Measuring Volatility in Dairy Commodity Prices

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Measuring Volatility in Dairy Commodity Prices[1]

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Abstract. *The policy environment facing the EU dairy industry continues to undergo considerable change under WTO and CAP reform. Movement away from supply management by the EU and a more liberal global agricultural trading system will involve greater price volatility for dairy commodities. It is anticipated that EU dairy prices will more closely align with world prices. World prices are both lower and more volatile than EU prices and it is further assumed that this increased volatility will be transmitted to EU prices. Price volatility is a concern for a number of reasons as it adds challenges for business planning, debt repayment, and, in some cases, solvency. Representative EU and world butter and SMP (Skim Milk Powder) prices are considered and using the ARMA and GARCH framework their volatility is quantified.*

Keywords: Price Volatility, ARMA, GARCH, Butter, SMP, Dairy Policy

1. Introduction

In the past the EU have employed a suite of policy instruments with the aim of isolated internal EU dairy prices from the greater volatility associated with world prices. Intervention purchasing placed a floor on prices while other measures such as production quotas, export refunds, import tariffs and subsidized consumption measures were used to ensure higher and much less volatile prices than those pertaining in world markets. This desire to maintain stable prices should translate to EU dairy commodity prices displaying constant variances which in turn should allow these prices to be modeled within the general ARIMA (AutoRegressive Integrated Moving Average) framework.

In contrast one may posit that world dairy commodity prices should not display a constant level of variance. These markets are largely unregulated and subject to shocks such as climatic events, economic events and policy events. In addition economic theory suggests that price stabilization policies in one region which trades with others will make prices in the less regulated region more volatile (Johnson 1975 and Matthews 1994). Furthermore the price inelastic nature of global dairy commodity supply and demand suggests that the prices associated with these commodities may be subject to sudden and relatively large price adjustments. This characteristic of these markets is amplified by the fact that global markets are considered thin, with only 7% of output traded and four major countries accounting for more than 80% of supply. Hence relatively small changes to supply or demand often lead to relatively large price fluctuations. Prices which display time varying level of variance are better modeled as GARCH (Generalised AutoRegressive Conditional Heteroskedasticity) processes in a univariate context.

The issue of price volatility in EU dairy markets has assumed critical importance in recent times in the context of further market liberalisation. One of the major arguments advanced against this trade liberalisation is that it would lead to transmission of international price volatility into domestic markets. The merit of this argument can only be judged by a detailed empirical analysis of price volatility in EU and international dairy markets. This study is a step in that direction. The volatility of EU and world butter and SMP (Skim Milk Powder) prices are modeled following the methodology presented by Moledina et al. (2003). The results show that up to the mid part of the current decade the EU prices could be considered stable as they are characterized by a constant variance. However the extreme volatility experienced in more recent years suggest that price/income risk management poses a new challenge for the EU dairy industry. World prices display periods of high volatility as well as periods of relatively low volatility. Should this pattern be transmitted to EU prices then planning and financing may be more difficult for all market participants. If the EU Commission proceed to disengage from market management as indicated then this challenge may become more acute.

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This paper commences with a brief review of past and current EU dairy policy along with the role of the EU in global dairy trade. Next the role of economic theory in explaining price volatility in regulated and unregulated markets is presented. This is followed by an outline of the models and methodology employed to quantify the volatility in both EU and world prices. The price series considered along with some preliminary analysis and detailed results are presented next. Finally these results are presented and discussed and some conclusions drawn before avenues for further research are considered.

2. The Regulatory Framework of the EU Dairy Industry

The EU dairy sector is subject to the Common agricultural Policy (CAP). The Treaty of Rome which was signed in 1958 by the six founding members of the European Economic Community (EEC) established a common market which included agriculture. Amongst the stated objectives for agriculture in Article 39 of this treaty was "to stabilise markets". The Commission's proposals for milk and milk products were incorporated into Regulation (EEC) No 804/68 which set out the common organisation of the market in milk and milk products. In this and subsequent regulations the EU has sought to regulate its dairy market by intervening primarily in its butter and SMP markets2. The choice of these commodities may be explained by the fact that these joint products provide a means of long term storage for milk fat and milk protein, the two most valuable components of raw milk. The special status accorded to these two commodities by the Commission suggests that any analysis of the EU dairy industry should consider these commodities in the first instance.

