Long Memory in Milk Prices: Evidence from EU-15

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Abstract In this paper we test for the presence of fractional integration, or long memory, in the monthly milk prices using ARFIMA(p,d,q) models. We consider data from 15 EU countries covering the period January 2001 to May 2008. The results suggest that twelve series show strong evidence of long memory. This indicates that shocks to the milk prices persist over a long period of time. We conclude that there is a high degree of predictability in the milk prices of EU-15.

Keywords: Milk prices, EU-15, long memory, ARFIMA

JEL Classification: Q13, Q18, C10, C22

1. Introduction

It is widely believed that the logs of time series contain a unit root (Granger and Joyeux, 1980; Hoskin, 1981). However, some series evidently do not possess a further unit root, while they show signs of dependence and possess long memory (Wang and Tomek, 2007). Long memory in time series can be defined as autocorrelation at long lags, of up to hundreds of time periods (Robinson, 2003). According to Jin and Frechette (2004b), memory means that observations are not independent (each observation is affected by the events that preceded it).

Long memory (or long-term dependence) has usually been described in terms of autocovariance or spectral density structure, in case of covariance stationary time series (Robinson, 2003). It describes the dynamics of the correlation structure of time series at long lags. Jin and Frechette (2004b) report that long memory models can increase forecasting accuracy and efficiency. It is a particularly interesting feature because its presence indicates evidence of non-linear dependence in the first and second moments (and of a predictable component).

Knowledge of the time series properties of agricultural prices has important economic implications. The empirical analysis of agricultural series (or commodity prices) provides useful information that can be used to evaluate the performance of empirical models. Knowledge of the long memory parameter will enable agriculture economists to determine whether price shocks are typically short-lived, long-lived, or infinitely lived (see Jin and Frechette, 2004b).
A small number of studies have tested the long memory hypothesis using data from agricultural markets. Kohzadi and Boyd (1995) apply the R/S test to monthly US cattle prices for the period 1922-1990. The results show evidence of nonlinear dynamics and long memory. Barkoulas et al. (1997) examine a variety of internationally traded commodity prices using a fractional integration model. The empirical results suggest that commodity prices have long memory.

Recently, Jin and Frechette (2004b) test for long memory in daily and weekly agricultural cash price returns (corn, Kansas City wheat, wheat, oats, soybeans, soybean meal, soybean oil, spring wheat, wheat No. 1 cash) using the rescaled range statistics R/S test. Empirical results indicate evidence of long memory in more than half of the agricultural commodities.

The focus of this paper is to examine if long memory is present in the milk farmgate prices of the European Union (EU). Milk prices are important determinants of agricultural conditions in all economies. Milk production takes place in all EU Member States and represents a significant proportion of the value of EU agricultural output as it forms a very important part of the agricultural economy (European Commission, 2006). Furthermore, a series of reform to the CAP[1] in 2003, may result in EU milk prices falling in line with world prices. Hence, the investigation of whether the long memory hypothesis exists in EU milk prices is of great interest. In this paper, we use monthly farmgate milk data from 15 EU countries. Our findings are also important since no previous work has examined this hypothesis using milk data from a large sample of EU countries.

The objectives of this paper are twofold: (i) to examine and justify the presence of long memory (via fractional integration) in the prices of milk in EU-15, and (ii) to test the validity of time series models on the presence of long memory in monthly milk series.

The remainder of this paper is organized as follows: Section 2 presents the long memory methodology and describes our data. Section 3 shows the empirical results, while the paper closes with some concluding comments in Section 4.

2. Methodology and Data

Previous studies used the standard Autoregressive Fractional Integrated Moving Average[2] (ARFIMA) model to examine the intertemporal dynamics of agricultural prices (Barkoulas et al., 1997). Fractional integration is a generalization of integer integration, under which time series are usually presumed to be integrated of order zero or one. According to Jin and Frechette (2004a), in ARFIMA models, mean die out at a slow hyperbolic rate of decay determined by a fractional integration parameter, which affects the long-term behaviour of the mean (short-run dynamics are modelled by conventional AR and MA parameters). ARFIMA(p,d,q) can be used to estimate the parameter d, which describes long-run memory properties. ARFIMA process is defined as follows:

$$\Phi(L)(1-L)^d y_t = \mu + \vartheta(L)\varepsilon_t \quad (1)$$

where $d \in (-0.5, 0.5)$ is the fractional difference operator and μ can be any deterministic function of time. If μ is zero, this process is called fractionally differenced ARMA.

