conduced over the last 25 years always contained some ambiguous measure, such as the use of the crisis reserve in case of exceptional market disturbances. While the existence of crisis reserve is clear with some allocated public funds, the definition of an exceptional market disturbance is lacking. During the two episodes of low market prices of dairy products (2009 and 2016), producers successfully lobbied European policy makers who provided additional supports to dairy farmers. This crisis management may have contributed so far to the absence of liquidity of European futures contract on dairy products.

A coherent quantification of these aforementioned factors in the case of European futures on dairy products is highly challenging, requiring a huge amount of data (or assumptions when data are not available such as the policy expectations by economic agents on the use of the crisis reserve). Below we develop an original economic framework allowing us to quantify two factors that contribute to the low participation of European dairy processors on futures market.

3. Theoretical Modelling

Commodity futures markets may exist even if commodity producers and users do not take financial contracts. But it is natural and common to analyze the existence of futures markets by first investigating the likely hedging demands by physical producers/users. We focus on the potential participation of European dairy processors on two futures contracts: butter and SMP. These two futures contracts were first proposed by Euronext in 2010, then stopped and reopened by Euronext and EEX in 2015 (EC, 2017).

The eventual participation of dairy processors to the futures market depends among others on their structures, objectives and constraints. Due to the limited available data on the European dairy processing industry, we develop a generic approach. We assume that the objective of the representative dairy processor is to maximize his expected utility of profit subject to the stochastic price of inputs and outputs and technological relationship (the possibility to produce dairy products given an amount of milk delivered by dairy farmers). Formally, the program of the representative dairy processor is given by:

$$max_{Y,X,H} EU(\pi_s) = \sum_s w_s U(\pi_s)$$

Subject to

$$\pi_s = PY_s.Y - PX_s.X + (F - tf - PY_s).H$$

$$T(Y, X, K) = 0$$

With : s is the state of nature (the random price of output and input), E the expectation operator, $U(\pi_s)$ the utility function, w_s the probability of this state of nature, π_s the profit, PY_s the vector of risky output dairy prices, Y the vector of dairy product productions, PX_s the vector of risky input prices, X the vector of variable input uses, F the vector of futures prices on dairy products, tf the vector of transaction costs supported by the dairy processor when participating in futures market, H the vector of hedging demands, $T(Y,X,K)$ the production possibility set (PPS) and K the level of fixed factors.

This PPS is written in very general form but, as explained below, is highly involved to capture the complex relationships between input and outputs of the dairy processing technologies. The First Order Conditions (FOC) determining the optimal behavior of the representative dairy processor are given by:

$$EU_\pi(\pi_s).\left(PY_s - \lambda.T_Y(Y,X,K)\right) \leq 0 \tag{1}$$

$$EU_\pi(\pi_s).\left(PX_s - \lambda.T_X(Y,X,K)\right) \leq 0 \tag{2}$$

$$EU_\pi(\pi_s).(F - tf - PY_s) \leq 0 \tag{3}$$

$$\pi_s = PY_s.Y - PX_s.X + (F - tf - PY_s).H \tag{4}$$

With: λ is the lagrangian multiplier associated with the PPS constraint, $U_\pi(\pi_s)$ the first order derivative of the utility function. Equation (1) is the FOC related to the production levels, equation (2) the FOC related to the levels of variable input uses and equation (3) the FOC related to the demands of futures. It should be clear that the three FOCs, together with the definition of profits (equation 4), form a square system that must be solved simultaneously. In this system, the hedging demand is only implicitly defined. If we assume that the levels of productions, variable inputs and input prices are fixed, that the absolute risk aversion is also constant (given by coefficient α) and finally that the distributions of output prices expected by the dairy processors are normal $N(\mu_{PY}, \sigma_{PY})$, then this system reduces to the usual hedging demand :

$$H - Y = \frac{\sigma_{PY}^{-1}}{\alpha}(F - tf - \mu_{PY})$$

The FOCs (1) to (3) are expressed in complementarity format, meaning that the dairy processor may not produce one dairy product or many participate in the futures market if, for instance, transaction costs are too high. This system of equations (1) to (4) implies that the derived demand of futures by the representative dairy processor depends, among other factors, on his technical constraints (captured by the derivative of the PPS).

To facilitate the comparative static analysis, let's simplify the previous general framework. We assume that there is only one aggregate variable input, so that the PPS can be written as $X = X(Y, K)$, that the input price is fixed (and normalized to one), that the representative dairy processor has only two decision variables, the production level of one dairy product Y^i (the other production levels are fixed Y^{-i}) and the futures demand for this product H^i. Furthermore, we write the stochastic output price as $PY_s^i = \mu^i + \sigma^i . \epsilon_s$ with μ^i the expected price, ϵ_s a random variable with mean zero and σ^i a mean preserving spread parameter for the distribution of output prices. Finally we assume that initially the hedging demand is also null and the utility function is quadratic (risk aversion implies that the constant second order derivative $U_{\pi\pi}$ is negative). In this simplified setting, equations (1) and (3) become (where we note the futures price net of transaction by FT^i):

$$EU_\pi(\pi_s).\left(\mu^i + \sigma^i . \epsilon_s - X_{Y^i}(.)\right) = 0 \qquad (1')$$

$$EU_\pi(\pi_s).\left(FT^i - \mu^i - \sigma^i . \epsilon_s\right) = D(.) < 0 \qquad (3')$$

The hedging demand is initially null because the function D (which implicitly defines the hedging demand) is negative. This hedging demand will become positive if this function reaches zero. We are now in a position to show that the production flexibility (captured by the derivative $X_{Y^i}(.)$) influences the hedging demand. In that respect, lets' consider an increase of price volatility (σ^i), starting from $\sigma^i = 1$. (We can also perform a comparative static analysis with respect to μ^i to measure the influence of the production flexibility on the hedging demand). We are interested by the evolution of the function D. From equation (3'), we obtain (see the appendix for the derivation):

$$dD(.) = E\begin{pmatrix} -U_\pi(\pi_s).\epsilon_s - U_{\pi\pi}.\left(PY_s^i - \mu^i\right)^2.Y^i \\ +U_{\pi\pi}.\left(\left(FT^i - \mu^i\right).\left(\mu^i - X_{Y^i}(.)\right) - \left(PY_s^i - \mu^i\right)^2\right).dY^i \end{pmatrix} \qquad (5)$$

