An empirical analysis of U.K. milk contract prices 2004-2016

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Abstract

Milk quotas were introduced in 1984 to the EU dairy market to control the structural surpluses resulting from imbalances between supply and demand for milk encouraged by subsidies to the sector. These quotas were abolished on the 31st of March 2015 leaving the sector to operate closer to free market conditions. Milk in the UK is marketed through contracts and the purpose of this paper is to analyse, using time series methods, to what extent market factors are driving the observed evolution of UK contract prices. The five groups of contracts considered are: retailers' aligned contracts, standard liquid contracts, A&B contracts, cheese manufacturing contracts and other manufacturing contracts. Results indicate that, although market factors play a role in influencing all contract prices, their effect is different by type of contract, and quota abolition does not have a significant effect on the time series behaviour of contract prices.

JEL codes: M31, L11

Keywords: Milk prices, United Kingdom, contract prices, time series analysis.

1. Introduction

The purpose of establishing EU dairy quota was to control the oversupply of milk that would affect market prices and the amount of support needed for the sector (European Commission, 2015). Since its elimination in March 2015, the dairy sector has been increasingly operating

under market forces. All this has coincided with a context of international events such as the closure of Russian markets for EU food products, the reduction in demand for dairy products in China and other Asian economies, as well as the production expansion in New Zealand and the United States (Giles, 2015).

The elimination of the quota has triggered a number of analyses focused on its potential effects. Groeneveld et al. (2016) studied how likely the quota abolition is to lead to more intensive farms in the Netherlands, and the potential impact of legislation introduced to prevent it. Samson et al. (2017) studied the environmental impact of potential increases in milk production in Netherlands due to the quota elimination. Salou et al. (2017) analysed the effects of the quota elimination on the distribution of dairy production across various production systems in France. Another topic analysed has been that of how conflicts arising because of the quota abolition, such as the so-called 'German Milk Conflict' Alpmann and Bitsch (2017) developed between two farm organisations representing opposite interests on the common policy debate, namely market liberalisation versus regulation. In addition, Kersting et al. (2016) studied how a tradable/non-tradable production quota could influence firm entry and exit to/from the German dairy market. This paper's focus on the analysis of contract prices will contribute to the literature on the quota abolition impact on farm prices.

Understanding price behaviour has been pointed out as a critical element to decision making in uncertain conditions, and that can influence significantly the returns of dairy market participants (Bjørn & Li, 2016) [1]. Bergmann et al. (2015) analysed the European Union (EU) farmgate prices after the 2003 reform focusing on average prices in Germany, Ireland and the

[1] Note that what Bjørn and Li (2016) called the "world milk" price is not a measure of farmgate milk prices but an aggregate of three different milk price indicators (weights in parentheses): skimmed milk powder and butter (35 per cent); cheese and whey (45 per cent) and whole milk powder (20 per cent) (p. 1).

EU. A similar analysis was carried out by Nicholson and Stephenson (2015) in the US also using average milk prices.

This paper's approach differs from the aforementioned studies due to the fact that it focuses on analysing contract prices instead of the average United Kingdom (UK) milk price. Whilst an analysis similar to the above studies could have been carried out based on average milk price data, that would have been too aggregated as milk in the UK is marketed through contracts and each one has a different price. Moreover, although in the UK the period after the elimination of the milk quota has been characterised by a decreasing trend in the average price of milk (as observed in all EU farmgate milk prices across the EU), when disaggregated milk contract prices are observed, they show significant heterogeneity (with some of them growing), reaching up to 18 pence per litre in August 2015, when the average price was 23.3 pence per litre. This situation has raised concern about whether the average milk farmgate price for the UK calculated by Defra was a good indicator of the general trend of overall farmgate prices (AHDB, 2015).

The objective of this study is to empirically examine what factors are driving the prices observed in dairy contracts in the UK. Given the large number of factors along the dairy supply chains that could affect farmgate prices, the main goal of this paper is to understand to what extent market variables such as domestic production, world production, prices for final products affect contract prices, and moreover, whether the elimination of quota has represented a structural change in the relationships between the aforementioned variables and the contract prices. Specific questions to be addressed are:

- What are the factors influencing the prices in different milk contracts in the UK?

- How downstream wholesale and retail prices are transmitted to farm gate milk prices and whether this has changed after the end of the quota system?
- Are there differences between the ways in which market variables affect the different contract prices?

The analysis was based on an assembled database of standardised monthly contract prices for the period 2004 to 2016 that are published by the UK Agricultural and Horticultural Development Board (AHDB). For the analysis, contracts were aggregated into five categories: contracts aligned to retailers, standard liquid contracts, A & B contracts[2], cheese manufacturing contracts and other manufacturing contracts.

The paper proceeds with a brief overview of the UK dairy sector, followed by data and methods, discussion of results, and conclusions.

2. An overview of the dairy sector in the UK

According to Giles (2015) the dairy sector in the UK is going through a period of high uncertainty because of retailers' price wars, the increasing alignment of domestic dairy prices with world prices, which have been reducing milk prices, and also because of the elimination of the milk quota in March 2015, which has exposed the sector to market forces. . Figure 1 presents the real and nominal average milk price in the UK (Defra prices) as well as the minimum and maximum nominal price observed for milk. The decrease in real milk prices shown in Figure 1 is a reflection of how competitive the sector has become and the increasing

[2] The A&B milk contract are comprised of two prices: the 'A' price is set in advance and is generally based on returns achieved in the processor's core markets. 'B' price is paid for excesses or shortfalls in production (or 'B' volumes) and is determined from actual market returns or spot trade in most cases (AHDB, 2016a).

competition from other food products (such as fruit juices, cereal bars) due to changes in food purchasing patterns (Foster & Lunn, 2007).

Note that the situation shown in Figure 1 can vary enormously due to the fact that most dairy producers are tied to contracts that often specify which retailers they will supply. Whilst the three nominal price indicators have become relatively close to one another over time', approximately since the beginning of 2014 the difference between the maximum and minimum milk contract price has increased significantly.

Figure 2 portrays the evolution of the per capita purchases of milk and dairy products (excluding cheese), and cheese. Whilst the evolution of cheese purchases shows a moderately increasing trend, the purchases of milk and dairy products have shown a strong decline (particularly during the 1970's and 1980's). This decline is mostly explained by the decrease in the consumption of full fat milk, only partially replaced by semi-skimmed and skimmed milk, likely due to changes in consumption patterns (e.g., motivated by healthier consumption and substitution by products such as juices) (Foster & Lunn, 2007).

Figure 2 here

On the supply side, the observed contraction of the dairy products market (most of the UK dairy products are destined for the domestic market) has been followed by what is called a structural adjustment of the sector, depicted in Figure 3. Both the number of dairy cows and dairy holdings in the UK have decreased steadily by 23 per cent and 57 per cent since 1995, respectively. The trend is associated with an increase in the herd size per holding (AHDB, 2016a).

Figure 3 here

Despite the fact that the number of dairy holdings and dairy cows has been decreasing, this has not been strongly reflected in the production of milk, which has remained stable (Figure 5). This is due to the fact that the average production of milk per cow has been increasing steadily at a rate of 1.6 per cent per year (Figure 4).

Figure 4 here

The concentrated structure of retailing is an important characteristic of the UK food market (AHDB, 2016a). As shown in Table 1, the top five retailers (i.e., Tesco, Sainsbury's, Asda, Morrisons and The Co-operative) represent over 70 per cent of the sales of liquid milk and cheese, which are the two main dairy categories on the UK market.

Table 1 here

Both retailers and manufacturers establish contracts with farmers. In the case of retailers, these contracts are carried by manufacturers (e.g., the processor Arla has contracts with farmers who produce exclusively for retailers Tesco or Sainsbury's). Another interesting characteristic of the contracts is their confidential nature (even between farmers) preventing detailed comparisons amongst contracts besides prices paid.

Although somewhat dated, the MDC (2005) report pointed out that contracts provided by milk buyers made farmers unresponsive to actual market's needs reducing profits for

everyone, particularly farmers. Specific problems with some contracts included: "[1] Contracts which do not pay farmers on the basis of what the customer wants/needs or on the basis that the customer buys the milk. Often contracts reflect the pooling of overall milk sales rather than specific market needs; [2] prices which are set by looking at unimportant or varying market indicators (lack of transparency); [3] contracts which incentivise level supply by more or less than the value of that level supply to customers; [4] farmers who compound these problems by not maximising the price they get from contracts; [5] milk prices which can be changed at short notice or retrospectively without the option of the farmer ceasing to supply that customer" (MDC, 2005, p. 1).

After farmers staged a series of protests and blockades during 2012 (BBC, 2012), UK dairy farmers and processing firms reached an agreement on a voluntary code of practice for future contracts for milk supplies (NFU, NFUS & Dairy UK, 2012). The agreed code aims to address a number of long standing issues with dairy contracts (such as those mentioned above) in a way that works for both producers and purchasers. However, according to the NFU "[…] following the launch of the voluntary code, we have seen a number of positive moves by processors, however contractual problems still remain and that's why we are urging our dairy members to take a close look at any contracts they may be offered" (The Northern Echo, 2016). In February 2017, the NFU launched a contract checking service for farmers looking for legal advice on contract issues.

In summary, it is not clear from the scarce evidence available what factors drive the price offered to farmers in contracts. In the absence of information on the structure of the contracts (i.e., what determines the final price), this paper takes an empirical approach to investigate the major drivers.

3. Empirical work

The purpose of this section is twofold: first, to present the main features of the dataset used for the analyses and second, to provide a brief overview of the methods employed.

3.1. Data

The analysis was executed on a database of contract prices for the period 2004 to 2016, assembled using information provided and published online by the UK Agricultural and Horticultural Development Board (AHDB). The selected period of analysis was based on data availability (i.e., no data on contract prices were available before 2004).

The contract prices are based on the AHDB Dairy Standard Litre, which standardises the milk content (i.e., butterfat, protein, bacterial and somatic cell counts both per millilitre) when computing the contract prices, and therefore allows a comparison between different contract prices. This is based on 1 million litre/year producer on every other day collection (EODC) unless every day collection (EDC) is available on a profile equivalent to the UK national average profile of the past three years. Monthly variations for constituents, volume and hygiene are based on UK averages over the prior three milk years. The AHDB Dairy standard litre is reviewed in April each milk year to examine whether the standard litre currently being used needs to be amended. This will depend on whether significant changes in the pattern of milk production have taken place (AHDB, 2016b).

The dataset was augmented with information about wholesale prices for downstream products such as skimmed milk powder, butter and cream and also information about the EU production and production statistics from outside the EU (Argentina, Australia, New Zealand and the United States).

Data on the actual UK raw milk farmgate price and wholesale prices for downstream products such as skimmed milk powder, butter, cream, and cheddar cheese were sourced from Defra. Data on the EU internal market prices for raw milk, skimmed milk powder, butter, cream and different types of cheese were compiled from the EU Milk Market Observatory. Finally, UK retail price indices for milk butter and cheese were from the Office for National Statistics.