We make the econometric assumptions that (i) the residuals $\varepsilon_t \sim iid(0, \sigma^2)$ and (ii) the roots of the AR and MA parameters fall outside the unit circle and do not have common roots.

Significance of *d* parameter is evidence of long memory. The *iid* assumption implies conditions on the dependence of the sequence (for a stationary sequence, mixing implies ergodicity).

When *d* parameter has values greater or equal to 0.5, the series does not have stationary covariance. When *d* is between 0 and 0.5, the lag length increases the autocorrelations decay hyperbolically to zero (a large portion of the variance is explained by low frequency components), while when $d = 0$, decays exponentially to zero (the process is stationary). If *d* is between -0.5 and 0, then it is usually identified as having intermediate memory, since autocorrelations are always negative (a large portion of the variance is explained by high frequency components, such that the spectral density at frequency zero is zero). For $d = 1$ the process is said to have a unit root, for $-0.5 < d < 0.5$ the process is stationary and invertible.

In the use of ARFIMA(p,d,q) models, correct specification of *p* and *q* is important. According to Robinson (2003), under-specification of *p* or *q* leads to inconsistent estimation of AR and MA coefficients, but also of long memory parameter *d*, as does over-specification of both, due to a loss of identifiability. In this paper, we select a parsimonious ARFIMA(*p*,*d*,*q*) model using the Akaike (AIC) information criterion.

The AIC information criterion is given by: $$AIC = -2(\hat{\ell}/n) + (2(p+q+2))/n \qquad (2)$$

where $\hat{\ell}$ is the value of the maximized likelihood. The best (selected) model has the smallest AIC value. The selected ARFIMA model is also a flexible model that can be used to study long memory and short-run dynamics simultaneously (Boes et al., 1989; Floros et al., 2007).

We use monthly observations from DG Agri-C4 on farmgate milk prices[3] for EU-15 (Italy, Finland, Sweden, Portugal, Denmark, France, Netherlands, Germany, Spain, Austria, Ireland, Belgium, United Kingdom, Greece and Luxembourg). Milk is the most important product sector in terms of value at approximately 14 % of agricultural output in the EU. In 2004, milk production was worth about EUR 43 billion at farm level[4]. The turnover of the dairy processing sector was EUR 117 billion. According to the European Commission (2006), the EU is a major player in the world dairy market and is the leading exporter of many dairy products, most notably cheeses. Further, milk prices are determined by several factors, and therefore, they are varied over time[5]. Hence, it is of great interest to examine the behaviour of long datasets using ARFIMA models.

The sample period is January 2001 to May 2008 (the number of observations is 89). The price of milk is expressed in GBP pence per litre. Figure 1 graph price series in levels. It shows a structural break[6] which corresponds to the general shock to food prices experienced over 2007. Summary statistics on the prices are reported in Table 1. The mean monthly price per litre ranges from 19p (Austria) to 25.12 (Finland). All series show positive skewness (the distribution is skewed to the right), while the distribution is peaked (leptokurtic) relative to normal. We also reject the hypothesis of normal distribution at the 5% level (for all series).We further examine each log-series for evidence of a unit root, employing ADF t-tests as well as KPSS and Phillips-Perron (PP) unit root tests. Note that KPSS tests are consistent against stationary long memory alternative, and hence they can be used to distinguish between short memory and stationary long memory process (Lee and Schmidt, 1996). Here, regression by both PP and KPSS tests suggests that fractionally differenced process may be an appropriate representation for milk log-price series (the results from unit root tests are not reported).