Under risk aversion, the terms of the first line of equation (5) are positive. As expected the hedging demand increases following an increase of price volatility. But the terms of the second line show that this demand positively depends on the evolution of the production volume dY^i. This evolution is obtained by differentiating the equation (1') (see the appendix for the derivation):

$$dY^i = \frac{E\left(U_\pi(\pi_s).\epsilon_s + U_{\pi\pi}.\left(PY_s^i - \mu^i\right)^2.Y^i + U_{\pi\pi}.\left(PY_s^i - \mu^i\right)\left(X_{Y^i}(.) - \mu^i\right).Y^i\right)}{E\left(U_\pi(\pi_s).X_{Y^iY^i}(.) - U_{\pi\pi}.\left(PY_s^i - X_{Y^i}(.)\right)^2\right)} \qquad (6)$$

Under risk aversion, the production volume unambiguously decreases when the price volatility increases. The production flexibility appears in the denominator of this expression. If the production flexibility is null ($X_{Y^iY^i}(.)$ reaches infinity), the production is fixed and the demand of futures contract by the dairy processor unambiguously increases. On the other hand, if the production flexibility is large ($X_{Y^iY^i}(.)$ equals zero), then the representative dairy processor reduces his production due to the increase of price volatility. This limits his hedging demand.

Returning back to our system of equations (1) to (4), it generalizes the 2 commodities model developed by Bekkerman and Tejeda (2017) to n commodities, taking into account both output and input price risks. It captures our first factor, which is the production flexibility of dairy processors.

The second factor we introduce is the price transmission between dairy product and raw milk prices. The milk package adopted in 2012 allows the establishment of milk producer organizations (PO) that can jointly negotiate contracts terms with dairy processors, including a price or a price formula. So far the number of officially recognized PO varies a lot across EU member states, partly reflecting the number of cooperatives vs industrial firms in the dairy processing industry (Windjan et al., 2017). Moreover, there is a wide diversity of POs, differing for instance on the length of contracts (between few months to 5 years) and the milk price arrangement (Revoredo-Giha et al., 2019). Some POs and dairy processors agree on fixed price over a short period while others define complex price formulae for longer periods. For instance, the French raw milk price formulae includes the price evolution of industrial dairy products and also includes the evolution of feed costs supported by milk farmers.

To encompass this wide variety of situations, we add the following general equation to our system:

$$PX_s = F(PY_s) \qquad (7)$$

This new equation does not define a new production and financial endogenous variable. It only links the milk price paid by dairy processors to the dairy product prices in the different states of nature. The function F captures the diverse policy regulation on the transmission between dairy product prices and milk prices. Below we assume that this function is exogenous to the representative dairy processor. The case of a fixed price of raw milk ($PX_s = PX$) is captured by the function F being independent of the prices of dairy products. On the other hand, this function can reproduce the milk price equivalent formula refereed to in our footnote 1 and that corresponds to the pre-reform determination of raw milk price. At the extreme, if the raw milk price adjusts so that the dairy processor profits are constant across the state of nature, then his hedging demand is null (respectively, indeterminate) if the futures prices less transaction costs is lower than (respectively, equal to) the expected prices.

4. Empirical implementation

The main challenges for the implementation of our theoretical model relate to the statistical calibration of the parameters involved in the utility function and the PPS. Necessary data on individual European dairy processors are rare (Jongeneel et al., 2011). For instance, Hirsh et al. (2019) assess the so-called tactical production flexibility of these processors and not their operational flexibility because they do not have their many production decisions (only the aggregate sales of dairy products). In their analysis of the soft landing of milk quotas, Bouamra Mechemache et al. (2008) assume that the unitary costs of processing milk components (fat and protein) into dairy products are constant.

Below we pursue three statistical investigations, starting first with a price only analysis, then introducing national production data and finally European demand data on public stocks.

4.1.Insights from price data

Our first statistical contribution elaborates on the price cointegration approach developed by Chavas and Kim (2006), which suggests that American dairy processors optimally adopt their behavior to the policy environment. More precisely, these authors developed a conceptual model of hedonic pricing of dairy products where the PPS is expressed in terms of milk components (fat and protein). They implement their model on three dairy products (butter, SMP and cheese) using only monthly prices and distinguish two regimes: the government regime when the government purchases are greater than 10% of total demand and the market regime otherwise. They showed that there was only one cointegration relationship between these three prices under the government regime and two cointegration relationships under the market regime. Moreover, they show that under both regimes, one cointegration vector is closely related to the hedonic pricing of dairy products. This suggests that over the long term the dairy product prices are consistent with the pricing of milk components. Furthermore, under the market regime, the authors speculate that dairy processors may exert market power and/or manage inventory and production differently.

We follow the approach of Chavas and Kim (2006) with one main difference. These authors did not introduce the raw milk prices under their analysis, because the composition of raw milk is not fixed (while butter/SMP and cheese are assumed to have fixed compositions). In our European case study, we also observe that the composition of milk varies significantly over months. To overcome this issue and better use all price information to identify the behavior of dairy processors, we first compute two processing margins of one ton of milk. The first process transforms raw milk into butter and SMP (hereafter we name it the industrial margin and note it IM) and the second process transforms raw milk into Emmental, whey powder and fat (hereafter we name it the emmental margin and note it EM):

$$IM_t = PY_{b,t}.\frac{io_{f,m}}{io_{f,b}} + PY_{s,t}.\frac{io_{p,m}}{io_{p,s}} - PY_{m,t} \tag{8}$$

$$EM_t = PY_{e,t}.\frac{1}{8} + PY_{b,t}.\frac{(io_{f,m}-io_{f,e})}{io_{f,b}} + PY_{wh,t}.\frac{(io_{p,m}-io_{p,e})}{io_{p,wh}} - PY_{m,t} \tag{9}$$

With $io_{i,j}$the content of component i in product j and b,s,e,wh,m,f,p stand for butter, SMP, Emmental, Whey powder, milk, fat and protein respectively and t the time index. .

The formulae of industrial margin makes clear that if, for instance, the milk content of fat increases, then the production of butter increases while the production of SMP remains constant. As regards the emmental margin, we assume that this process always deliver 80 kg of emmental and that the variations in milk composition are fully captured by the variations of residual fat (which is valued at the butter prices) and whey productions.[2] We compute these margins at the EU level using monthly prices of raw milk, monthly milk compositions and weekly prices of dairy products. We also deflate the two margins by the European consumer price index (available from Eurostat) to reflect general price increases affecting processing costs.