It should be noted that it is not possible to analyse each of the observed contract prices because of contracts changing frequently.[3] Therefore, following AHDB approach, it was decided to group the contracts into five categories: contracts aligned to retailers (liquid milk going to specific retailers, e.g., Tesco), standard liquid contracts (liquid milk contracts not associated to retailers), A&B contracts (see footnote 1), cheese manufacturing contracts, and other manufacturing contracts (milk destined to dairy products other than cheese, e.g., yoghurt, ice cream). Note that in the case of AHDB data, the last two categories are merged into one, i.e., "manufacturing contracts".

[3] For instance, since 2004 the database records a total of 152 different contracts with a monthly average of 65 contracts and a standard deviation of 13.5. Whilst Wensleydale contract price (for cheese) and Wyke Farms (standard liquid) have been observed for the entire sample, Dairy Crest, Arla and Muller have been introducing and replacing contracts frequently during the sample period.

Quantities traded under each contract are not available and therefore it was not possible to compute weighted averages of contract prices; simple averages were used instead[4]. Despite this, the evolution of the contract prices in our analysis is similar to that of contract prices presented on the AHDB website. Figure 5 presents the evolution of the different contracts groups. Note that, although they show some differences, all contract prices seem to follow roughly similar trends up to approximately March 2015, when the quota ended.

Figure 5 here

The starting point of the time series analyses is the descriptive analysis of the data, in particular whether the variables are stationary. Table 2 presents descriptive statistics for the data used in the analysis, and information about the stationarity of the variables, obtained using the Phillips-Perron test (Phillips & Perron, 1988). This test proposes a non-parametric method of controlling for serial correlation when testing for a unit root. The results indicate that the dataset is made of a combination of I(0) (i.e., stationary in levels) and I(1) variables (i.e., stationary in first differences).

Table 2 here

3.2. Methods

Similar to other papers on milk prices (e.g., Bjørn & Li, 2016; Bergmann et al., 2015; Nicholson & Stephenson, 2015), the approach used in this paper is empirical and based on the symmetric autoregressive distributed lag approach (ARDL) to cointegration introduced by Pesaran and Shin (1999) and developed by Pesaran et al. (2001).

[4] As regards the classification of contracts, see AHDB website (http://dairy.ahdb.org.uk/market-information/milk-price-calculator/).

Using this method to test for long run equilibrium has a number of advantages compared with previous methods such as those used in Engle and Granger (1987), Phillips and Hansen (1990) or Johansen and Juselius (1990). The ARDL is based on the estimation of the Unrestricted Error Correction Model (UECM) and therefore it is appropriate when having I(0) and I(1) variables.

The method can be used with small samples producing robust results and allows estimating the error correction model with just linear transformation, obtaining the long run relationships between time series, and eliminating serial correlation. The symmetric ARDL regression can be defined as follows:

$$(1) \qquad y_t = \alpha + \sum_{j=1}^{p} \phi_j y_{t-j} + \sum_{j=0}^{q} \left(\theta_j x_{t-j}\right) + \varepsilon_t$$

Where, y_t is the dependent variable; y_{t-j} are lags of the dependent variable and x_{t-j} are explanatory variables other than the lags of y_t, which can have lagged and current values. The terms p and q indicate the number of lags of the dependent and other explanatory variables, respectively; α, φ_j and θ_j are coefficients, and ε_t is an error term.

The Bounds testing approach (Pesaran et al., 2001) was used to test for the existence of long run relationships among variables. The unrestricted error correction equation to be used in the Bounds test is as follows:

$$(2) \qquad \Delta y_t = \beta_0 + \sum_{j=1}^{p-1} \gamma_j \Delta y_{t-j} + \sum_{j=0}^{q-1} \varphi_j \Delta x_{t-j} + \beta_1 y_{t-1} + \sum_{j=2}^{q-1} \beta_j x_{t-1} + \nu_t$$

Where β_0 is the intercept, β_1 and β_j correspond to the long run relationships parameters, γ_j and φ_j capture the short run dynamics of the model, and ν_t stands for the error term.

The Bounds testing procedure involves the estimation of equation (2) by ordinary least squares and the performance of two separate tests on the estimated coefficients. First, an F-test examining the null hypothesis that $\beta_1 = 0$ and $\beta_j = 0$ (no cointegration) against the alternative that $\beta_1 \neq 0$ and $\beta_j \neq 0$ (cointegration), and second, a t-test examining the null hypothesis that $\beta_1 = 0$ (no cointegration) against the alternative that $\beta_1 \neq 0$ (cointegration).

The distributions of the F- and t-statistics under the null hypotheses are non-standard as they depend on the order of integration of the underlying time series (Pesaran et al., 2001). To address this problem, Pesaran et al. (2001) provide two sets of critical values: a lower value assuming that all regressors are I(0), and an upper value assuming that all regressors are I(1). Consequently, the null hypothesis of no cointegration is accepted if the respective sample test statistic is below the corresponding lower critical value. By contrast, the null hypothesis is rejected if the test statistic exceeds the relevant upper critical value. In cases where the test statistic is in-between the two bounds, the results are inconclusive (Adämmer et al., 2016).

In order to ease the interpretation of the ARDL equations, they were expressed in terms of error correction equations as in (3):

$$(3) \qquad \Delta y_t = \beta_0 + \sum_{j=1}^{p-1} \gamma_j \Delta y_{t-j} + \sum_{j=0}^{q-1} \varphi_j \Delta x_{t-j} + \rho ECT_{t-1} + \varepsilon_t$$

Where the term ρ represents the speed of adjustment, links the long run with the short run adjustment process. When the ECT coefficient (i.e. ρ) is negative and statistically significant it indicates an adjustment of the dependent variable towards its long run equilibrium; the larger the magnitude of the ECT coefficient, the higher the speed of the adjustment to shocks.

It is important to highlight that the small sample available after the quota elimination (i.e., April 2015 to October 2016) makes it difficult to test structural change in the behaviour of the contract prices. Therefore, three complementary approaches were considered: First, a Chow test was performed (Chow, 1960) comparing the results for the period September 2013 to March 2015 with the post quota period (April 2015 to October 2016)[5]. Second, additive and multiplicative dummies were used to test whether there was a departure from the estimated ARDL equation (i.e., equation 1). This was done by estimating equation (4):

$$(4) \qquad y_t = \alpha + \sum_{j=1}^{p} \phi_j y_{t-j} + \sum_{j=0}^{q} \left(\theta_j x_{t-j}\right) + \delta_q \left\{ \alpha_q + \sum_{j=1}^{p} \phi_{qj} y_{t-j} + \sum_{j=0}^{q} \left(\theta_{qj} x_{t-j}\right) \right\}$$

Where δ_q is a dummy variable that takes the value of 1 for the post-quota period and 0 otherwise. The tests, therefore, were based on the null hypotheses of α_q, φ_{qj} and θ_{qj} being equal to zero. Lack of rejection of those null hypotheses imply no change in the ARDL parameters.

[5] Whilst a much larger pre-quota sample could have been chosen, the choice of the period September 2013 to March 2015 was to match the same number of months of the post-quota period.

The third method consists in using rolling regressions for the sample period ending in February 2009 with a window of 20 months (i.e., the number of periods of the post-quota sample). For each contract group price, Equation 1 was estimated 93 times and the parameters plotted over time to observe their stability. The choice of February 2009 was due to data availability: for example the New Zealand (NZ) milk production data were only available since 2007.

The choice of variables entering the contract price equations was motivated by economic theory. Based on information provided in section 2, it is assumed that processors negotiate a contract price (and probably other milk features, although we do not have information about it) with farmers based on market factors, and their own market expectations. This could be illustrated in a stylized model where the first order condition solving the processor's profit maximizing problem is:

$$(5) \qquad P^P \cdot \frac{\partial f\left(Q^M\right)}{\partial Q^M} = w$$

Where P^P is the price of the processed good (i.e., a dairy product like cheese), Q^M is the quantity of milk transformed by the processor, $f(\cdot)$ is the production function of the processed product and w is the negotiated contract price for milk. From the farmer's profit maximization, the supply of milk is given by the first order condition (6):

$$(6) \qquad w = \frac{\partial C\left(P^F, Q^M\right)}{\partial Q^M}$$

Where $C(\cdot)$ is the farmer's cost function that depends on the feed price P^F and the level of output Q^M (which in this simple case is equal to the processor utilisation).

At the equilibrium, one has

$$(7) \qquad P^P \cdot \frac{\partial f(Q^M)}{\partial Q^M} = \frac{\partial C(P^F, Q^M)}{\partial Q^M}$$

Thus, factors affecting positively both the price of the processed product and the expectations on the demand for the processed product should lead to an increase in the price paid for milk (i.e., the contract price) and an increase in the price of feed should provide the same effect as it would increase the milk marginal cost of producing milk.[6] In addition, expectations regarding an excess of milk supply should lead to lower contract prices. Of course, the simple model shown in equations (5) to (7), does not provide any information about the contract price dynamics, which needs to be discovered empirically.

4. Results and discussion

The following section presents and discusses the results of the estimation of models for each of the five different types of contract prices, discussion also results of alternative model specifications to test for the stability of the parameters over time (Chow-tests, a model with a post-quota dummy interacted with the explanatory variable, and rolling regression models).

[6] Note that the equilibrium condition (7) aims to highlight the potential variables being introduced in the bargaining between producers and processors. In a more formal setting (Salanié, 2005), the same problem could be represented by a Stackelberg game where the "principal" (i.e., the processor) offers the "agent" (i.e., the farmer) a contract (e.g., a milk price) that takes into consideration the agent's decision process and maximises the principal's pay off. The action taken by the farmer consists of delivering the milk to the processor and the bargaining process ends with the agent delivering or not the milk.

4.1 ARDL estimation results

Since an ARDL model can be estimated via least squares regression, the standard Akaike Information Criterion (Akaike, 1973) was used for model specification selection. . All variables presented in Table 3 were potentially considered for the estimation of the equations but only the ones with statistically significant coefficients were included in the final model specification.

Although the contract prices are based on the AHDB Dairy Standard Litre, and not on farm-gate prices, the average UK farm gate milk price and the UK milk production were replaced by fitted terms obtained regressing these variables on a series of exogenous variables, in order to avoid a potential endogeneity problems.[7]

The residuals of all equations were tested for normality using the Jarque-Bera test (Jarque & Bera, 1981), for autocorrelation employing the Breusch-Godfrey Lagrange Multiplier test (Godfrey, 1988), and for the existence of a long-run relationship using Bounds tests (Pesaran et al., 2001). In addition, recursive coefficients were also computed to evaluate whether they were converging smoothly as the sample size increased.