In order to establish a common market with common prices, the CAP relied on a system of market interventions. Foremost amongst these market interventions are intervention buying3, market protection (import levies) and market development (export subsidies). Moe specifically to achieve its aims the Commission has used intervention purchasing, aid for private storage (APS) for butter and cheese, import levies, tariff rate quotas, export refunds, together with a number of other subsidies designed to promote internal consumption such as subsidised butter sales to non-profit making organisations, the bakery sector, ice-cream manufacturers and manufacturers of concentrated butter. I addition SMP used in animal feed has also attracted subsidies, as well as skim milk used in the production of casein (casein aid).

A milk supply quota was introduced in the EU in 1984 as a response to the growing imbalance between production and internal EU consumption and an increasing demand on EU finances of operating the schemes just outlined. One effect of introducing this quota has been that dairying has been the subject of little policy reform until the Luxembourg agreement which was agreed in June 2003. This reform has seen the introduction of the single farm payment for dairy farming in April 2005. This premium is compensation for the reduction in the intervention prices (25% for butter and 15% for skimmed milk powder). In addition this payment was decoupled from the milk quota and added to the Single Payment from April 20054. This payment has an obvious income stabilising effect for dairy farmers. However the lower intervention prices along with a lowering of the quantities automatically accepted into intervention stores has the opposite effect for the commodity prices.

Reform of the milk quota regime continued in the "Health check" (November 2008) where it was agreed that quotas will expire by April 2015. In order to ensure a 'soft landing' quotas will be increased by one percent every year between 2009/10 and 2013/145. In the press release which accompanied this reform it is stated that policy reform should be one which "converts market intervention into a genuine safety net6". To this end for butter and SMP all sales to intervention will be by tender and optional above a limit of 30,000 tonnes for butter and 109,000 tonnes for SMP. Furthermore sales to intervention will only be allowed between March and August each year. Such a position implies that intervention would be used as

2 It should also be noted that casein, wholemilk powder, liquid milk and certain varieties of cheese have to a lesser degree also been regulated by the CAP.
3 Intervention buying of produce by government agencies is generally referred to as intervention. The use of this term can confuse as it refers to only one form of government intervention. Henceforth intervention will refer specifically to intervention buying, while government intervention in the market will be referred to as policy intervention.
4 This premium is worth approximately 3.6 cent a litre for quota owned at 31th March 2004.
5 For Italy, the 5 percent increase will be introduced immediately in 2009/10.
6 http://europa.eu/rapid/pressReleasesAction.do?reference=IP/08/1749&format=HTML&aged=0&language=EN&guiLanguage=en

a measure of last resort in times of crisis rather than creating a floor price. The private storage aid for cheese is now abolished along with the disposal aid for butter for pastry and ice cream and for direct consumption. While some market support is proposed to continue, such as the private storage aid for butter, the skimmed milk powder for animal feeding allowance and the aid for casein production is now optional and at the discretion of the Commission to decide if and when it should be applied. This aid may be fixed in advance or by means of tendering procedures.

In addition to reform of the CAP the EU dairy industry has also experienced reform due to the inclusion in 1986 of agriculture and food in the eighth round of negotiations of the General Agreement on Tariffs and Trade (GATT). This round, known as the Uruguay round, concluded in December 1993 and became effective from July 1995 to the end of June 2001[7].
The measures relevant to the EU dairy industry may be summarised as:

1. Increased market access. All import restrictions were to be converted to tariffs and reduced on average by 36% over a six year period. Each tariff was to be reduced by a minimum of 15%.
2. Reduced export subsidies. A reduction of 21% in volume with a corresponding reduction in expenditure of 36% over a six year period.
3. Reduced domestic support. Domestic subsidies to be reduced by 20% over six years.

While these measures may appear far reaching and highly significant from the EU viewpoint, their actual effect was mitigated by the base reference period chosen. During this period, 1986-90, subsidised exports from the EU were at a relatively high level so the reduction in subsidised exports required to meet the GATT commitments were small for SMP and butter and were above the 1991-92 levels. However this agreement ensured that the EU dairy industry could no longer operate independent of the global dairy industry and vice versa. Indeed the move to less regulated markets as signaled by this agreement has been reinforced in more recent negotiations for the current Doha round.

For example in a speech delivered to the Agricultural Committee of the European Parliament in November 2007 the Agricultural Commissioner clearly stated EU policy re export refunds “I have already signalled clearly that export refunds are now entering their twilight years. Within the Doha Round of world trade talks, the European Union has offered to phase them out by 2013. But whatever happens to the Doha Round, export refunds don't have a place in the CAP toolbox of the future” (Fischer-Boel, 2007). While export refunds have been reintroduced in January 2009 in response to the sharp deterioration of global dairy markets, this response is seen as a temporary measure. Likewise it is anticipated that any WTO agreement will signal substantial cuts on any import levies which currently apply to dairy products. The reduction in supply control and a more liberal trading environment will mean a much closer alignment between EU and world prices and the introduction into the EU of the greater volatility inherent in the world prices.