Similar to Chavas and Kim, we consider different policy regimes with similar numbers of weekly observations: the first regime/period extends from the campaign 2001 to the 2006 campaign (up to march 2007) when the intervention prices are reduced. It appears that the market prices during this first period were not much volatile and followed the reduction of intervention prices. The second regime/period corresponds to the soft landing of quotas (from april 2007 to march 2015). Compared to the previous one, dairy processors may had uncertainties on the evolution of milk deliveries by milk farmers. This period also saw the first major price swings, with “high” prices in 2007/2008 and “low” prices in 2009/2010. The last period corresponds to 2015 up to now, without quotas but still volatile dairy product prices. In this last period, dairy processors have more latitude to negotiate with dairy farmers on milk volumes and prices.

Before presenting results, we underline that another advantage of our margin cointegration analysis over a standard price cointegration analysis is that we can be more confident on the economic interpretation of cointegration results. Indeed, from a standard price cointegration analysis, it is impossible to identify if demand or supply forces are explaining the strength of the long run cointegration results (Fackler and Goodwin, 2001). Finding that the long run

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[2] In a sensitivity analysis, we assume that 100 kg of emmental are obtained from one ton of raw milk. The results are qualitatively unchanged.

cointegration relationship between prices has changed can simply reflect a changing demand pattern, not a shift in the supply behavior. But finding that the long run cointegration relationship between margins has changed is more likely driven by changes in supply behavior. However this margin cointegration analysis can not reveal the exact level of production flexibility specified in our theoretical framework. Nor it can reveal if the change in supply behavior is motivated by a change in the trend of prices (μ^i) or a change in their volatilities (σ^i).

We first report the Augmented Dickey Fuller tests on each series (and their first order differences) for the three periods. We allow for the inclusion of constant drift and time trend terms. We find that over the different periods, we fail (respectively accept) to reject the null hypothesis of unit root for the industrial margin (respectively for the difference of the industrial margin). Most of the time, we also fail to reject the null hypothesis of unit root for the emmental margin. In the second period, we obtain the same result when we do not include a constant drift or time trend.

Table 1. Stationarity tests of processing margins

Period	Specification (critical values 5%)	IM	EM
01-2001/03-2007	None(-1.95)	-0.51	0.90
	Drift(-2.89)	-1.69	0.16
	Trend(-3.45)	-1.72	-2.02
	Difference(-1.95)	-10.37	-12.00
04-2007/03-2015	None(-1.95)	-1.57	-0.91
	Drift(-2.89)	-1.81	-3.91
	Trend(-3.45)	-1.81	-4.10
	Difference(-1.95)	-10.85	-21.14
04-2015/04-2021	None(-1.95)	-0.56	-0.02
	Drift(-2.89)	-1.68	-1.93
	Trend(-3.45)	-1.85	-2.01
	Difference(-1.95)	-7.79	-14.19

We then perform Johansen cointegration tests to check if the processing margins are linked in the long run. If we find one long run cointegration relationship, this would indicate that the dairy processors adapt their production portfolio to market conditions, hence have some production flexibilities. Here too, we allow for different specifications, i.e. with seasonal dummies, trend or constant, using the trace or eigenvalue tests. All results are robust to the different specifications. We report below the case without seasonal dummies, a constant and the eigenvalue test. Critical values are 15.67 at 5% level of significance for the absence of cointegration and 9.24 for the alternative of (at least) one cointegration relationship. Results for the first period are 16.61 and 8.93 respectively. Thus the Johansen test rejects the null hypothesis of no cointegration between these two margins for this first period, suggesting that dairy processors adapt their production portfolio to the dairy margin. Results for the second period are similar (values of tests are 39.70 and 6.90 respectively). On the other hand, we accept the null hypothesis of no cointegration relationship between the two margins for the last period (values of tests are 7.75 and 3.71 respectively). These results already suggest that the behavior of dairy processors has changed over the different policy regime, similar to the Chavas and Kim.

Even more important, we find that the long run cointegration relationship between the two margins are different across the two periods, suggesting that the European dairy processors have different production flexibilities (likely thanks to previous investment decisions). More precisely, Table 2 reports the coefficient estimates of the two equation regressions for the two first periods.

Over both periods, the evolution of the industrial margin significantly depends on the past levels of margins. However the own effect is less important in the more recent period (-0.010 compared to -0.036, with the difference statistically significant). Moreover the evolution of the industrial margin depends positively on his past evolution only in the first period. As regards the evolution of the emmental margin, it statistically depends only on the past industrial margin in the first period. In the more recent period, all effects are statistically significant. In particular, the evolution of the emmental margin depends on his past evolution and past level, suggesting that the dairy processors optimally adapt their emmental production to the new policy environment.

Table 2. Cointegration results on processing margins

2001/2007	ΔIM_t Estimates	SE	ΔEM_t Estimates	SE
ΔIM_{t-1}	0.061	0.077	0.058	0.079
ΔEM_{t-1}	-0.014	0.075	0.001	0.077
IM_{t-1}	-0.036**	0.013	-0.039**	0.013
EM_t	0.040**	0.011	0.011	0.011
2007/2015				
ΔIM_{t-1}	0.168**	0.051	0.131*	0.079
ΔEM_{t-1}	0.037	0.036	-0.291**	0.051
IM_{t-1}	-0.010**	0.006	-0.027*	0.008
EM_t	0.035**	0.014	-0.086**	0.019

To summarize, all these statistical results suggest that the cointegration between processing margins have changed in the last twenty years, reflecting the likely change of behavior of dairy processors. These results parallel those of Chavas and Kim who showed that the cointegration relationships are different across policy regimes. As Chavas and Kim, it is nevertheless not possible to go further in the analysis by using only price information.