Table 3 presents the results of the ARDL models in terms of the error correction form. Model diagnostics are presented at the bottom of the table. The overall model fit was good and the different tests did not reveal presence of autocorrelation or non-normality of the residuals. Furthermore, the results of the Bounds tests for cointegration rejected the null hypothesis of

[7] In both regressions the instruments used were lags of the UK raw milk price, UK, New Zealand, Australia and USA milk production.

no cointegration for all regressions. Most of the recursive coefficients showed smoothly convergence as the sample expanded.[8]

The upper panel of Table 3 presents the short run dynamics of the ARDL equations. This is followed by the error correction adjustment coefficient (i.e., the coefficient associated to the error correction variable) and the lower panel of Table 4 shows the long-run terms.

Table 3 here

As shown in Table 3, each contract seems to follow different dynamics, which is expected since all contract prices respond to the needs of different milk uses. Moreover, the prices also had different seasonal patterns as shown by the seasonal dummies (dummy-month in Table 3). The values of the adjustment coefficients are all negative and statistically significant ranging from -0.463 for the A&B contracts to -0.164 for the "manufacturing others" contracts. This indicates that past disequilibria take more than a period to being incorporated into prices.

The short term dynamics shown in Table 3 indicate that a number of factors affect the current change in contract prices. From all the non-UK variables, only EU variables and New Zealand's production variable seem to have some effect on the contract prices. Whilst one should expect the EU variables to affect the UK market, New Zealand production variable have to be related to expectations on the world market. Note that coefficients associated with changes in production from the US, Australia or Argentina were not found statistically significant and therefore those variables removed from the equations.

[8] Recursive estimates of the coefficients are not presented in the paper but are available from the authors upon request.

Table 3 also shows that the coefficient associated to the lagged dependent variable, $Price_{t-1}$, was statistically significant for all contracts irrespective of the period of analysis. Moreover, in three of five equations the coefficient of the second lag of the dependent variable, $Price_{t-2}$, was also statistically significant. This indicates that all the contract prices have a large degree of persistence.

The long term results in Table 3 shows the expected signs for all estimated coefficients, namely, the response of the contract prices is positive to an increase in the average price for milk and the cost of production (i.e., price of compound feedingstuff) and negative to changes in milk production. There were, however, two exceptions: the response to EU milk production, and the response to New Zealand milk production, were both positive for the aligned contract prices. The coefficients of the UK processed products prices, e.g., wholesale Cheddar cheese prices, were found to be positive and significant for the manufacturing cheese contract prices.

Also, an increase in the New Zealand milk production was found significant and negative for the A&B contracts but not for the aligned contracts. Now we turn to the analysis of factors driving the prices in each contract:

Retailers' aligned contracts

Table 3 shows that the UK average milk price has a significant relationship with the retailers' aligned contract price (0.23 and 0.284 for the short and long term coefficients, respectively), whilst the relationship with milk production was found significant only in the short term (the

long term coefficient, although negative, is not significant). The positive relationship with the UK average price may be associated to the indication that contracts reflect the pooling of milk rather than factors associated to the final use of milk (MDC, 2005).

The price of the compound feeding-stuff (i.e., feed costs) was found to have a positive relationship with the retailers' aligned contract price but only in the long term (the coefficient was 0.26), which may indicate that these contracts compensate farmers for the increase in their costs of production (Farmers' Weekly, 2015). The fact that the coefficient of the EU average farm-gate price was found to be statistically significant and positive (0.79) indicates that milk imports play a role on the determination of the retailers' aligned contract price.

Standard liquid contracts

The response of the price for the standard liquid contracts to increases the UK price of raw milk was found positive (see Table 4) , with a statistically significant long term coefficient equal to 0.55, indicating that the pooling of overall milk sales is important for the price offered to farmers. Similar to the retailers' aligned contracts, the response of the price under the standard liquid contract price was positive, with a statistically significant coefficient for the compound feedstuff price equal to 0.19 in the short term and 0.42 in the long term, which means that production costs are one of the drivers of those prices. It should be noted that the coefficient of the downstream price of milk in the UK (retail price) was not found to have a statistically significant relationship with standard liquid contracts prices, and neither were the coefficients of the changes in the production or prices from abroad (i.e., Argentina, Australia, EU, New Zealand and USA).

A&B contracts

For the case of A&B contracts, Table 3 shows that an increase in the UK raw milk prices has a positive impact on the contract price with a coefficient of 0.53 in the short term and 1.38 in the long term (both coefficients being statistically significant) showing, again, the potential effect of milk pooling. In contrast with the other liquid milk contracts (i.e., retailers' aligned and standard liquid), the coefficient of the downstream price (i.e., UK retail milk price) was found positive and statistically significant in the short term (0.37), and negative and statistically significant only for the period pre- abolition of the quota (-0.53).

The coefficient of production costs (represented by the price of the compound feedstuff) was found not to have a statistically significant effect on A&B contract prices. From all the potential international factors only changes in New Zealand milk production was found to influence the price offered in the A&B contract showing a negative long term coefficient (-0.10). Finally, an interesting result was the negative and statistically significant long term coefficient for the use of milk on the production of cheese and cream in the UK (-0.21 and -0.42, respectively). This may indicate that the price offered to farmers is also driven by the competition with other dairy activities.

Manufacturing cheese contracts

The coefficient of the UK price of raw milk was found significant and with a positive effect on the contract price being equal to 0.32, in the short term and 0.53 in the long term, showing again the potential effect of milk pooling and not reflecting the specific requirements of cheese producers. In fact, the price of cream was not found explaining the price of this

contract in a statistically significant way. Similar to the case of A&B contracts, changes in production costs do not seem to affect the price paid under this contract type neither in the short nor the long term. Downstream prices were found to have a positive effect on the price of this contract, with an estimated long term elasticity with respect to the UK wholesale cheddar price equal to 0.47. With respect to international influences on the contract price, the coefficient of the EU milk production was the only one found to have a negative and statistical significant effect i only in the short term (-0.07).

Manufacturing others contracts

According to Table 3 the response of the contract price of other manufacturing products to an increase in the UK farm-gate milk price was positive and equal to 0.20 in the short term and 0.72 in the long term. Moreover, an increase in the UK milk production was found to have a negative long term effect on the contract price equal to -1.72. These results indicate that the price offered under this contract also responds to milk pooling and not necessarily to the particular requirements of the industry. A negative response to the increase in the EU milk production was found significant only in the short term (-0.05). No international variable was found influencing the contract price.

4.2 Chow test results

Table 4 presents the results of the Chow test for a structural change in parameters between the period previous to the elimination of the quota and the post quota period (both sample being the same size). The results of the test indicate that, at the 5 per cent level of significance, there seems to be a structural change after the quota elimination only in the

standard liquid contracts model. Note, however, that these results are also affected by the small sample size considered and do not provide any additional information on the source of the structural change (i.e., what coefficients were affected by the abolition of the quota), which are discussed below.

Table 4 here

4.3 Model with pre- and post-quota specific coefficients

Table 5 presents the results of the ARDL models estimated interacting a post-quota dummy with all the covariates in the model. The results indicate clearly that in the cases of retailers' aligned, standard liquid and manufacturing others contracts are no differences in the parameters before and after the quota elimination.

For A&B contracts, the only two statistically significant post quota coefficients were on the use of milk for cream and the seasonal dummy corresponding to April. For manufacturing cheese contracts, post quota changes were found in three coefficients, namely those associated to: the second lag of the contract price which became more negative (the elasticity decreases by -0.66), the coefficient of the UK average raw milk price lagged one period, and the seasonal dummy corresponding to September. From these results it is clear that the elimination of the quota did not affect significantly the contract price equations presented in Table5

Table 5 here

4.4 Rolling regressions

Table 6 and Figures 8 to 10 present the results of the rolling regressions for selected parameters of the ARDL equations.[9] As mentioned, the equations were estimated with a sample of 20 observations, i.e., of the same size of the post-quota sample. The months in the x-axis of the figures correspond to the ending month of the sample, i.e., the last point presents estimates for the post-quota sample. The dotted line in the figure corresponds to April 2015 and represents the period when post-quota observations start entering into the regressions. It is important to note that a sample period of 20 month is not necessarily a large sample for estimating the parameters of a model that contains variables that are non-stationary. Nevertheless, the exercise was carried to show the degree of stability of the coefficients.

Table 6

Figure 6

Figure 7

Figure 8

Figure 9

Figure 10

In general, it is difficult to discern a pattern in the figures as all of them show a great degree of volatility of the estimated coefficients (only few of the estimated parameters showed coefficients of variation below 50 per cent). Interestingly, the volatility of the coefficients can also be seen in the evolution of the seasonal dummy variables. It is possible that this observed volatility may be reduced as more observations become available for the post-quota period.

[9] Figures with the evolution of all the coefficients (i.e., including seasonal dummies, trends and intercepts) from the rolling regression can be found in an online annex.

The parameters are very volatile and this provides evidence to the fact that a number of factors affecting the contract prices change in importance over time with some frequency. This aspect has already been mentioned in the dairy literature as it brings the issue of lack of transparency on the milk contracts (MDC, 2005).

5. Conclusions

The purpose of this paper has been to study determinants of dairy contract prices in the UK market. Because of milk in the UK being marketed through contracts, and also because of the elimination of the EU quota, the different contract prices have diverged significantly from the average milk price.

Using an autoregressive distributed lag approach (ARDL) approach, the results show that market factors do influence contract prices and that, for most part, their effect is different by type of contract, with each contract adjusting at different speeds to previous periods' shocks. The results also indicate that some of the issues of milk contracts highlighted elsewhere in the literature still remain. The fact that the average UK milk price is an important component of the observed contract prices implies that contract prices reflect the pooling of overall milk sales rather than specific factors related to the specific customer market served. Contract prices seem to depend also on a number of factors which seem to change in importance over time, as shown by the rolling regression results, which has been mentioned in the literature as

lack of transparency in the contracts. Moreover, the results also seem to indicate that the elimination of the quota has not had a significant impact on the behaviour of the contract prices.

However, it is important to highlight that a limitation of this study is the short period available to analyse the effects of the elimination of the milk quotas on the different contract prices. Additional data could allow for estimating rolling regressions models with larger samples or modelling the post quota period separately from the pre-quota period. Another possible avenue to improve the results of this paper is that of obtaining more accurate information about the actual characteristics of the different contracts, and developing structural models of how contract prices are determined. In fact, contracts between farmers and downstream agents in the supply chain can deliver the required stability and increase the integration along the supply chain; however, to ensure that they fulfil their purpose a more detailed analysis of their features is needed. Under the new post-quota setting in which farmers seem to be more exposed to the vagaries of the market, there is an increasing need to deliver tools or propose devices to reduce producers' exposure to market changes. Such detailed analysis would facilitate the creation of these new negotiating devices.