In summary the EU framework was designed to maintain producer prices at a level higher than those which apply in an unregulated market by providing a number of market support measures. The aims of these measures have been to maintain farm incomes and reduce internal EU price volatility especially when prices are falling. However the process of moving the EU dairy industry along the path to market liberalisation is clearly underway. It is clearly envisaged that this process will see EU prices more closely align with world prices and thus EU prices are expected to be more volatile as they are less protected from local and global shocks.

3. The effect of the CAP on World Markets and the role of the EU in global dairy trade.

As discussed later the EU accounts for volumes in excess of 25% of world trade in butter and SMP in most of the years covered by this study. Thus it is reasonable to assume that the operation of the CAP will have consequences on the world market. Johnson (1975) illustrated by means of a simple hypothetical example that it is possible to achieve internal price stability, but this occurs at the cost of increasing international price instability. This is illustrated by means of the following simple example. Assume that

[7] During this round the principle of standstill and rollback was agreed. Members agreed that no new restrictions contrary to the GATT would be introduced and existing trade practices contrary to GATT would be phased out.

half of the world's consumption of a commodity occurs within economies that stabilise internal prices though the control of trade. There is an autonomous shock that reduces world output of the commodity by 4% and the only stocks available are working stocks. Further assume that the short-run price elasticity of demand for the world for the commodity is –0.1. If the national price stabilisation schemes work then the economies of half the world will have to increase their price by 80% (approximately). If no economy stabilised its prices the increase for the world would be approximately 40%[8]. Matthews (1994) clearly demonstrates the price enhancing and stabilizing effects of many of the policy tools employed by EU. He concludes that in essence the EU policy of maintaining internal producer prices at a level above the free market equilibrium level has served to reduce the world market price. In addition as the import demand in the rest of the world fluctuates, the level of the volatility in the world prices has been increased by EU policy.

Global trade in dairy produce was estimated at 43 million tonnes of milk equivalent in 2007 if intra EU trade is ignored. This represents just over 7% of global cows milk production. This trade is dominated by 4 exporters (New Zealand, EU, Australia and USA) who account for over 82% of exports. While its market share continues to decline, the EU still accounts for approximately 30% of this trade (13 million tonnes) (IDF 2008). The buyer side of the market is far less concentrated and the quantities purchased are often subject to very large fluctuations from year to year. This may in part be explained by the fact that many of these developing countries are buyers and imports are linked to export earnings and exchange rates, both of which are subject to large fluctuations. For example Russian purchases of butter doubled to 109,000 tonnes from 2000 to 2001 while Brazilian purchases of whole milk powder more than halved to 43,000 tonnes in the same period (IDF 2007). With only 7% of milk traded globally, as little as a 1% change in global production or consumption can have very large effects on world prices. The thin nature of these markets helps explain the high levels of volatility recorded on world dairy markets. The significance of the EU in terms of global butter and SMP exports is presented in Table 1.

Table 1: EU % Share of Global Exports

	1994 EU-I2	1998 EU-15	2000 EU-15	2002 EU-15	2004 EU-25	2006 EU-25
Butter	20	21	20	19	38	26
SMP[1]	16	18	31	15	25	19

Source: Agra Europe "Dairy Review" various issues. 1) Including SMP contained in animal feeds and in buttermilk powder.

The net result of policy adopted by the EU, along with economic theory would a priori suggest that the volatility of the EU prices, which are insulated, would be lower than that of world prices. Furthermore given its desire to maintain price stability the EU policy, if successful, should translate to price series which display a constant level of variance. In the case of world price there should be no expectation of constant levels of variance as these markets are more fully liberalised and subject to the full effects of shocks and global events such as stock market crashes, oil crises along with industry specific developments, (for example in the dairy industry BSE, Foot and Mouth and policy development), and this allows one to hypothesise that world prices should display time varying levels of volatility. The methodology outlined in the following section allows for time series to be tested for constant or time varying volatility as well as quantifying the levels of this volatility.

4. Methodology

A number of approaches have been utilized by economists to model the time-varying pattern of agricultural commodity prices. Of these the moving average (MA) model, autoregressive (AR) model, or the more general, autoregressive integrated moving average (ARIMA) model, was usually fitted to identify the structure of a time series (Box & Jenkins, 1976). In more recent times more complete but complex price models have been developed with models such as the autoregressive conditional heteroskedasticity (ARCH) model (Engle,1982), and generalized ARCH (GARCH) model (Bollerslev,

[8] The level of volatility would be moderated if stocks are available to cover the shortfall in production.