4.2. Insights from price and production data

Our second statistical contribution combines previous price information with available quantity information on production. Indeed, while production data on individual dairy processors are unavailable, Eurostat provides monthly productions of some dairy products and raw milk deliveries to dairy processors (and their fat/non fat composition) at the EU member state level since 1968. However the database is complete only for Germany and France. The analysis below is restricted to these two EU member states, assuming the existence of a representative dairy processor in each country. Moreover the nomenclature of dairy products is not fully similar to the nomenclature of dairy product prices. For instance, only the total cheese production is available while the European milk observatory price dataset provides four prices of cheese (edam, gouda, emmental and cheddar). We restrict the analysis to butter, SMP and WMP, which are present on the two databases. Finally, the quantity database does not report the various inputs used by the dairy industry for the different processing activities (such as labor, capital, energy products, …). Accordingly, we adopt a dual approach where the PPS and the behavioral assumptions are subsumed in the specification of objective function. In that respect, we assume in our theoretical model that the representative dairy processor maximizes his expected utility subject to the PPS. Lence (2009) demonstrated that the joint estimation of the utility function and the PPS is impossible with typical production data. Accordingly, we concentrate our analysis on the 2001 to 2007 period when the intervention prices were reduced. As the figure 1 shows, the market prices during this period were not much volatile and roughly followed the reduction of intervention prices. Thus we can reasonably assume that dairy processors adapt to the true market signals during that period (in other words, that expected prices equal true prices), where milk quotas were unchanged. We use this period to identify some features of the PPS of dairy processors. We will later assume the risk behavior of dairy processors when implementing our theoretical model. During that period, the quantity of milk components (fat and protein) available for processing were exogenous to the decisions of dairy processors. We thus specify a restricted profit function, i.e. conditional on the availability of fat and protein. We adopt the quadratic function normalized by the variable input price (we again use the consumer price index). From the Hotelling lemma, we obtain the following system of supply functions:

$$Y_t = A.PY_t + B.K_t \tag{10}$$

Where K_t the availability of fat and protein materials, A and B two matrices of parameters to be estimated. The first matrix is a square matrix capturing the price responses (which are unspecified in our previous cointegration analysis). If all coefficients of this matrix are null, this means that the representative dairy processor is not able to adapt his production portfolio to the price, only to the exogenous availability of milk components. In that case, when faced with volatile prices or an expected change in the long term trend, a risk averse dairy processor will have a positive hedging demand. On the other hand, if these coefficients are huge (in absolute terms), this means that the representative dairy processor can quickly adapt his production portfolio, which reduces his hedging demand when confronted later to risky prices.

The A matrix is symmetric and positive semidefinite if the PPS is strictly convex. This property rules out possible discontinuities associated with indivisible factors (Ginsburgh et Keyser, 2002, chapter 2). Below we do not impose these constraints. Turning to the econometric estimation of these coefficients, we add to the system of equations 10 a vector of additive disturbances, which we assume to be identically distributed, serially independent, normal random vectors with mean zero. We perform Seemingly Unrelated Regressions (SUR) for both the German and French data. Table 3 reports these econometric results, with Heteroscedastic and Autocorrelation Consistent (HAC) standard errors.

Table 3. Dairy production estimates

German data	Y_b Estimates	SE	Y_s estimates	SE	Y_w estimates	SE
Constant	-12.18*	5.770	-80.958**	9.960	-8.894**	-3.170
PY_b	-0.032	0.021	0.336**	0.068	-0.038**	-3.268
PY_s	-0.042	0.037	0.277**	0.102	-0.034	-1.639
PY_w	0.006	0.058	-0.532**	0.175	0.079*	2.419
K_f	1.373**	0.130	1.281**	0.388	0.368***	6.087
K_p	-0.830**	0.171	-0.511	0.494	-0.182*	-2.136
French data	Y butter Estimates	SE	Y SMP estimates	SE	Y WMP estimates	SE
Constant	-31.365**	4.903	-34.142**	9.272	-32.286**	12.204
PY_b	0.067**	0.024	0.133*	0.060	0.073	0.050
PY_s	0.058	0.039	0.157	0.105	-0.010	0.053
PY_w	-0.082	0.057	-0.329*	0.149	0.029	0.114
K_f	0.722***	0.105	-0.190	0.188	0.221	0.121
K_p	-0.012	0.134	1.332**	0.235	0.088	0.134

We find that five price coefficients among the nine price coefficients are statistically significant in the German case, only three in the French case. One possible explanation is the greater share of long live differentiated products (such as specialty cheese) offered by French dairy processors. Moreover, statistically significant coefficients are of the expected sign. For instance, the German responses of SMP/WMP production to their own price are positive. Statistically significant cross price responses also make sense: an increase of German butter price favors the joint production of SMP and not of the competing WMP production. Conversely, an increase of WMP price reduces the SMP productions. The sign of the statistically significant C parameters are also consistent with a priori knowledge. In both countries, an increase of fat availability favors the production of butter. An increase of protein availability has a positive effect of SMP production only in the French case.

These new statistical results again confirm the production flexibility of European dairy processors and moreover reveal some heterogeneity.

4.3. Insights from price and public stock data

The previous statistical analysis is restricted to only two EU member states and three products. We pursue a third statistical analysis at the European level, using information on monthly public stocks and market equilibrium conditions. In the previous section, we only focus on the production side of the market, assuming exogenous market price. The evolution of market prices result from the interaction between supply and demand dynamics. The reductions of intervention price decided by European policy makers in the Agenda 2000 and Health check CAP reforms were in practice implemented by a reduction of public stocks. We exploit this information as follows. Let's assume for all dairy products the existence of two types of demands: the net demand by (domestic and foreign) consumers that is price dependent (with D the price response, C the constant) and the exogenous variation of public stocks decided by the EC (noted by ΔS). The total demand is given by:

$$D_t = C - D.PY_t + \Delta S_t \tag{11}$$

At each month, there is an equilibrium between the production delivered by the European dairy processors and the total demand. So combining (10) and (11), we obtain:

$$PY_t = (A + D)^{-1}.(C - B.K_t + \Delta S_t) \tag{12}$$

We are still interested by the A matrix capturing the production response of dairy processors. Unfortunately the parameters of this matrix are not identified, as they are added to the parameters of the D matrix, capturing the price response of consumers. We are not able to individually estimate them. However, we can reasonably assume that many off diagonal parameters of this matrix are null. In particular, it is reasonable to assume no substitution between butter and SMP, the former being mainly used for human consumption, the latter for animal feeding. In the same vein, there is probably a very limited substitution at the demand level between butter or SMP and some cheese. Accordingly this means that the off diagonal elements of the matrix $(A+D)^{-1}$ are non null only if the off diagonal elements of the matrix A are non null.