6. References

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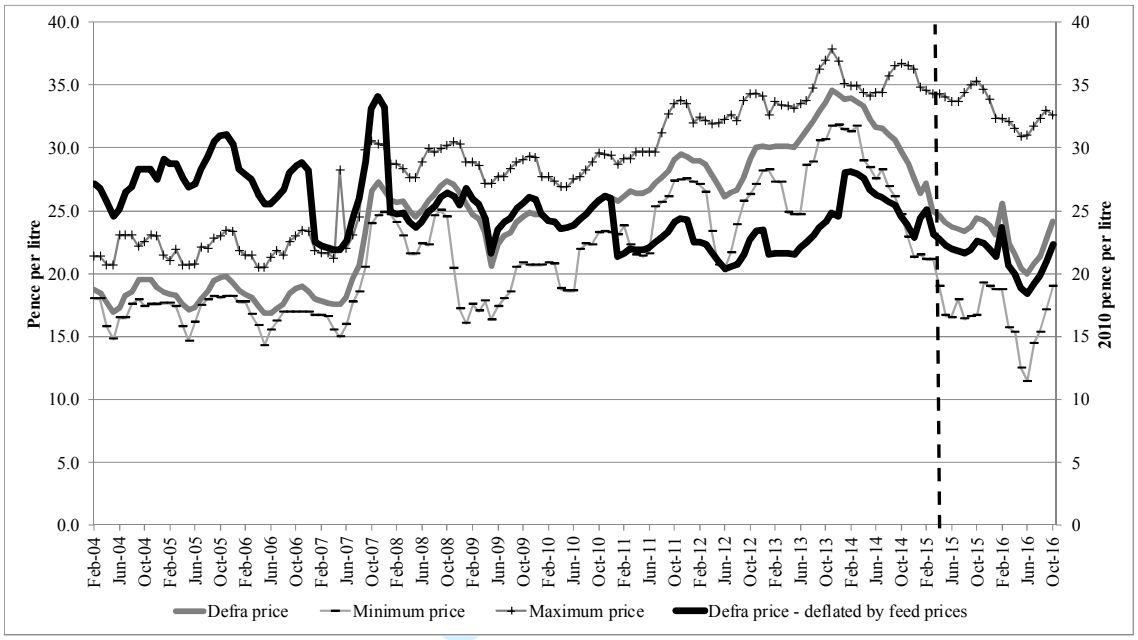
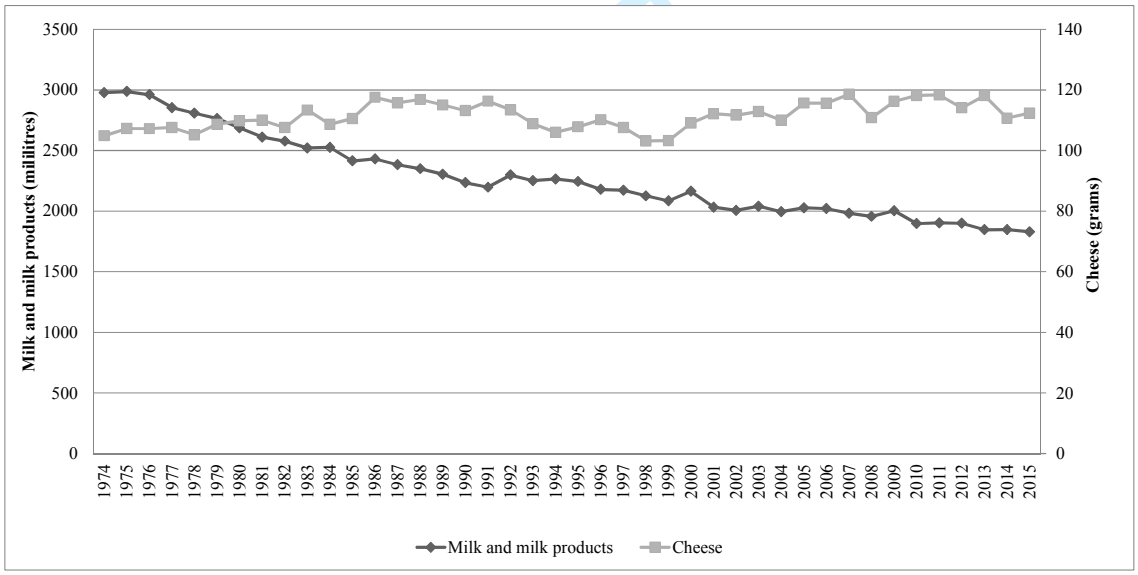
Figure 1: UK - Maximum, minimum contract prices, Defra average milk price (in nominal and real terms)



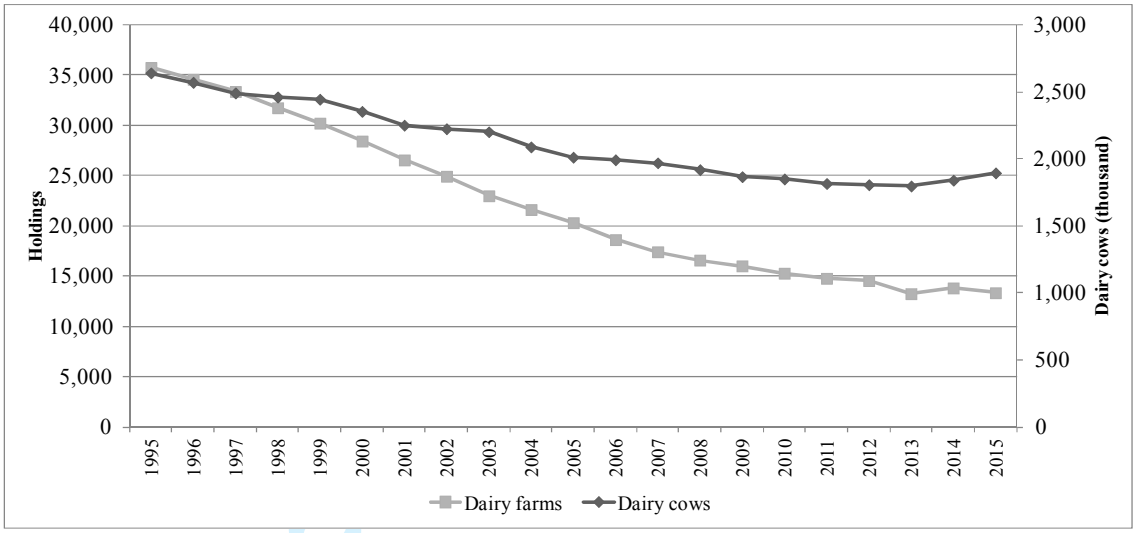
Source: Own elaboration based on AHDB and Defra information.
Note: The dotted line indicates the end of the dairy quota in March 2015.

Figure 2: UK weekly per-capita consumption of milk and dairy products (excluding cheese) and cheese.



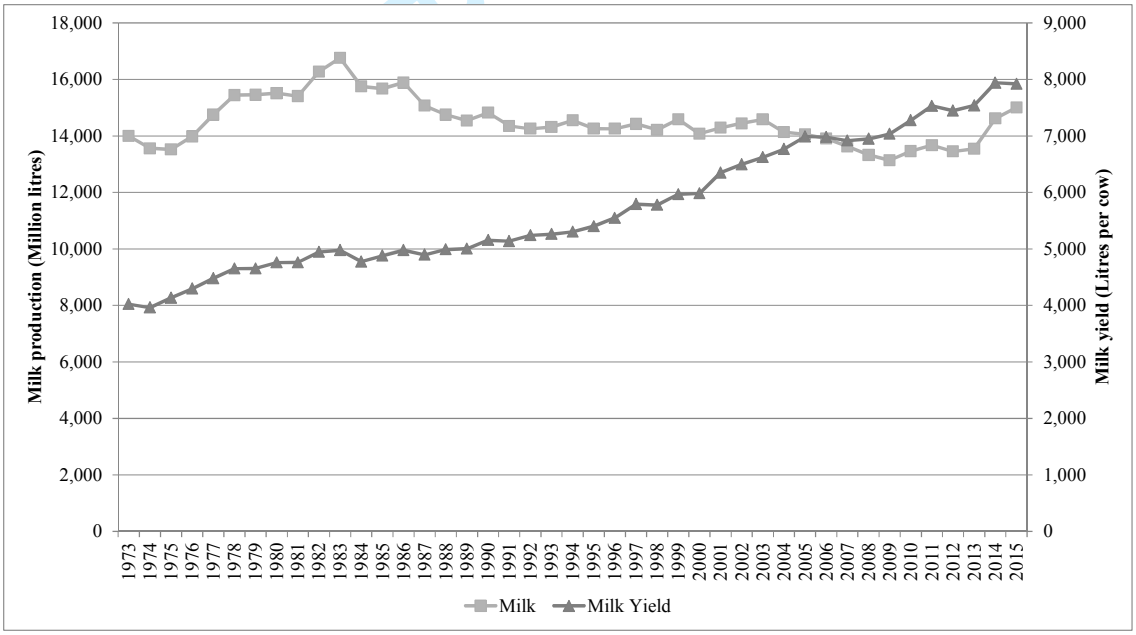
Source: Family Food, Defra

Figure 3: UK - Dairy farms/holdings and dairy cows



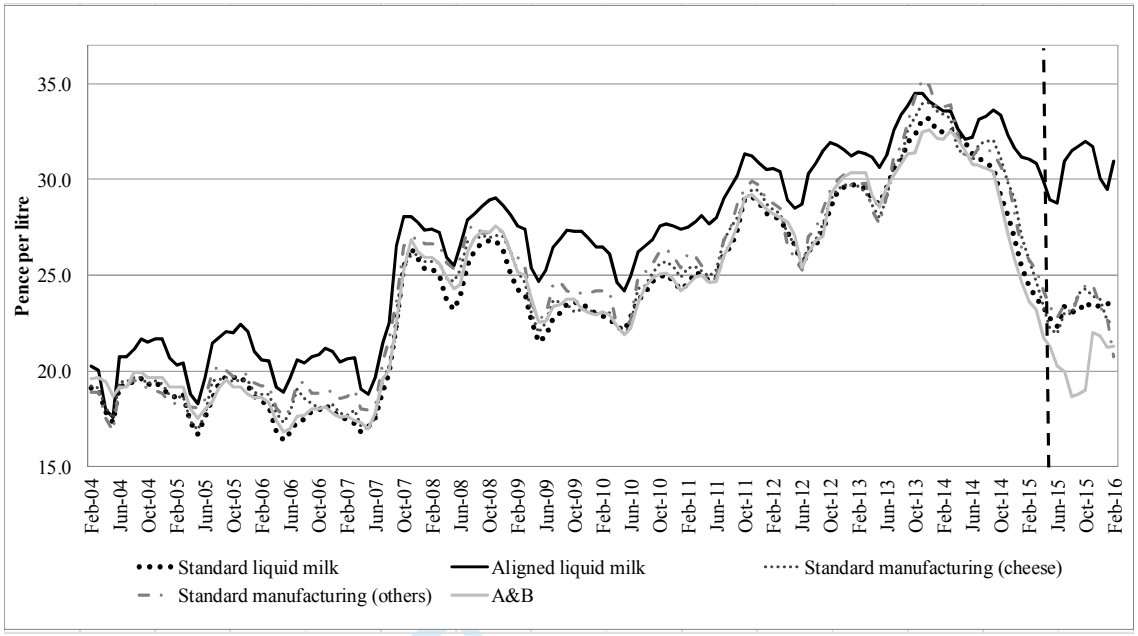
Source: AHDB and Defra.