1986) receiving the most attention. ARCH models allow the shocks in more recent periods to affect the current volatility positively while the GARCH models, which generalizes the ARCH model, postulates that not only previous shocks, but also previous volatilities affect current volatility. These models are now described in more detail.

4.1 ARMA models

The general form of the ARMA(p,q) model may be presented as:

$$Y_t = X_t^{'}\beta + \sum_{i=1}^{p}\phi_i Y_{t-i} + \varepsilon_t + \sum_{j=1}^{q}\theta_j \varepsilon_{t-j} \qquad (1)$$

where Y_t is the dependent variable; Y_{t-i} for i = 1,2,. . .,p are lagged dependent variables; X_t denotes the explanatory variable vector (column vector); ε_t is the error term and assumed to be white noise; ε_{t-j} , j = 1,2,. . .,q are lagged error terms; t denotes the time period; β (a column vector), ϕ_i and θ_j are parameters. It is important to note that in this model the error terms are assumed to be a Gaussian process with a mean of zero and a constant variance σ^2 .

4.2 Conditional heteroskedasticity models (ARCH and GARCH)

To describe data series with time-varying volatility, ARCH or GARCH models are utilised. These models allow the variance of error terms to change over time. An ARCH(q) model is commonly defined as:

$$Y_t = X_t^{'}\beta + \varepsilon_t \qquad (2)$$

where

$$\varepsilon_t \mid \Omega_{t-1} \sim N(0, h_t)$$

$$h_t = \omega + \sum_{i=1}^{q}\alpha_i \varepsilon_{t-i}^2 \qquad (3)$$

where ε_t is the error component in the ARCH model; h_t is the time-varying variance of the error; Ω_{t-1} is the information set available at t-1; ω, α_i for i = 1,2,. . .,q and β are parameters. ε_t's are not serially correlated, however, their dependency lies on the evolution of the variance.

A GARCH(p,q) model may be presented in the same manner except that lagged terms of the variance are now included and may be represented as follows,

$$h_t = \omega + \sum_{i=1}^{q}\alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p}\gamma_j h_{t-j} \qquad (4)$$

with γ_j for j = 1,2,. . .,p as additional parameters.

The basic ARCH (q) model is considered a short memory process in that only the most recent q residuals have an impact on the current variance. The GARCH (p,q) model however allows a longer memory processes, in which all the past residuals can affect the current variance either directly or indirectly through the lagged variance terms. In this model the sum of αi + γi gives the degree of persistence of volatility in the series[9].

[9] Furthermore the αi and γ_i must be non negative.

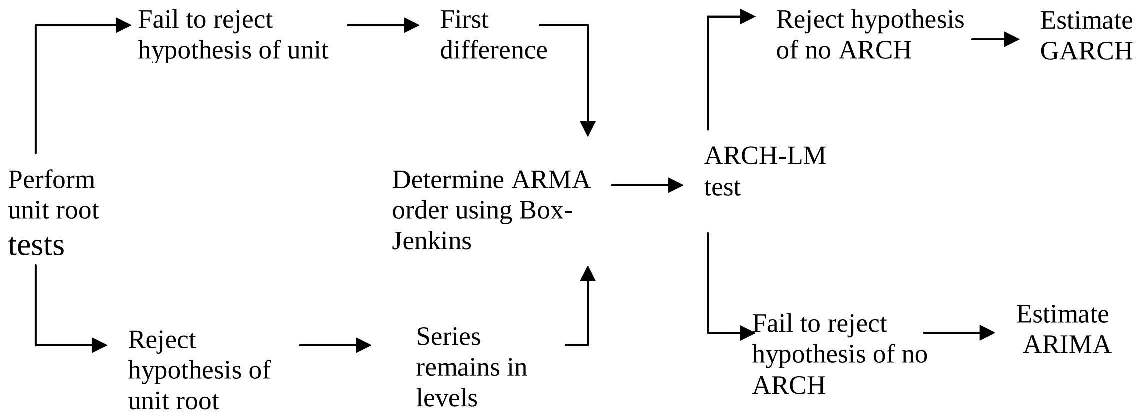

Figure 1 – Flowchart of methodology to compute conditional volatility
Source – Moledina *et al*. (2003)

The closer the sum to 1, the greater is the tendency of volatility to persist for longer periods. If the sum exceeds 1, it is indicative of an explosive series with a tendency to meander away from mean value. The basic framework used to quantify the volatility in the EU and world butter and SMP prices is summarized in Figure 1.