We estimate with the SUR method the system of equations 12 using the price of five commodities: butter, SMP, WMP, cheddar and emmental. On the right hand side, we include four explanatory variables: the fat and protein compositions of milk, the variation of public stock of butter and SMP. We again estimate these parameters over the period 2001/2007, adding normal disturbances with mean zero. Results are reported in Table 4. According to the ADF tests, the monthly prices of dairy products are not stationary. The fat and protein compositions are also non stationary, we check that the residuals of our regressions are stationary. Note that, compared to our first statistical contribution, we have here less data and degree of freedom, hence the ADF tests are less powerful.

Table 4. Market price estimates

	ΔS_b	ΔS_s	K_f	K_p
PY_b	0.879**	-0.346**	0.164	-0.299
SE	0.231	0.150	0.397	0.480
PY_s	-0.346**	-0.023	0.351	-0.322
SE	0.150	0.160	0.298	0.363
PY_w	0.157	-0.306**	0.422	-0.479
SE	0.139	0.117	0.284	0.345
PY_c	0.435	-0.710**	0.157	-0.226
SE	0.228	0.215	0.375	0.456
PY_e	0.220**	0.247**	0.290*	-0.399**
SE	0.080	0.075	0.120	0.146

We are mostly interested by the significance of the parameters associated to the variations of public stocks, with the exception of the coefficients of butter (respectively SMP) stock on butter (resp SMP) price. These coefficients may be different from zero only due to the own price effects on demand, not due to the technology of dairy processors. In the table 4, we impose symmetry to ease analysis, results are qualitatively unchanged if we relax this assumption.

It appears that the variations of SMP public stocks over the period 2001/2007 had significant impacts on the market prices of all other dairy products. Furthermore, the impact on the butter market price is of the expected sign: an increase of SMP public stocks has a negative effect on butter price as this increase may stimulate the joint production of SMP and butter. The impacts of SMP public stocks on the cheese prices are significant but different, suggesting that the dairy processors change their production portfolio. We also find that the own effect of SMP public stocks on the SMP market price is not significant while the own effect of butter is positive. This could result from high (respectively low) price elasticity of demand of SMP (respectively butter) which is related to the different profiles of consumers (animal feed industry for the SMP and final consumer for Butter). Finally we found that the milk compositions have no significant impacts on dairy product prices, with the exception of protein composition on the emmental market price. This effect is negative as expected: a larger availability of milk component exerts a downward pressure on price.

4.4. Calibration assumptions

Overall, our three statistical efforts tend to indicate that dairy processors are not “passive” economic actors, simply processing the fat and protein delivered by milk farmers. They adapt their production decisions in order to maximize profits and possibly to avoid risks. However we are not able to precisely identify all structural parameters. We are thus forced to make calibration assumptions when implementing our theoretical model. We now explicitly explain the calibration of the parameters of this model.

We focus on the behavior of the “average” dairy processor. He processes milk (composed of fat and non fat components) using variable inputs (including labor) and capital (plants) into five dairy products: butter, SMP, WMP, cheese and an aggregate of Other Dairy Products(ODP). We calibrate our theoretical model using pre reform data of 2001 and using by default data from the milk market observatory and from Bouamra Mechemache et al. (2008) for technical coefficients (how much fat in raw milk, butter, whole milk powder, cheese, …). As regards cheese, we assume that one ton of cheese requires 0.7 ton of fat and 8 tons of skimmed milk, that the initial cheese price amounts to 3600€/ton. As regards ODP, we first determine the total sale of the average dairy processor, assuming that their milk purchase to farmers represent 50% of this sale. Then we deduct from this value the sale values of the first four dairy products to determine the initial value of ODP production. The composition of ODP is also determined residually, between the supply of components from milk purchase and the demands of components for the production of the first four dairy products. At the input side, we assume that the purchase of raw milk represents 50% of the total sale, the purchase of other variables inputs and labor represents 40% of the total sale. Finally the profit is given by the return to capital and amounts initially to 10% of the total sale. All these percentage figures come from French survey on industry (Esane database).

For the parameters of the PPS, we follow Finger et al (2019) who themselves uses guess estimates from the CAPRI model. In practical terms, the PPS is specified assuming a strong separability between inputs and outputs. At the input side, we specify a CES function between our three inputs.

At the output side, we specify a parsimonious CET function. As in CAPRI, we start with 0.5 value for the elasticity of transformation.

As regards the risk dimension , we have even less econometric evidence of the risk attitude for food processors. We assume a standard power utility function, and calibrate the the risk aversion coefficient such that the risk premium represents 1 of expected profits. In the calibration phase, weassume that the market prices of dairy products are rather stable: their coefficient of variation amount to 2% for butter, SMP and WMP, 1% for cheese and ODP while the milk price paid by the average dairy processor is fixed. Finally, we implement our first order conditions (1) to (4) assuming 10 state of nature and that the prices of dairy products follow Gaussian distributions.

5. Simulation results

Our initial situation correspond to the pre reform situation with “high and stable” prices of dairy products and milk prices (reported in the first column of Table 5). In this initial situation, we assume that the futures markets on butter and skimmed milk powder are absent (equivalently prohibitive transaction costs) because the price risks on dairy products (coefficient of variation of 2%) are limited. We now conduct several simulations to identify the likely participation of dairy processors in futures markets.

Our first simulation (reported in the second column of Table 5) implements the price decrease decided during the 2003 Mid Term Review (by 22.5% for butter, 12.5% for SMP and 17.5% for WMP). We also assume that this reform induces a decrease of milk price by 17.5%. The results of this first simulation are standard and similar to Bouamra Mechemache et al. for instance. The average dairy processor reduces his production of butter and milk powders. On the other hand, he increases the production of cheese. Thanks to the reduction of the milk price, he is ready to process more milk (by 0.8%) if milk farmers decide to produce more (despite the milk price reduction but thanks to the support given by direct payments).

Our second simulation consider the same decrease of expected prices but also an increasing variability of butter and milk powder prices such that their coefficients of variation increase up to 15%[3]. In this scenario, we assume that the milk price paid by the average dairy processor remains fixed as in the first scenario. In other words, the volatility increases only on the output side, not at the input side in this scenario. As expected, this second simulation leads the average dairy

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[3] For instance, the market prices of butter expected by the average dairy processor vary between 1963€/ton and 2726€/ton

processor to further decrease his production of butter and milk powders. Compared to the first simulation, he also processes less milk in order to limit his exposition to output price volatility.