3. Empirical Results

The most common method for estimating the fractional integration parameter *d* is the ARFIMA time series method (Robinson, 2003). We estimate different ARFIMA specifications (with $p+q \leq 2$), as described previously, with conditional Maximum Likelihood (ML) using the OxMetrics language (PcGive software). The selected ARFIMA model, for all samples, is ARFIMA(1,d,0) which shows the smallest AIC value. Estimates for the selected ARFIMA models are provided in Table 2, along with t-statistics.

These estimates indicate evidence of long memory (high degree of predictability) in twelve out of fifteen price series (Italy, Finland, Sweden, Denmark, France, Germany, Spain, Austria, Ireland, Belgium, UK, Luxembourg) with $0 < d < 0.5$. Positive values of the fractional differencing parameter indicate a short of long-memory known as persistence. Persistence is characterised by positive autocorrelations, and exhibit low variance at low frequencies. Note that, when *d* parameter is positive and significant, then the series may have infinite conditional variance.

Only Portugal, the Netherlands and Greece show insignificant *d* parameter. Hence, the results show weak evidence of long memory in three cases only, indicating that shocks to their milk prices may persist over a short period of time. For these three series, the evidence implies unpredictability of future milk prices based on historical prices.

Furthermore, Figure 2 presents the variation of significant *d* parameter for all eleven countries which support the long memory hypothesis. The results show that significant *d* parameter ranges from 0.24 to 0.48 (Belgium and Luxembourg have the highest long memory parameter). Hence, empirical evidence shows that the lag length increases the autocorrelations decay hyperbolically to zero.

4. Conclusions

Long memory systems are characterised by their ability to remember events in the long history of time series data and their ability to make decisions on the basis of such memories. It implies the perfect arbitrage is impossible and invalidates standard derivative pricing models based on martingale assumptions.

The price of an asset (or commodity) determined in an efficient market should follow a martingale process in which each price change is unaffected by its predecessor and has no memory. So, if the price series exhibit long memory (or long-term dependence), they display significant autocorrelation between distant observations. Therefore, the series realisations are not dependent over time, thus violating the market efficiency hypothesis.

The milk sector is of great importance to the EU. According to the European Commission (2006), milk sector is important for the economy and the employment. In particular, milk is the number one single product sector in terms of value of agricultural output.

Very little research has focused on the estimation of long memory using data from agricultural (milk) prices. Since there are factors that influence milk prices (and their predictability), this paper examines if there is evidence of long memory in EU farmgate milk prices. An important issue in the empirical analysis is whether milk prices can be specified in terms of I(d) statistical methods, with the possibility that *d* is a fractional number (parameter *d* describes long memory). This study examines milk prices for evidence of long memory employing an ARFIMA(p,d.q) method using monthly data for the EU-15 over the period January 2001 – May 2008.

The results from the selected ARFIMA(1,d,0) models suggest that twelve price series display evidence of long memory (where $0 < d < 0.5$ and significant). This indicates that shocks to these prices persist over a long period of time[7]. In addition, positive values of the long memory parameter indicate a short of long-memory known as persistence (which is characterised by positive autocorrelations and exhibit low variance at low frequencies). Even though supply is controlled[8], demand and trade show little fluctuations and price shocks are mainly policy-driven, we conclude that there is a high degree of predictability in twelve series of EU-15. The long memory hypothesis is stronger for Belgium, Luxembourg and Germany (economies with high consumption of milk products) where *d* parameter is close, but no equal, to 0.5. Our results are in line with Kohzadi and Boyd (1995), Barkoulas et al. (1997) and Jin and Frechette (2004b) for a variety of commodity prices.

Further research should (i) investigate the predictability of milk prices using ARFIMA-GARCH time-series methods, and (ii) run a sensitivity analysis to ascertain the robustness and temporal stability of the long memory.

Endnotes

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1. On 26 June 2003, EU farm ministers adopted a fundamental reform of the Common Agricultural Policy (CAP); for more information, see European Commission (2003).

2. ARFIMA has been introduced by Granger and Joyeux (1980) and Hoskin (1981), as a generalization of the ARIMA model, to capture parsimoniously long-run multipliers that decay very slowly. It is associated with impulse response weights and spectral density function exploding at zero frequency.