Figure 4: UK - Evolution of milk production and yields



Source: Defra

Figure 5: UK - Evolution of contract prices by group for the period 2004 to 2016



Source: Own elaboration based on AHDB data.

Note: The dotted line indicates the end of the dairy quota in March 2015.

Table 1. Great Britain retailing of liquid milk and cheese - Value market shares (%)

	Liquid milk			Cheese		
	2014	2015	2016	2014	2015	2016
Top 5 retailers 1/	70.5	70.1	69.4	78.0	76.1	73.3
Total hard discounters 2/	6.5	7.3	8.4	8.1	10.2	12.0
Total independents and symbols 3/	4.2	4.1	3.5	0.7	0.6	0.6
Total bargain stores 4/	0.5	0.4	0.4	--	--	--
Milkman	6.9	7.0	6.8	--	--	--
Other retailers	11.5	11.3	11.5	13.2	13.1	14.1

Source: AHDB, Kantar Worldpanel data.

Notes:

1/ Tesco, Sainsbury's, Asda, Morrisons and The Co-operative.

2/ Aldi and Lidl

3/ Small retailers e.g., Costcutter, Premier.

4/ Small retailers e.g., One Pound Store.

Table 2. Descriptive statistics of the used variables

Variables	Original units 1/	Obs.	Mean	St.Dev.	Min	Max	Levels		First diff.	
							P-P 2/	Sig	P-P 2/	Sig
Price aligned	ppl	153	3.28	0.18	2.87	3.54	-1.77	0.39	-8.49	0.00
Price cheese	ppl	153	3.16	0.19	2.83	3.53	-1.86	0.35	-7.25	0.00
Price standar liquid	ppl	153	3.15	0.19	2.80	3.50	-1.75	0.40	-6.74	0.00
Price other manufacturing	ppl	153	3.17	0.19	2.82	3.56	-1.87	0.35	-7.43	0.00
Price A&B liquid	ppl	153	3.14	0.20	2.70	3.48	-1.80	0.38	-9.06	0.00
UK milk production	million litres	153	7.04	0.07	6.89	7.24	-5.52	0.00	-	-
UK condensed milk production	million litres	153	3.97	0.44	3.24	4.54	-2.62	0.10	-4.76	0.00
UK milk powder production	million litres	153	5.35	0.54	3.95	6.23	-1.30	0.61	-3.43	0.02
UK butter production	million litres	153	3.10	0.14	2.75	3.43	-6.16	0.00	-	-
UK cheese production	million litres	153	5.72	0.11	5.40	6.01	-4.97	0.00	-	-
UK cream production	million litres	153	3.15	0.13	2.88	3.42	-4.13	0.00	-	-
UK yougurt production	million litres	153	3.17	0.20	2.81	3.48	-1.84	0.36	-20.55	0.00
UK butter price	£/tonne	153	7.78	0.25	7.40	8.24	-1.82	0.37	-7.22	0.00
UK SMP price	£/tonne	153	7.48	0.24	7.07	7.94	-2.10	0.25	-7.42	0.00
UK mild cheddar price	£/tonne	153	7.97	0.15	7.74	8.20	-1.13	0.70	-7.13	0.00
UK mature cheddar price	£/tonne	153	7.84	0.17	7.55	8.15	-1.62	0.47	-6.84	0.00
UK bulkcream price	£/tonne	153	7.00	0.26	6.62	7.57	-2.24	0.19	-8.82	0.00
UK raw milk price	ppl	153	3.17	0.20	2.82	3.54	-1.74	0.41	-8.13	0.00
EU butter price	£/tonne	153	8.27	0.17	7.75	8.70	-2.64	0.09	-6.00	0.00
EU SMP price	£/tonne	153	10.27	0.23	9.78	10.92	-1.96	0.31	-5.49	0.00
EU WMP price	£/tonne	153	8.14	0.20	7.60	8.65	-2.35	0.16	-6.02	0.00
EU Cheddar price	£/tonne	153	8.29	0.17	7.83	8.61	-2.08	0.25	-8.81	0.00
EU Edam price	£/tonne	153	8.24	0.15	7.91	8.66	-2.14	0.23	-6.33	0.00
EU Gouda price	£/tonne	153	8.24	0.16	7.87	8.65	-1.95	0.31	-6.46	0.00
EU Emmental price	£/tonne	153	8.62	0.12	8.31	8.82	-0.50	0.89	-11.46	0.00
EU WP price	£/tonne	153	6.80	0.35	5.95	7.52	-2.56	0.10	-8.00	0.00
EU-15 raw milk price	£/tonne	153	6.02	0.14	5.63	6.35	-2.03	0.27	-7.12	0.00
EU milk production	million litres	153	9.35	0.10	8.64	9.56	-3.51	0.01	-	-
EU drinking milk production	million litres	152	7.87	0.04	7.78	7.96	-10.08	0.00	-	-
EU cream production	million litres	153	5.34	0.12	4.28	5.54	-4.78	0.00	-	-
EU skimmed milk powder production	million litres	153	4.49	0.31	2.98	5.14	-3.03	0.03	-	-
Compound feedingstuff price	Index (base 2010)	153	4.60	0.23	4.21	4.94	-1.38	0.59	-12.64	0.00
Feed wheat price	Index (base 2010)	153	4.61	0.33	3.98	5.20	-1.55	0.51	-10.33	0.00
Feed barley price	Index (base 2010)	153	4.67	0.32	4.09	5.29	-1.65	0.46	-11.51	0.00
Feed oats price	Index (base 2010)	153	4.66	0.39	4.01	5.53	-1.57	0.50	-15.59	0.00
New Zeland milk production	million litres	113	6.97	1.05	4.49	8.07	-3.90	0.00	-	-
Australia milk production	million litres	111	6.63	0.20	6.36	7.00	-4.05	0.00	-	-
USA milk production	million litres	115	8.89	0.05	8.78	9.01	-5.19	0.00	-	-
Argentina milk production	million litres	112	6.71	0.12	6.43	6.93	-4.70	0.00	-	-
UK retail millk price	Index (base 1987)	153	5.40	0.13	5.15	5.52	-1.96	0.30	-11.10	0.00
UK retail butter price	Index (base 1987)	153	5.50	0.26	5.12	5.83	-1.14	0.70	-13.95	0.00
UK retail cheese price	Index (base 1987)	153	5.36	0.14	5.13	5.54	-1.334305	0.61	-15.47	0.00

Notes:
1/ All the variables in the table are in logarithms.
2/ P-P denotes the Phillips-Perror test.

Table 3. Results of the estimation of error correction equations and cointegration tests

	Milk contract prices														
	Aligned			Standard liquid			A&B			Manufacturing cheese			Manufacturing others		
	Coeff.	St. dev.	Sig.	Coeff.	St. dev.	Sig.	Coeff.	St. dev.	Sig.	Coeff.	St. dev.	Sig.	Coeff.	St. dev.	Sig.
Short term coefficients 1/															
Price (t-1)	0.230	0.079	0.004	0.531	0.061	0.000				0.272	0.056	0.000			
UK raw milk price	0.262	0.054	0.000				0.528	0.107	0.000	0.324	0.067	0.000	0.202	0.085	0.018
EU 15 raw milk price (-1)													0.098	0.070	0.160
Compound feedingstuff price	0.040	0.063	0.530	0.185	0.073	0.013							0.176	0.085	0.039
UK retail milk price (t-1)							0.371	0.208	0.079						
UK milk production	0.067	0.037	0.069												
EU Cheddar price													0.141	0.053	0.009
UK use of milk in cheese							-0.117	0.059	0.051						
UK use of milk in cream							0.152	0.044	0.001						
EU milk production										-0.065	0.025	0.012	-0.045	0.161	0.781
EU milk production (t-1)										0.268	0.089	0.003			
NZ milk production	0.017	0.004	0.000				0.050	0.020	0.014						
NZ milk production (t-1)							-0.036	0.015	0.024						
dummy - February													0.016	0.011	0.139
dummy - March										0.039	0.011	0.000	-0.003	0.022	0.886
dummy - April	-0.049	0.007	0.000	-0.028	0.006	0.000	-0.032	0.013	0.014	-0.057	0.010	0.000	-0.003	0.014	0.848
dummy - May	-0.036	0.008	0.000										0.011	0.013	0.409
dummy - June				0.033	0.007	0.000							0.062	0.013	0.000
dummy - July				0.032	0.007	0.000	-0.182	0.074	0.016	0.064	0.010	0.000	0.075	0.024	0.003
dummy - August	-0.043	0.009	0.000				-0.189	0.066	0.005				0.035	0.018	0.052
dummy - September				0.031	0.006	0.000				0.029	0.008	0.000	0.024	0.019	0.216
dummy - October				0.016	0.006	0.013				0.028	0.009	0.003	0.016	0.019	0.399
dummy - November													0.015	0.012	0.204
dummy - December										0.035	0.009	0.000	-0.004	0.017	0.804
Trend				0.000	0.000	0.046									
Error correction adjusment	-0.332	0.056	0.000	-0.207	0.067	0.002	-0.463	0.071	0.000	-0.221	0.045	0.000	-0.164	0.050	0.001
Long run coefficients															
Intercept	6.140	1.005	0.000	-0.504	0.371	0.177	4.822	1.252	0.000	-3.633	1.892	0.057	9.466	3.168	0.003
UK raw milk price	0.284	0.064	0.000	0.550	0.159	0.001	1.381	0.074	0.000	0.529	0.141	0.000	0.722	0.242	0.003
EU 15 raw milk price													-0.521	0.334	0.121
Compound feedingstuff price	0.260	0.072	0.001	0.421	0.177	0.019							0.136	0.194	0.484
UK wholesale mature Cheddar price										0.471	0.156	0.003			
EU Cheddar price													0.715	0.285	0.013
UK retail milk price							-0.527	0.199	0.010						
UK milk production	-0.021	0.235	0.930										-1.722	0.560	0.003
UK use of milk in cheese							-0.210	0.098	0.035						
UK use of milk in cream							-0.417	0.087	0.000						
EU milk production	0.798	0.256	0.002							0.147	0.149	0.325			
NZ milk production	0.008	0.009	0.393				-0.095	0.027	0.001						
Statistics			**Sig.**			**Sig.**			**Sig.**			**Sig.**			**Sig.**
Number of observations	112			151			111			151			150		
Adjusted R-squared	0.75			0.61			0.56			0.73			0.66		
Jarque-Bera	1.28		0.53	0.87		0.65	1.01		0.60	3.99		0.13	1.45		0.48
Breusch-Godfrey (2)	0.28		0.76	1.43		0.24	0.30		0.74	0.50		0.61	1.14		0.32
ARDL Bounds Test 1	438.37		0.00	292.90		0.00	730.37		0.00	46644.54		0.00	539.49		0.00
ARDL Bounds Test 2	0.33		0.00	0.21		0.00	0.46		0.00	0.22		0.00	0.16		0.00
Log likelihood	317.53			378.69			235.11			386.94			369.91		

Note: 1/ Coefficients of variables in differences.