Table 5. Results of the four simulations (in % with respect to the initial situation)

Simulation	Initial situation	Price reduction	Price volatility	Futures markets	Milk package 0.2	Milk package 1
Production						
Butter	1.8	-2.89	-5.06	-3.35	-1.85	-6.79
SMP	1.2	-10.85	-15.96	-11.97	-8.20	-10.73
WMP	1.0	-12.85	-15.17	-13.43	-11.74	-12.37
Cheese	4.2	11.80	12.02	11.92	11.38	-0.77
ODP	Index	-1.36	-1.42	-1.36	-1.36	-5.07
Hedging ratios (%)						
Butter	0	0	0	86.92	12.88	0
SMP	0	0	0	64.02	0	0
Milk market						
Demand	120	0.83	0.09	0.69	1.10	-4.90
Mean price (€/t)	330	-17.5	-17.5	-17.5	-17.5	-17.5
S.D price (€/t)	0	0	0	0	1.88	9.75

Compared to the second simulation, our third simulation introduces the futures markets on butter and SMP. We assume limited transaction costs on the futures market (10€ per contract) and unbiased futures prices. Compared to the previous simulation, the introduction of these futures market favors the production of butter and milk powders since the processor has the possibility to hedge their volatility risk on output prices. This translates to the milk farmers who benefit from higher demand of milk by the average dairy processor. We observe that the participation of dairy processors on the futures markets are significant. The hedging ratio is higher for butter than SMP, simply because the butter activity is more risky (the butter price is on average higher than the SMP).

We conduct the same third simulation assuming now that the average dairy processor has no possibility to change his production portfolio (results not reported in table 5). He always produces the same level of dairy products, using the same amount of milk. In this purely theoretical situation, the dairy processor suffers more from the increasing volatility of output prices. Accordingly he is ready to participate more on the futures markets. We find that their hedging ratios reach 87.4% for butter and 78.6% for SMP. For this last product, this is a significant increase compared to the previous result. This conforms with the theoretical result developed above.

Our final simulation introduces some features of the milk package, namely that the milk prices paid to the milk farmers may be partly determined by the butter and SMP prices, depending on the

European member states. So far, we assume that the milk price paid by the dairy processor is fixed and known by the dairy processor before deciding his participation to futures markets. Now, we assume that the dairy processors and milk farmers negotiate a milk price formulae where the final milk price is tied ex post to the evolution of butter and SMP prices. We first compute the stochastic milk price equivalent from these two dairy product stochastic prices, assuming fixed processing costs. Then we assume that the milk price paid by the average dairy processor is linearly dependent of this stochastic milk price equivalent. The equation (7) is specified as:

$$PX_s = \alpha_0 + \alpha_1 PME_s = \alpha_0 + \alpha_1 \left(\left(PY_{b,s} - PC_b\right). \frac{io_{f,m}}{io_{f,b}} + \left(PY_{s,s} - PC_s\right). \frac{io_{p,m}}{io_{p,s}} \right) \qquad (13)$$

Wheren PME is the price of milk equivalent, PC_b, PC_s are the processing costs of butter and SMP (from Jongeneel et al., 2001), α_1 the sensitivity of the milk price to the milk price equivalent, α_0 a constant. Up to now, α_1 was nil. Below we consider two values of this parameter. The constant α_0 is adjusted so that the expected milk price remains the same.

Results of this last simulation are reported in the last two columns of table 5 and are compared to the results of the previous simulation with futures markets. If the sensitivity of the milk price to the butter/SMP prices is low (α_1 =0.2), the margin associated to the processing of milk into butter and SMP becomes less volatile. Accordingly this stimulates the production of these two products. For instance, we find that the butter production decreases by 1.8%, compared to 3.3% without the milk package. On the other hand, the margin associated to the processing of milk into cheese become more volatile. Accordingly the cheese production increases slightly less (11.4% compared to 11.9%). Overall the milk demand by the average dairy processor increases up to 1.1% (compared to 0.7%) because the dairy processor transmits part of the output price volatility to the milk farmers. Above all, we find that the demand of futures considerably decreases for butter (the hedging ratio decreases to 12.9%) and even this demand of futures vanishes for SMP. One may conclude from this simulation that futures markets are not really useful. In fact the volatility of output prices is now partly supported by the milk farmers: the standard deviation of milk price amounts to 1.9€/ton. Whether the milk package is beneficial to the milk sector depend on the risk aversion of milk farmers and their eventual scale economies, which are not analyzed in this paper. We just underline that this simulation ends up with larger demand of milk and higher price volatility for milk farmers.

Finally, if the sensitivity of the milk price to the butter/SMP prices is high (α_1 =1), this leads to more important production effects. For instance, the butter production decreases by 6.8% and even the cheese production decreases (by 0.8%). The reason is that the margins associated to the processing of milk into cheese or ODP become highly volatile. The risk averse dairy processor then prefers to reduce his global activity. The milk demand decreases by as much as 4.9%. The futures on butter and SMP are not useful in this case. The outcome is also negative for milk farmers as they face less milk demand from the dairy processor and higher milk price variability.

Concluding remarks

This paper deals with the low liquidity of European futures markets on dairy products. We focus the analysis on the potential participation by dairy processors. We find that both their production decisions and the transmission of volatility to the milk prices are critical factors that likely explain their limited participation.

In a more normative way, the introduction of liquid futures markets may benefit both dairy processors and milk farmers (as nicely discussed by O'Connor et al, 2015). Concretely they can engage ex ante in milk price negotiation using futures prices. This will reduce the risk exposure of both dairy processors and milk farmers. Our simulation model allows the quantification of these benefits.

Our analysis is based on many modelling assumptions. In particular we develop a static analysis preventing us to make a distinction between the long term trend and the short term volatility risks and assuming a fixed level of capital in the dairy processing sector. In our setting , the futures markets and the milk price formulae allowed by the milk package appear highly substitutable. Future researches may test if this result remains robust to a dynamic analysis with trend and volatility risks, futures available for different maturities, investment decisions, milk price formulas with possible time lags. New normative analysis including the attitude of milk farmers are also recommended to define the most appropriate hedging tools for the European milk economic agents.