5. Data

In this study the USDA North European FOB (Free On Board) wholesale skim milk powder and butter prices are taken as representative world prices[10], while the EU prices are ex-dairy/factory Dutch price series sourced from Agra Europe[11]. Prior to January 2001 all EU price series were quoted in their home currency and have been converted to a common currency, the ECU/Euro (€), using exchange rates supplied by the Central Bank of Ireland. These exchange rates are daily closing mid-market indications expressed as units of currency per ECU/Euro (€). Simple averages were calculated to derive the monthly exchange rate series. In the case of the World prices initial quotes were in US dollars and converted to ECU/Euro (€) using corresponding exchange rates. Prices for the four series from January 1990 to February 2009 (230 months) are considered in this study. The nomenclature used to name these wholesale series follows the following convention. For each series the last three letters designates the product (SMP = Skim Milk Powder while BUT = butter) while the first letter(s) designate the location of the series (W = World and EU = EU).

6. Results

In studies of price volatility it is common practice to consider the log return of the time series rather than the price series in levels. The log return (growth rate) for each series in this study is calculated

[10] The USDA publishes a monthly high and low quotation and the series considered in this analysis is the mid point of these quotations.
[11] The butter series are reported in "Milk Product" while the SMP series are reported in "Preserved Milk"

as $Ln\left(\frac{P_t}{P_{t-1}}\right)$. These series are presented in graphical form in Appendix 1[12]. An examination of the graphs clearly shows the greater volatility associated with world prices and points to the success of the EU in attaining its goal of stabilising prices. A second point to be noted in these graphs is that increased volatility is displayed by all series in the most recent years. This increased volatility is placed in context by the following comment from Henry van der Heyden, chairman of Fonterra, the world largest dairy engaged in international trade, (Nov 2008)[13] *"It is clear that 2007/08 has fundamentally changed market dynamics and volatility is more likely to be the norm, rather than the exception, in the medium term,"*

While the greater volatility of the world series is evident in these graphs, the extent of this increased volatility is better captured by the much larger coefficient of variation[14] reported for the world series in Table 2[15]. Further consideration of the remaining summary statistics in Table 2 shows that all series display excess kurtosis and non normal distributions while both of the butter series are skewed. These results show that all series display the classical signs of volatility.

Table 2: Summary statistics of series 1990:02 to 2009:02.

	WSMP	WBUT	EUBUT	EUSMP
Sample Mean	0.000607	0.001463	-0.001756	-0.000958
Standard Error	0.056066	0.058993	0.029820	0.036618
t-Statistic (Mean=0)	0.163857 (0.870)	0.375259 (0.708)	-0.890932 (0.374)	-0.395934 (0.693)
Coefficient of Variation	92.35	40.32	16.98	38.27
Skewness	-0.210 (0.193)	1.372 (0.000)	-0.810 (0.000)	-0.287 (0.076)
Kurtosis (excess)	1.641 (0.000)	8.874 (0.000)	16.768 (0.000)	5.782 (0.000)
Normality Test Chi^2 (2)	21.30 (0.000)	91.37 (0.000)	424.18 (0.000)	130.04 (0.000)

As a prerequisite to modelling the dynamics of the time series it is necessary to determine whether the series behave as stationary or non-stationary processes. In accordance with standard econometric practice each of the series was tested for stationarity using the Augmented Dickey Fuller (ADF) test. This test indicates that there is strong evidence (95% confidence levels) to reject the null hypothesis of a unit root for all series (Table 3).
While this table only reports the results of the models with the best lag structure as selected by the Bayesian (BIC) information criterion each series was initially considered with zero to 12 lags inclusive. In all model the null hypothesis of a unit root was clearly rejected.

Table 3: Summary statistics of series

Series	**ADF Statistic**	**Critical Value 5%**
WSMP (2)	-6.098	-1.94
WBUT (0)	-9.621	-1.94
EUBUT (0)	-6.802	-1.94
EUSMP (3)	-6.418	-1.94

Note the BIC Criterion was used to choose the lag structure which is reported in parentheses.