Table 4. Results of Chow tests for structural change before and after the quota elimination

Milk contract prices	Sum of squared errors			Degrees of freedom 1	Degrees of freedom 2	F test	Sig.
	Both periods	Period 0	Period 1				
Aligned	0.0054	0.0001	0.0036	13	14	0.4740	0.9062
Standard liquid	0.0098	0.0011	0.0019	12	16	3.0393	0.0202
A&B	0.0482	0.0011	0.0204	12	16	1.6670	0.1680
Manufacturing cheese	0.0086	0.0004	0.0015	15	10	2.3213	0.0910
Manufacturing others	0.0083	0.0001 **1/**	0.0003	19	2	2.5375	0.3203

Notes: Period 0 is September 2013 to March 2015 and Period 1 is April 2015 to October 2016. 1/ x10000.

Table 5. Estimated coefficients of regressions with interactive quota dummies

	Milk contract price equations														
	Aligned			Standard liquid			A&B			Manufacturing cheese			Manufacturing others		
	Coeff.	St. dev.	Sig.	Coeff.	St. dev.	Sig.	Coeff.	St. dev.	Sig.	Coeff.	St. dev.	Sig.	Coeff.	St. dev.	Sig.
Coefficients															
Price (t-1)	0.857	0.116	0.000	1.289	0.081	0.000	0.624	0.068	0.000	0.891	0.068	0.000	0.720	0.062	0.000
Price (t-2)	-0.157	0.102	0.128	-0.565	0.064	0.000				-0.144	0.062	0.022			
UK raw milk price	0.322	0.079	0.000				0.498	0.071	0.000	0.315	0.073	0.000	0.225	0.061	0.000
UK raw milk price (t-1)	-0.229	0.093	0.016	0.172	0.073	0.020				-0.191	0.078	0.015			
Compound feedingstuff price	0.077	0.029	0.009	0.100	0.028	0.001							0.186	0.081	0.024
Compound feedingstuff price (-1)													-0.165	0.084	0.053
UK wholesale mature Cheddar price (-1)										0.128	0.029	0.000			
UK retail milk price (t-2)							-0.203	0.054	0.000						
EU 15 raw milk price (-2)													-0.025	0.041	0.542
EU Cheddar price													0.069	0.031	0.027
UK use of milk in cheese							-0.089	0.034	0.011						
UK use of milk in cream							-0.116	0.028	0.000						
UK milk production	0.049	0.038	0.196												
UK milk production (t-2)													-0.236	0.067	0.001
EU milk production										-0.156	0.048	0.002			
EU milk production (t-1)	0.164	0.049	0.001							0.395	0.092	0.000			
EU milk production (t-2)										-0.170	0.083	0.043			
NZ milk production	0.016	0.004	0.001				0.026	0.013	0.044						
NZ milk production (t-1)	-0.014	0.004	0.001				-0.078	0.032	0.017						
NZ milk production (t-2)							0.016	0.010	0.108						
dummy - February				0.011	0.007	0.112							0.034	0.010	0.001
dummy - March										0.044	0.011	0.000	0.041	0.010	0.000
dummy - April	-0.050	0.008	0.000	-0.030	0.007	0.000	-0.011	0.010	0.281	-0.045	0.010	0.000	-0.022	0.009	0.016
dummy - May	-0.029	0.009	0.001										0.024	0.013	0.058
dummy - June				0.035	0.007	0.000							0.066	0.014	0.000
dummy - July				0.029	0.007	0.000	-0.101	0.052	0.054	0.054	0.009	0.000	0.119	0.017	0.000
dummy - August	-0.039	0.010	0.000				-0.115	0.048	0.018				0.068	0.013	0.000
dummy - September				0.029	0.007	0.000				0.013	0.008	0.091	0.055	0.012	0.000
dummy - October				0.011	0.007	0.111				0.027	0.009	0.002	0.046	0.011	0.000
dummy - November													0.030	0.009	0.002
dummy - December										0.036	0.009	0.000	0.027	0.009	0.004
Trend				0.000	0.000	0.102									
Intercept	-1.545	0.469	0.001	-0.127	0.083	0.128	1.836	0.349	0.000	-1.249	0.322	0.000	1.282	0.424	0.003
Coefficients multiply by quota dummy															
Price (t-1)	0.111	0.330	0.736	-0.073	0.409	0.859	-0.066	0.128	0.605	-0.190	0.259	0.465	-2.270	1.579	0.153
Price (t-2)	-0.149	0.291	0.610	0.189	0.264	0.475				-0.662	0.161	0.000			
UK raw milk price	-0.009	0.189	0.961				0.244	0.336	0.469	0.347	0.189	0.069	1.728	1.477	0.244
UK raw milk price (t-1)	0.124	0.300	0.680	-0.200	0.270	0.460				1.009	0.433	0.021			
Compound feedingstuff price	-0.322	0.295	0.277	-0.413	0.280	0.143							0.390	0.683	0.569
Compound feedingstuff price (-1)													1.148	1.068	0.284
UK wholesale mature Cheddar price (-1)										-0.166	0.161	0.303			
UK retail milk price (t-2)							0.001	1.298	0.999						
EU 15 raw milk price (-2)													1.075	0.666	0.109
EU Cheddar price													0.508	0.528	0.339
UK use of milk in cheese							-0.022	0.288	0.938						
UK use of milk in cream							-0.471	0.116	0.000						
UK milk production	0.143	0.289	0.622												
UK milk production (t-2)													-2.556	1.568	0.106
EU milk production										0.159	0.059	0.008			
EU milk production (t-1)	0.496	0.263	0.063							-0.163	0.396	0.681			
EU milk production (t-2)										-0.471	0.301	0.120			
NZ milk production	0.022	0.016	0.183				0.091	0.065	0.168						
NZ milk production (t-1)	-0.015	0.011	0.188				-0.185	0.184	0.318						
NZ milk production (t-2)							0.086	0.062	0.168						
dummy - February				0.026	0.025	0.289							-0.159	0.149	0.288
dummy - March										-0.099	0.056	0.077	0.022	0.079	0.782
dummy - April	0.005	0.020	0.809	0.021	0.021	0.314	-0.164	0.028	0.000	-0.009	0.028	0.764	-0.183	0.117	0.121
dummy - May	-0.031	0.030	0.310										0.008	0.079	0.924
dummy - June				-0.018	0.024	0.442							-0.018	0.094	0.846
dummy - July				0.018	0.025	0.457	-0.305	0.327	0.354	0.030	0.031	0.332	0.092	0.145	0.525
dummy - August	-0.035	0.026	0.172				-0.293	0.252	0.249				0.062	0.102	0.544
dummy - September				0.012	0.018	0.506				0.072	0.020	0.001	0.040	0.097	0.684
dummy - October				0.035	0.019	0.063				0.022	0.029	0.461	0.038	0.097	0.693
dummy - November													-0.023	0.048	0.628
dummy - December										0.021	0.037	0.566	0.079	0.079	0.319
Trend				-0.002	0.002	0.407									
Intercept	-4.462	2.818	0.117	2.458	1.932	0.206	1.209	4.814	0.802	4.140	1.984	0.039	1.855	5.324	0.728
Statistics															
Adjusted R-squared	0.973			0.988			0.980			0.992			0.988		
Log likelihood	323.552			385.903			274.841			419.941			391.939		
F-statistic	160.066			536.804			234.174			679.341			346.482		
Significance (F statistic)	0.000			0.000			0.000			0.000			0.000		

Table 6. Results of rolling regressions

Regression	Statistic	Coefficients 1/																		
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
		r1lc2	**r2lc2**	**lpmuki**	**r1lpmuki**	**lcfs**	**lqmuki**	**r1lqmeu**	**lqnz**	**r1lqnz**	**d4**	**d5**	**d8**	**Intercept**						
Regression 1	Mean	0.62	-0.35	0.33	-0.04	0.11	-0.05	-0.02	0.01	-0.01	-0.03	-0.02	-0.02	1.47						
	St. dev.	0.37	0.29	0.45	0.33	0.25	0.07	0.10	0.01	0.01	0.03	0.02	0.02	1.55						
	CV (%)	59.53	-83.60	136.00	-931.57	230.23	-148.07	-604.84	123.53	-115.70	-90.64	-113.05	-99.80	105.32						
		r1lc5	**r2lc5**	**r1lpmuki**	**lcfs**	**d2**	**d4**	**d6**	**d7**	**d9**	**d10**	**t**	**Intercept**							
Regression 2	Mean	1.03	-0.56	0.47	0.09	0.01	-0.01	0.02	0.03	0.02	0.01	0.00	-0.17							
	St. dev.	0.44	0.22	0.61	0.33	0.01	0.01	0.03	0.02	0.01	0.02	0.00	1.74							
	CV (%)	42.67	-39.17	128.77	375.81	57.60	-90.22	163.34	51.89	47.45	120.20	-885.98	-994.79							
		r1lc1	**lpmuki**	**r2lrpifm**	**lqcuk**	**r2lqcruk**	**lqnz**	**r1lqnz**	**r2lqnz**	**d4**	**d7**	**d8**	**Intercept**							
Regression 3	Mean	0.42	0.71	-0.09	0.00	-0.13	0.01	-0.03	0.01	-0.03	-0.02	-0.04	0.49							
	St. dev.	0.31	0.30	0.74	0.13	0.25	0.04	0.13	0.04	0.05	0.23	0.20	4.39							
	CV (%)	72.92	41.70	-809.95	-23500.16	-188.06	280.91	-485.03	517.40	-207.33	-1110.81	-504.33	903.82							
		r1lc3	**r2lc3**	**lpmuki**	**r1lpmuki**	**r1lpmacuk**	**lqmeu**	**r1lqmeu**	**r2lqmeu**	**d3**	**d4**	**d7**	**d9**	**d10**	**d12**	**Intercept**				
Regression 4	Mean	0.52	-0.17	0.33	0.19	0.25	-0.14	-0.07	0.01	0.00	-0.01	0.03	0.01	0.00	0.01	0.28				
	St. dev.	0.36	0.17	0.53	0.52	0.32	0.17	0.34	0.28	0.03	0.03	0.03	0.03	0.02	0.03	3.06				
	CV (%)	69.43	-99.87	161.24	264.83	127.73	-126.52	-498.64	2816.76	1363.21	-203.49	83.40	236.40	691.25	420.57	1108.21				
		r1lc4	**lpmuki**	**r2lprmeu**	**lpceu**	**lcfs**	**r1lcfs**	**r2lqmuki**	**d2**	**d3**	**d4**	**d5**	**d6**	**d7**	**d8**	**d9**	**d10**	**d11**	**d12**	**Intercept**
Regression 5	Mean	0.05	0.84	-0.09	-0.06	0.29	-0.43	0.52	-0.02	-0.02	-0.03	-0.11	-0.12	-0.11	-0.05	-0.04	-0.02	0.02	0.00	-1.57
	St. dev.	2.71	3.12	1.30	0.91	2.11	2.47	2.65	0.20	0.26	0.20	0.43	0.51	0.70	0.35	0.34	0.35	0.12	0.15	11.17
	CV (%)	5686.54	371.73	-1405.92	-1468.92	728.85	-575.93	507.59	-1160.91	-1055.99	-653.97	-374.03	-435.62	-653.80	-661.56	-829.49	-1431.23	789.83	-2994.84	-711.27