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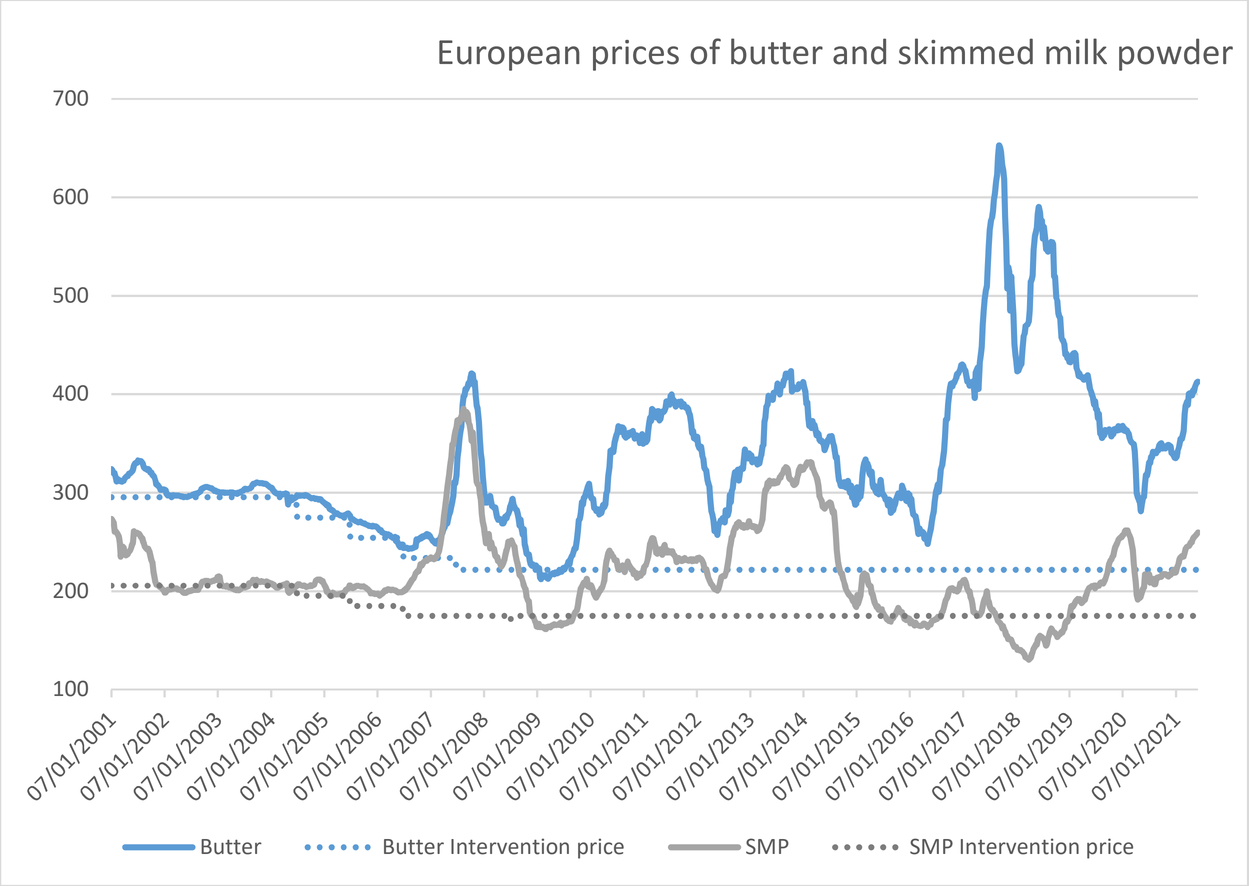
Figure 1.



Source: European commission – milk market observatory

Figure 2.

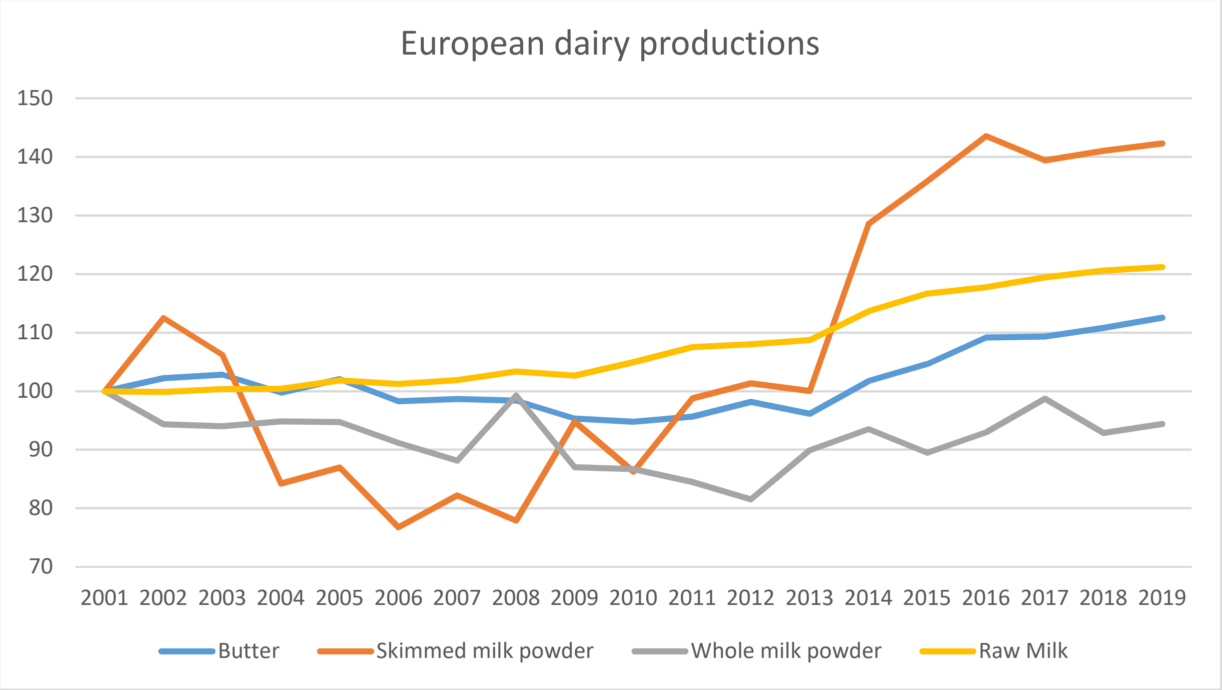
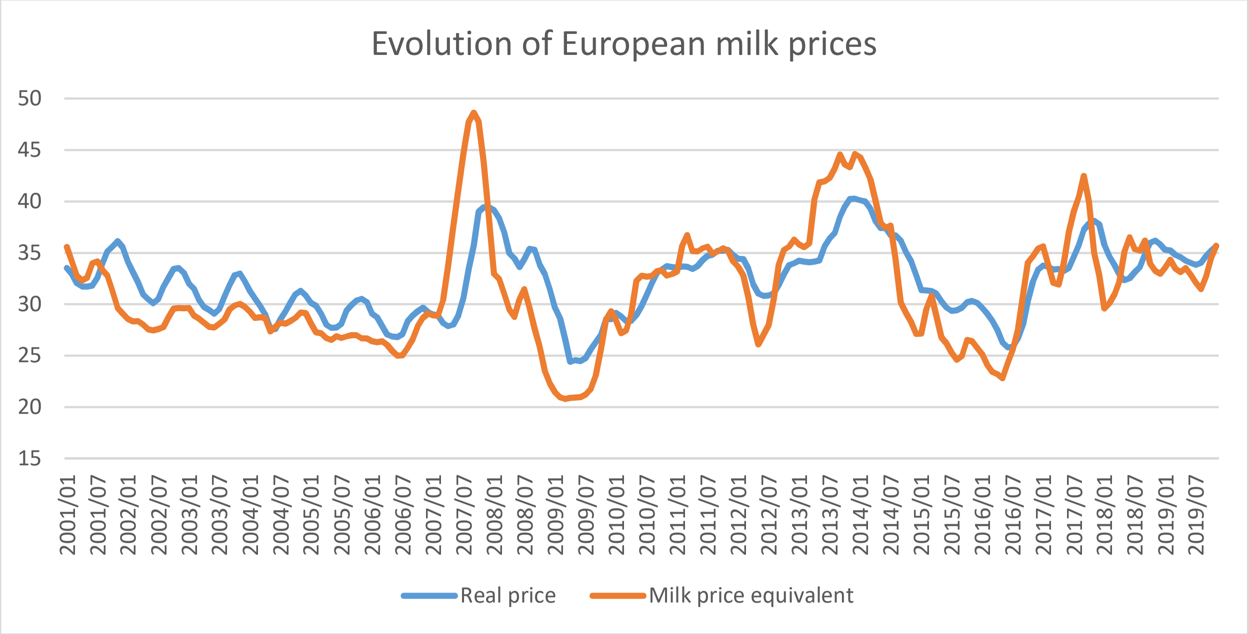