As all of the series may be considered stationary it is now appropriate to use the Box- Jenkins methodology to determine the values of p and q in the ARMA (p,q) process. Initially the values of p and q

[12] Note the scale is identical in all panels of this chart thus highlighting the greater volatility in the world prices.
[13] http://www.fonterra.com/wps/wcm/connect/fonterracom/fonterra.com/our+business/news/media+releases/fonterra+signals+ongoing+volatility+in+dairy+markets
[14] A common statistic for measuring the variability of a data series is the coefficient of variation (CV), which expresses the dispersion of observed data values as a percent of the mean.
[15] These and all subsequent estimations were undertaken using PcGive software.

were chosen by the BIC. The residuals from this specification were then tested for autocorrelation using the Portmanteau test up to lag 32. Where autocorrelation was detected the models were re-specified using the autocorrelation and partial autocorrelation functions for guidance. The specifications of the best fitting models are presented in Table 4. In all cases all the estimated coefficients are significant at the 5% level. The residuals of all the models were found to be free of autocorrelations (Test C) and thus may be considered to fit the data well. However all models clearly display non normal residuals (Test A) and ARCH (Test B). Likewise the ARCH test up to 4 lags reported in the final column clearly highlights the need to model the mean and variance of the series simultaneously and requires that any interpretation of these models is limited as they are severely limited by these findings. This unambiguous evidence of autocorrelation is further confirmed when the squared residuals were tested[16]. At this point of the analysis it is reasonable to assume that the variances of all the series vary overtime and both the mean and variance of the series should be modelled simultaneously as GARCH processes.

Table 4: Summary of ARMA models 1990:02 to 2009:02

Series	***p***	***q***	Tests Of Residuals A*	B	C	**ARCH 1-4 Test**
WSMP	|1,3,6 |	|3|	10.773 [0.005]**	27.873 [0.000]**	27.604 [0.689]	9.5294 [0.0000]
WBUT	| 1, 5 |	0	100.16 [0.000]**	7.9960 [0.005]**	39.006 [0.255]	2.0724 [0.0854]
EUBUT	|1,6|	1	339.91 [0.000]**	11.480 [0.001]**	29.495 [0.642]	5.2400 [0.0005]
EUSMP	0	2	307.72 [0.000]**	150.63 [0.000]**	34.101 [0.463]	37.610 [0.0000]

*A refers to Normality test: B refers to ARCH 1-1 test: C refers to Portmanteau (36) test.
Note: No constant terms were used in the mean equations as they were insignificant in all cases.

The results of modelling the series as GARCH processes are presented in Table 5. In this table the mean specification is presented in column two while the GARCH structure is presented in column three. It should be noted that the mean specification may differ from the specification in Table 4. This is not a cause for concern as firstly the models reported in Table 4 are poorly specified as evidenced by the ARCH tests and secondly both the mean and variance are now estimated together. In this case the adequacy of the models is tested based on the standardised residuals. In order to select between competing specifications the log likelihood was considered.

Table 5: Summary of GARCH models 1990:02 to 2009:02

Series	***Mean Specification***	***GARCH Order***	***Diagnostic tests Of Scaled residuals*** A*	B	C	***ARCH 1-4 test Of Squared Standardised Residuals***
WSMP	AR = |1,3| MA = 0	0,1	17.667 [0.000]**	0.063275 [0.939]	36.624 [0.304]	1.6524 [0.162]
WBUT	AR = |1,3,5| MA = 0	0,1	45.351 [0.000]**	0.99668 [0.371]	42.970 [0.115]	1.1524 [0.333]
EUBUT	AR = |1,2| MA = 0	(1,1)	27.279 [0.000]**	0.55181 [0.577]	55.944 [0.010]*	1.1931 [0.315]
EUSMP	AR = |1,2,5| MA =0	(1,1)	11.728 [0.003]**	2.0367 [0.133]	59.672 [0.003]**	1.2353 [0.297]

*A refers to Normality test: B refers to ARCH 1-1 test: C refers to Portmanteau (36) test.
Note no constant terms were used in the mean equations as they were insignificant in all cases.

[16] These results are available from the authors on request.

The results show that both of the world series are well specified indicating that ARCH models are appropriate. While both models display non normal standardised errors these model are free of autocorrelation and ARCH. The EU series are less well specified as they show evidence of autocorrelation along with non normality in their GARCH (1,1) specifications. The standard deviation of the models in Table 5 is presented in graphical form in Appendix 2 along with a summary of the models. In all models all of the coefficients are significant at the 5% level suggesting well specified and parsimonious models. In the EU model the sum of the alpha 1 and beta 1 coefficients is close to one indicating a high level of persistence in volatility. Indeed, as the sum of these coefficients is very close to one (0.998) in the EU butter model, this may be interpreted as an indication that the model is not appropriate as a value of one suggests an explosive series.