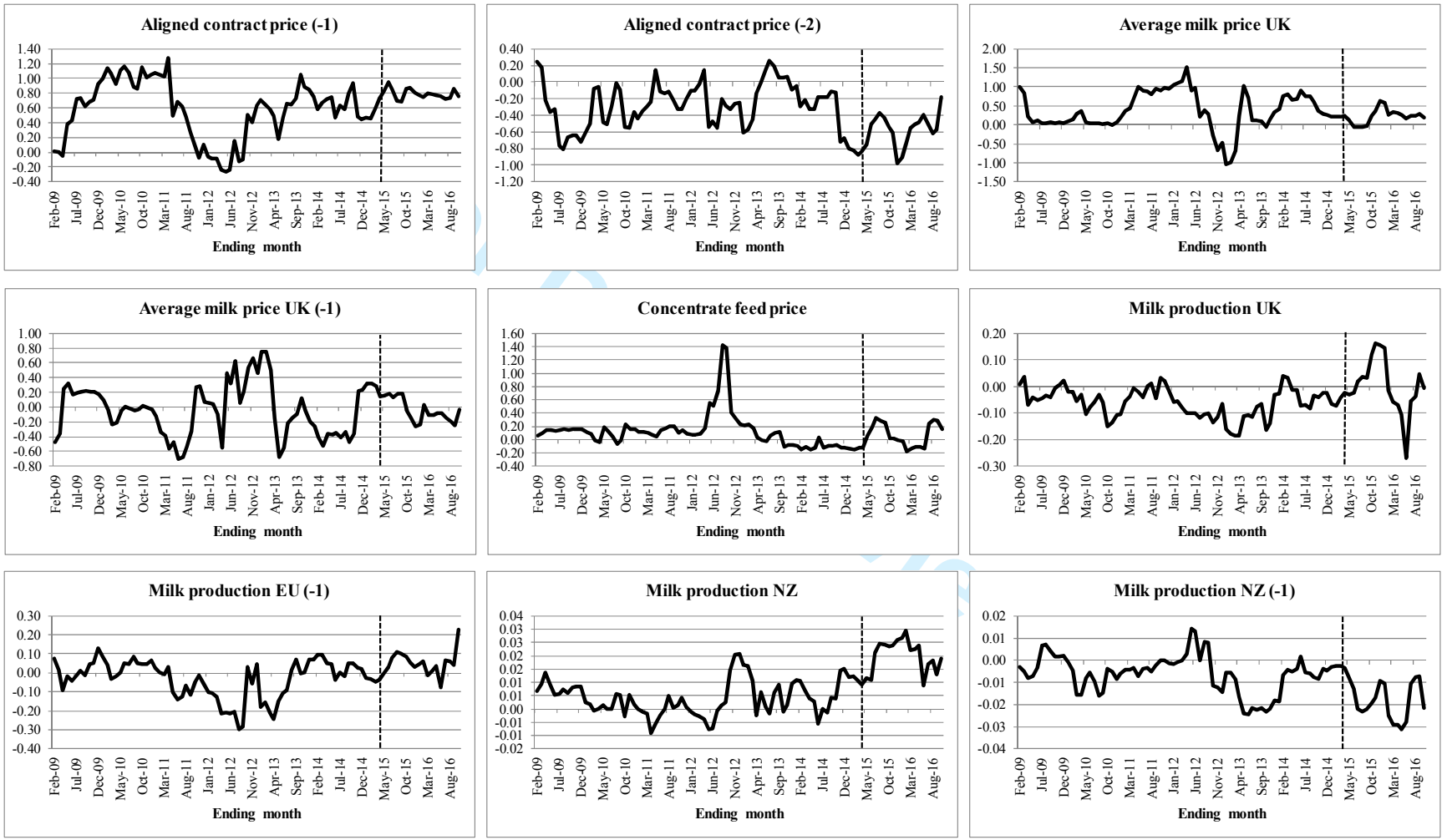
Notes: Regression 1=Aligned; Regression 2=Standard liquid; Regression 3=A&B; Regression 4=Manufacturing cheese; Regression 5=Manufacturing other.
1/ The prefix 'r1l' stands for first difference of the logarithm, 'r2l' stands for second differece of the logarithm and 'l' stands for logarithm of the variable.

Variables

c1 = Contract price - A&B
c2 = Contract price - Aligned to retailers
c3 = Contract price - Standard manufacturing cheese
c4 = Contract price - Standard manufacturing others
c5 = Contract price - Standard liquid milk
pmuki = Price of milk UK
cfs = Compound feedingstuff price for livestock
rpifm = Retail price index fresh milk
qnz = Quantity produced of milk New Zealand
pmacuk = Wholesale price of mature Cheddar UK
qmeu = Quantity of milk collected EU
prmeu = Price of cow's raw milk of EU 15
pceu = Price of Cheddar EU

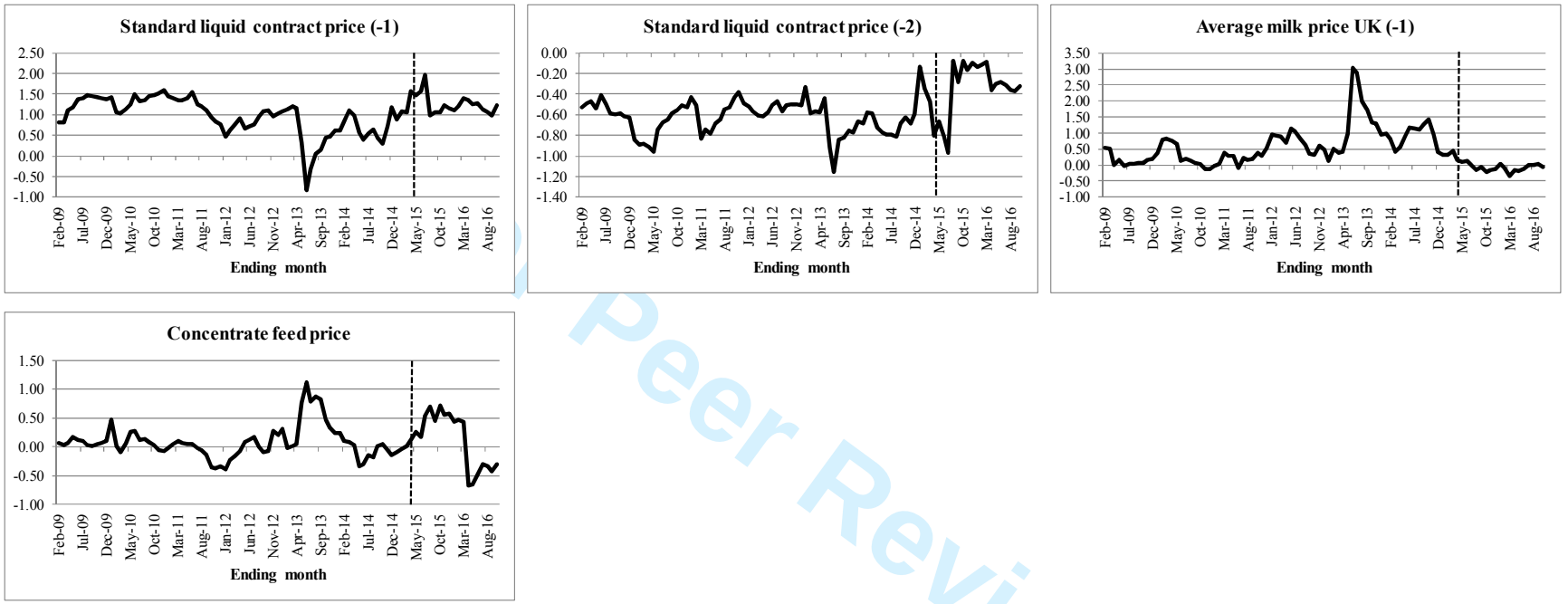
d2 = Seasonal dummy - February
d3 = Seasonal dummy - March
d4 = Seasonal dummy - April
d5 = Seasonal dummy - May
d6 = Seasonal dummy - June
d7 = Seasonal dummy - July
d8 = Seasonal dummy - August
d9 = Seasonal dummy - September
d10 = Seasonal dummy - October
d11 = Seasonal dummy - November
d12 = Seasonal dummy - December
t = trend