3. DG-Agri figures are average prices paid, collected from individual countries (see www.ec.europa.eu/agriculture).

4. Milk is not a heavily traded commodity outside the EU borders because of preservation limits. Only about 4% of EU fresh milk production is exported outside the EU, as trade mainly concerns

dairy and processed products, not fresh milk. This makes policy the main determinant of farmgate prices.

5. Milk prices for farmers in the EU are determined by several factors, such as: supply and demand on the internal market, world dairy product prices, quality requirements, competition and support from the CAP (see European Commission, 2006).

6. Structural breaks exist and they are mainly policy-driven, especially until 2007. An explicit account of policy changes (which occur simultaneously in EU countries) and their influence on prices provides a useful tool for predicting milk prices – this is not discussed here.

7. Since shocks are mainly due to policy and major policy changes are not frequent, it is not surprising that prices shows long memory.

8. Milk is a single market in which supply is regulated by a quota system currently subject to a slow phasing out, so market forces only act through demand and trade.

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Table 1. Descriptive Statistics for Milk Prices (EU-15)

PART A	BELGIUM	DENMARK	FINLAND	FRANCE	GERMANY
Mean	20.77702	22.18088	25.12189	21.67487	21.24623
Median	19.79457	21.59804	24.95211	21.27210	20.55551
Maximum	31.50830	30.89556	35.35954	31.46078	30.28743
Minimum	16.45395	19.24482	19.68840	17.83935	18.41435
Std. Dev.	3.603498	2.629499	2.988544	2.806726	2.830022
Skewness	1.678088	2.000463	0.821424	1.547729	1.796586
Kurtosis	5.121504	6.684530	3.909564	5.809928	5.584709
Jarque-Bera	58.46076	109.7042	13.07653	64.81260	72.65223
Probability	0.000000	0.000000	0.001447	0.000000	0.000000
Observations	89	89	89	89	89
PART B	**GREECE**	**IRELAND**	**ITALY**	**LUXEMBOURG**	**NETHERLANDS**
Mean	24.90450	20.52512	24.60612	23.08505	21.74253
Median	24.46449	19.22032	24.54893	22.22495	20.94263
Maximum	35.86277	33.11289	31.65650	34.11790	32.31195
Minimum	20.62863	16.10664	22.17103	19.23439	17.77982
Std. Dev.	3.519503	3.951771	1.831863	3.456770	3.434226
Skewness	1.730100	1.928839	1.760461	1.667574	1.261690
Kurtosis	5.907390	5.887904	7.174341	5.356621	4.109775
Jarque-Bera	75.74605	86.11370	110.5900	61.84340	28.17979
Probability	0.000000	0.000000	0.000000	0.000000	0.000001
Observations	89	89	89	89	89
PART C	**PORTUGAL**	**SPAIN**	**SWEDEN**	**AUSTRIA**	**UK**
Mean	22.20400	21.72253	22.04411	19.05681	21.99953
Median	21.49285	20.81819	21.17075	18.44865	21.27362
Maximum	34.38896	34.46974	29.45928	27.04462	33.47192
Minimum	18.34886	18.01278	19.48842	14.85184	19.09056
Std. Dev.	3.433739	3.819647	2.450935	2.463847	3.336545
Skewness	1.932721	2.273656	1.446437	1.657022	2.341841
Kurtosis	6.815833	7.194208	4.580804	5.615113	7.705886
Jarque-Bera	109.4041	141.9158	40.30092	66.08882	163.4717
Probability	0.000000	0.000000	0.000000	0.000000	0.000000
Observations	89	89	89	89	89

Notes:

This Table shows the summary statistics for milk prices in levels (£pence per litre). Skewness is a measure of asymmetry of the distribution of the series around its mean. Kurtosis measures the peakedness or flatness of the distribution of the series. Normality (under Jarque-Bera test) is a test statistic for testing whether the series is normally distributed.