Turning to the graphs, these clearly show the greater volatility of the world prices both in terms of its level and frequency[17]. Furthermore these graphs highlight the extreme nature of the volatility experienced in 2007/08. In the case of the EU series there is relatively low levels of volatility prior to this period. This fits with the a priori expectation that the series should display a constant variance. In light of this it was considered appropriate to re-estimate the EU series as ARMA processes for the period up to April 2004. This date coincides with the implementation of reforms contained in the Luxembourg agreement and in particular the lowering of intervention prices and the quantities automatically accepted into intervention stores. These results are now presented in Table 6.

Table 6: Summary of ARMA models 1990:02 to 2004:04

Series	***p***	***q***	Tests Of Residuals A*	 B	 C	ARCH 1-4
EUBUT	|1,4|	|1|	37.259 [0.0000]**	5.9443 [0.0158]*	45.350 [0.0745]	2.1605 [0.0758]
EUSMP	0	2	33.292 [0.0000]**	2.6897 [0.1028]	38.017 [0.2914]	0.87111 [0.4825]

*A refers to Normality test: B refers to ARCH 1-1 test: C refers to Portmanteau (36) test.
Note no constant terms were used in the mean equations as they were insignificant in all cases.

From this table we can see that the EU SMP series is particularly well modelled as an ARMA process as it displays normal errors which are free from autocorrelation and ARCH. The absence of ARCH in the error terms implies that the variance of the series may be considered constant up to mid 2004 and provides clear evidence that the Commission achieved it aim of stable prices. The standard deviation of the SMP series for this period was 0.018. In the case of the butter series the evidence is less clear as there is some evidence of ARCH at the lower order along with non normality. The standard deviation of this series was 0.012.

In summary the results as a whole broadly support a priori expectations. The world prices are better estimated as GARCH processes indicating that the volatility of these series changes overtime. In contrast up until early 2004 the European series display a constant level of variance.

7. Conclusions and discussion.

In summary it is possible to conclude that up to recent years the EU policy framework has served to maintain producer prices at a higher and more stable level than that which would apply in an unregulated market by providing a number of market support measures. World prices, which are less regulated, are thus more volatile as they are not protected to the same degree from local and global shocks.

The results show that the volatility experienced in 2007/08 is extreme from the perspective of both EU and world wholesale butter and SMP prices. This extreme episode may in part explain the fact that the simple GARCH models considered in this study may not fully capture the dynamics of the series considered. It is also reasonable to assume that alternative specifications of these models such as TGARCH (Threshold GARCH) AGARCH (Asymmetric GARCH) or any of the many alternatives

[17] Note the scale of the graph in this appendix is different in each instance.

outlined in Tsay (2005) or Enders (2004) may be more appropriate. The non normality recorded in many of the models may point to an omitted variable problem. For example it is felt that the EU policy decisions such as intervention purchasing had the effect of placing a floor under prices and the build up of stocks therein delayed price recovery in world markets. Likewise the use of export restitutions may have delayed price recovery and response in global markets. Thus models which explicitly capture these dynamics may be more desirable.

It should be noted that some volatility in commodity prices is desirable as it reflects the process of markets adjusting to changes in supply and demand conditions. However as more recent events show the level of volatility in dairy markets can be greater than anticipated and price volatility which cannot be offset by suitable price risk management strategies can create problems for all market participants. Investment may be postponed and consumers may substitute with cheaper alternatives. Furthermore the expected abolition of the milk quotas and the envisaged increase in production at farm level will require greater specialization and this will require that farmers and manufacturers place greater emphasis on risk management in the EU if they are to survive and compete in this new environment.

With regard to future developments it is reasonable to assume that the policy environment facing the EU dairy industry in the EU will continue to undergo considerable change due to WTO and CAP reform. Movement towards lower levels of CAP support prices, reduced intervention and a more liberal global agricultural trading system will involve greater price volatility for dairy commodities as prices align more closely with World prices. When considering the future form of world and EU commodity prices the following observation from Harvey may be considered,
"Although a freer world market is expected to be less volatile than one characterised by high insulation rates, it is unlikely to be as stable as the protected domestic market it replaces" (Harvey 1997).
Such a view suggests that future prices will be characterised by periods of volatility comparable to those displayed by world prices in the earlier period of this study. However if the following view as expressed by Adriaan Krijger (Chairman, International Dairy Federation (IDF) Standing Committee) proves more accurate
"Shorter and deeper cycles may well be the future. The real issue now is the increase in volatility and the challenge of how to cope with it"
then the response of EU dairy industry participants and policy makers may require a paradigm shift. In order to deal with these increased levels of volatility private market instruments such as futures markets and insurance products may be desirable, while price smoothing policy instruments may be required if a large exodus from the industry is to be avoided.