Figure 6. Rolling regression coefficients - Aligned contracts



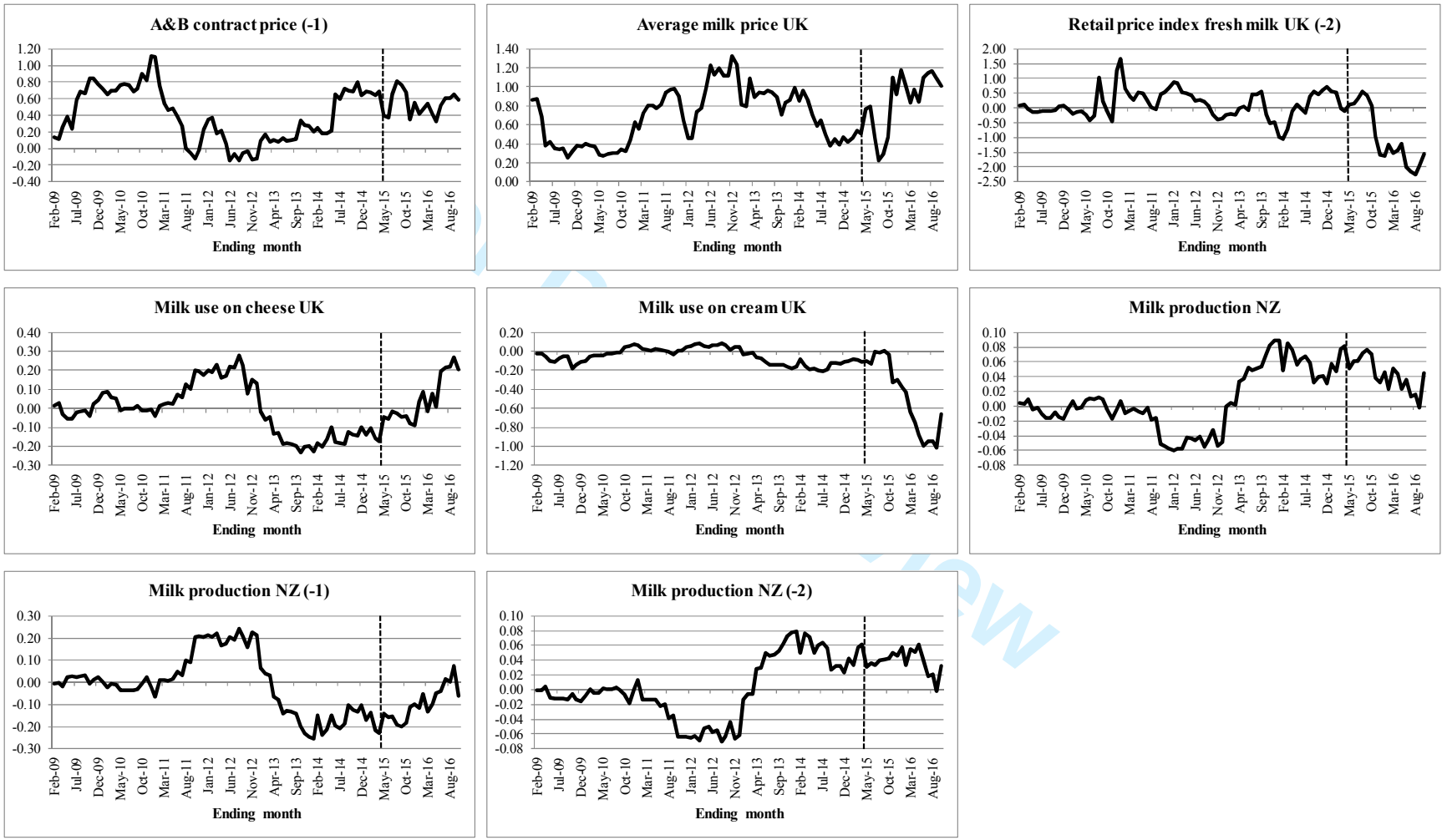
Note: The dotted line indicates the end of the dairy quota in March 2015.

Figure 7. Rolling regression coefficients - Standard liquid contracts



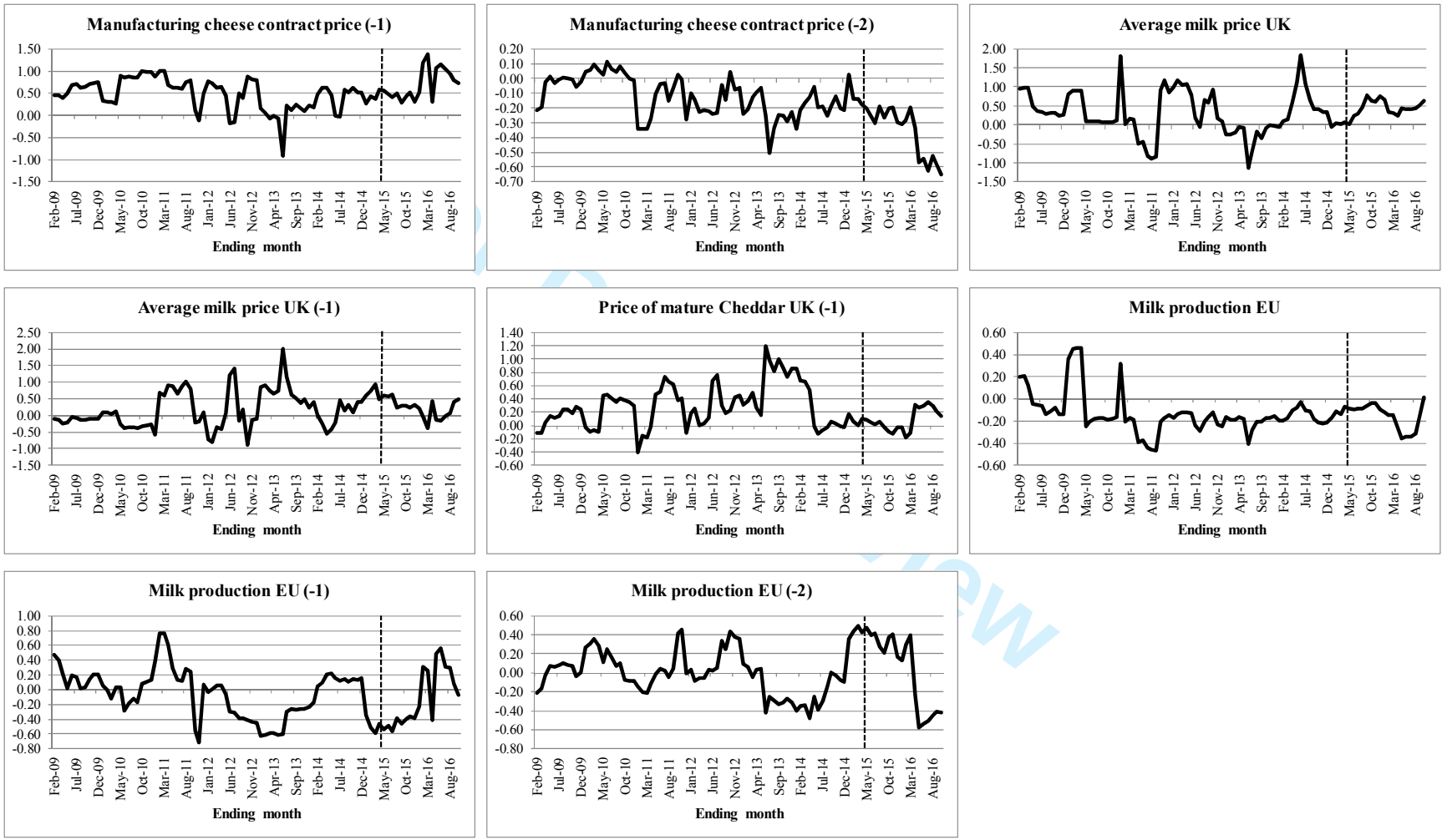
Note: The dotted line indicates the end of the dairy quota in March 2015.

Figure 8. Rolling regression coefficients - A&B contracts



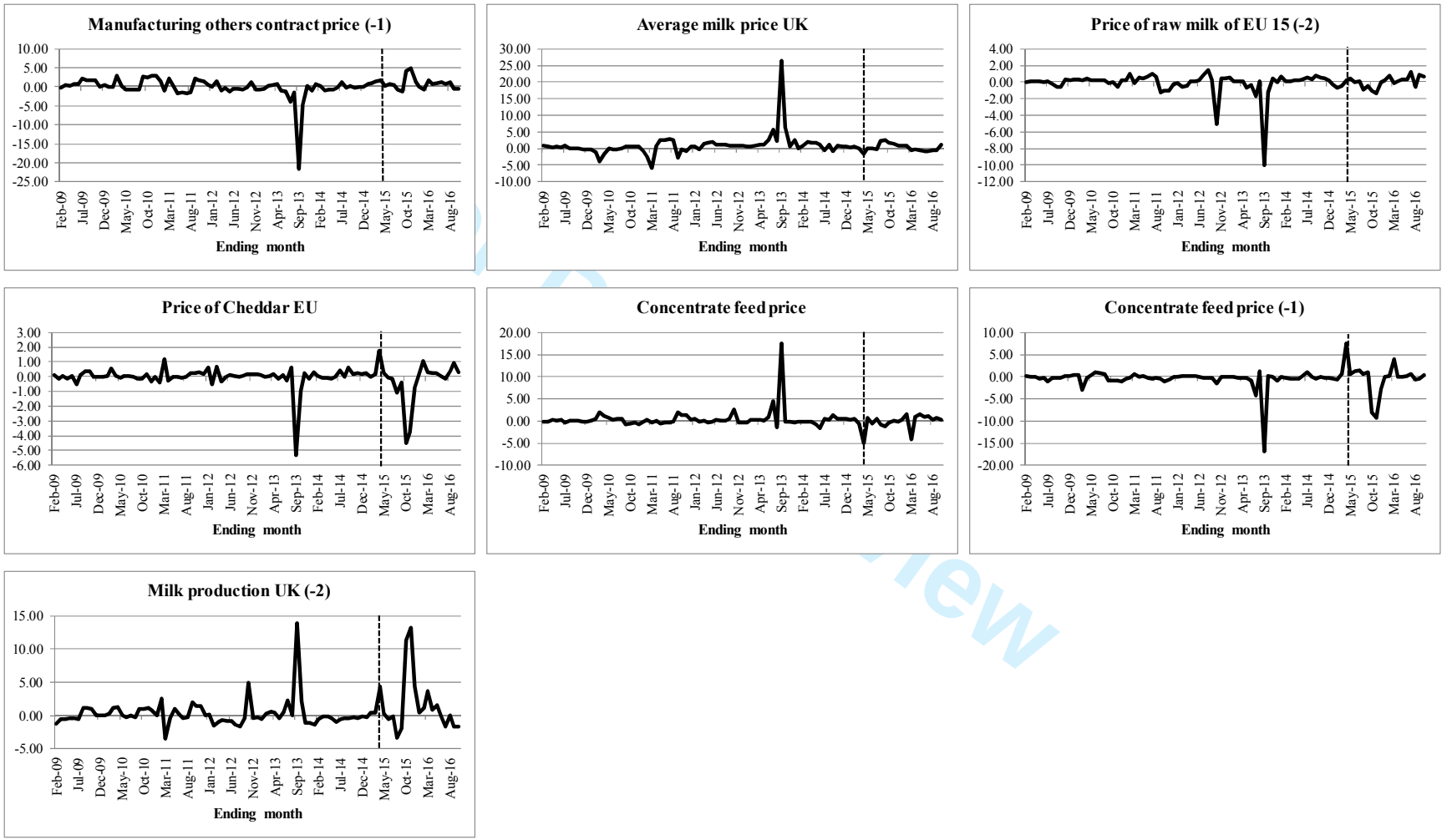
Note: The dotted line indicates the end of the dairy quota in March 2015.

Figure 9. Rolling regression coefficients - Manufacturing cheese contracts



Note: The dotted line indicates the end of the dairy quota in March 2015.

Figure 10. Rolling regression coefficients - Manufacturing other contracts



Note: The dotted line indicates the end of the dairy quota in March 2015.