Table 2. Empirical Results: ARFIMA(1,d,0) Models

COUNTRY	Constant	AR	d	AIC	LL
ITALY	3.256 (29.6)*	0.95 (20.9)*	0.246 (2.44)*	-5.0091	226.905
FINLAND	3.256 (20.4)*	0.768 (8.23)*	0.387 (3.54)*	-3.1477	144.076
SWEDEN	3.117 (22.5)*	0.853 (12.2)*	0.372 (3.47)*	-4.0979	186.356
PORTUGAL	3.143 (24.2)*	0.922 (15.4)*	0.198 (1.73)	-3.3595	153.502
DENMARK	3.131 (20.6)*	0.849 (12.0)*	0.382 (3.62)*	-4.0039	182.175
FRANCE	3.105 (12.4)*	0.776 (10.9)*	0.440 (6.09)*	-3.3196	151.725
NETHERLANDS	3.091 (35.2)*	0.769 (7.20)*	0.224 (1.53)	-2.3485	108.512
GERMANY	3.111 (5.96)*	0.869 (18.3)*	0.478 (16.3)*	-4.2105	191.371
SPAIN	3.197 (5.75)*	0.934 (22.8)*	0.452 (7.53)*	-4.4324	201.242
AUSTRIA	3.133 (8.94)*	0.858 (15.5)*	0.455 (8.05)*	-3.9487	179.718
IRELAND	3.051 (7.10)*	0.8503 (15.7)*	0.461 (9.16)*	-3.6157	164.902
BELGIUM	3.088 (4.00)*	0.863 (17.9)*	0.483 (21.4)*	-3.6536	166.586
UK	2.976 (13.8)*	0.792 (10.7)*	0.430 (5.23)*	-3.5509	162.019
GREECE	3.261 (21.5)*	0.963 (25.7)*	0.185 (1.82)	-4.2456	192.932
LUXEMBOURG	3.186 (4.53)*	0.853 (17.0)*	0.483 (21.4)*	-3.6977	168.551

Notes:
This Table shows the results of selected ARFIMA (1,d,0) models. AR indicates the autoregressive parameter, LL indicates the log-likelihoods, *d* indicates the long memory parameter, and AIC is the Akaike information criterion. T-statistics are in parentheses. * indicates significance at the 5% level.

Figure 1. Plot of Milk Prices (in levels): January 2001 – May 2008

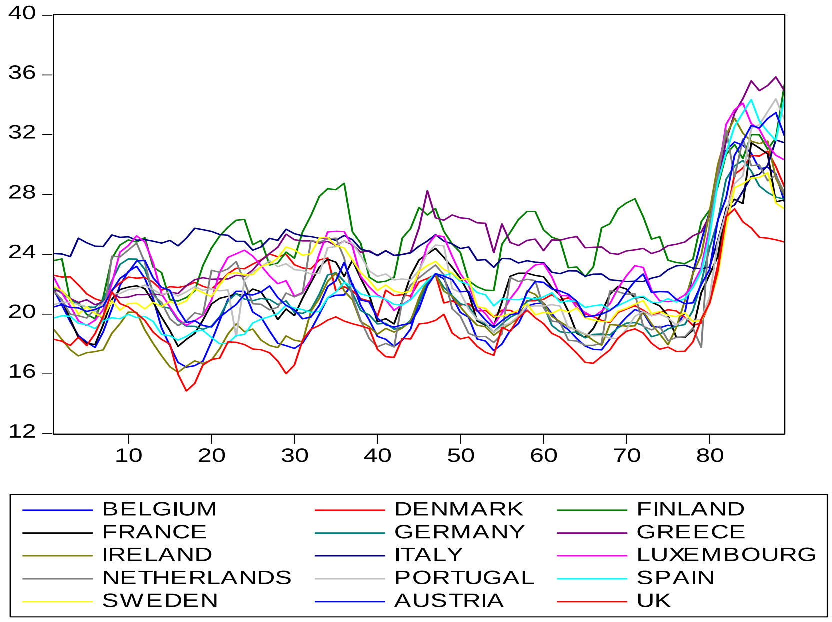

Figure 2. The Variation of Significant Long Memory Parameter (*d*)