European dairy productions
150
140
130
120
110
100
90
80
70
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Butter
Skimmed milk powder
Whole milk powder
Raw Milk

Figure 3


Evolution of European milk prices
50
45
40
35
30
25
20
15
2001/01
2001/07
2002/01
2002/07
2003/01
2003/07
2004/01
2004/07
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2015/01
2015/07
2016/01
2016/07
2017/01
2017/07
2018/01
2018/07
2019/01
2019/07
Real price
Milk price equivalent

Appendix :

The derivation below follows Chavas (2004, chapter 8).

For the equation 5 :

$$dD(.) = E\begin{pmatrix} -U_{\pi}(\pi_s).\epsilon_s \\ +U_{\pi\pi}.\left(FT^i - PY_s^i\right).\epsilon_s.Y^i \\ +U_{\pi\pi}.\left(FT^i - PY_s^i\right).\left(PY_s^i - X_{Y^i}(.)\right).dY^i \end{pmatrix}$$

We replace es par py – mu in the second line taking into account that sigma=1, add and susbtract mu in the parentheses of lines 2 and 3 to obtain:

$$dD(.) = E\begin{pmatrix} -U_{\pi}(\pi_s).\epsilon_s \\ +U_{\pi\pi}.\left(FT^i - \mu^i + \mu^i - PY_s^i\right).\left(PY_s^i - \mu^i\right).Y^i \\ +U_{\pi\pi}.\left(FT^i - \mu^i + \mu^i - PY_s^i\right).\left(PY_s^i - \mu^i + \mu^i - X_{Y^i}(.)\right).dY^i \end{pmatrix}$$

We expand

$$dD(.) = E\begin{pmatrix} -U_{\pi}(\pi_s).\epsilon_s \\ -U_{\pi\pi}.\left(PY_s^i - \mu^i\right)^2.Y^i \\ +\left(FT^i - \mu^i\right).Y^i.U_{\pi\pi}.\left(PY_s^i - \mu^i\right) \\ +U_{\pi\pi}.\left(FT^i - \mu^i\right).\left(PY_s^i - \mu^i\right).dY^i \\ +U_{\pi\pi}.\left(FT^i - \mu^i\right).\left(\mu^i - X_{Y^i}(.)\right).dY^i \\ -U_{\pi\pi}.\left(PY_s^i - \mu^i\right)^2.dY^i \\ +U_{\pi\pi}.\left(\mu^i - PY_s^i\right).\left(\mu^i - X_{Y^i}(.)\right).dY^i \end{pmatrix}$$

And then we use E(py-mu)=0

For the equation 6:

We differentiate the FOC 1' to obtain:

$$E\begin{pmatrix} U_{\pi}(\pi_s).\left(\epsilon_s - X_{Y^iY^i}(.).dY^i +\right) \\ +U_{\pi\pi}.\left(PY_s^i - X_{Y^i}(.)\right).\epsilon_s.Y^i \\ +U_{\pi\pi}.\left(PY_s^i - X_{Y^i}(.)\right)^2.dY^i \end{pmatrix}$$

Again we remplace e in the second line by PY –mu, add and substract Xy (ie PY –Xy+Xy-mu) and we directly obtain 6. Chavas explains all signs.

$$dY^i = \frac{E\left(U_\pi(\pi_S).\epsilon_S + U_{\pi\pi}.\left(PY_S^i - \mu^i\right)^2.Y^i + U_{\pi\pi}.\left(PY_S^i - \mu^i\right)\left(X_{Y^i}(.) - \mu^i\right).Y^i\right)}{E\left(U_\pi(\pi_S).X_{Y^iY^i}(.) - U_{\pi\pi}.\left(PY_S^i - X_{Y^i}(.)\right)^2\right)} \tag{6}$$