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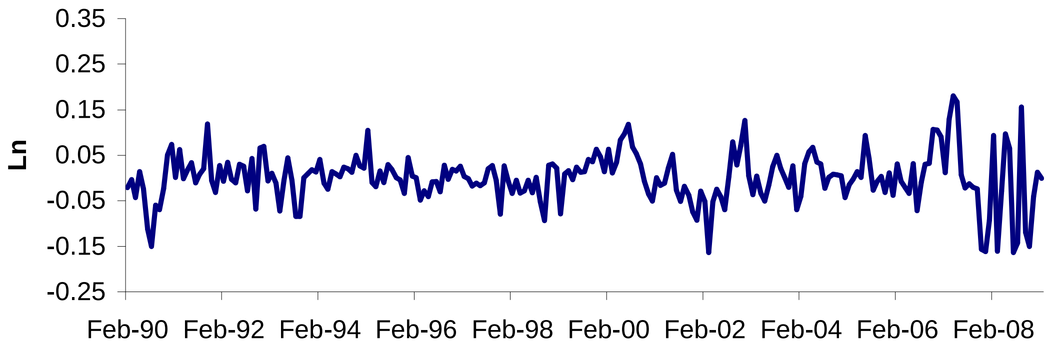
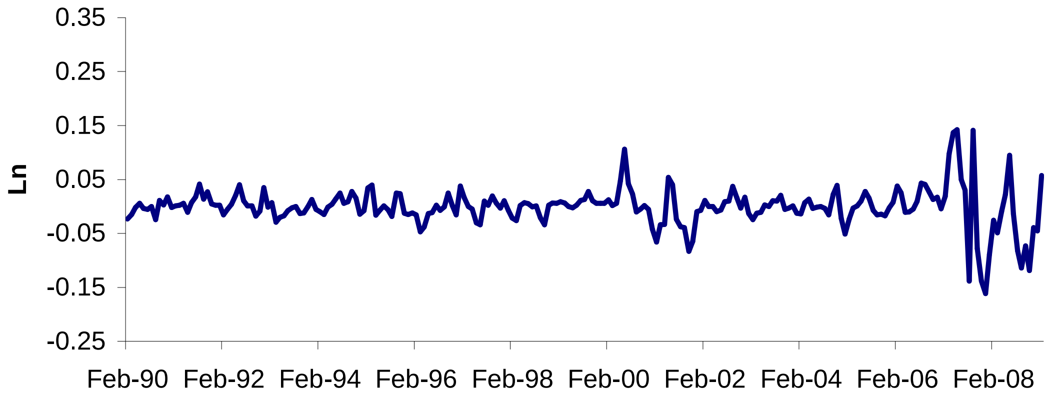
Appendix 1 Price series growth rates

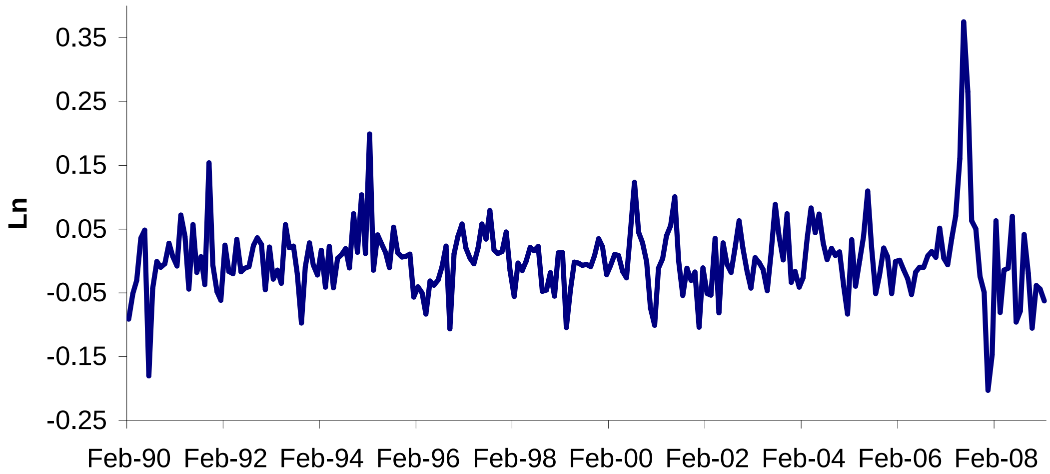
(a) World SMP Price Growth Rate 1990-2009



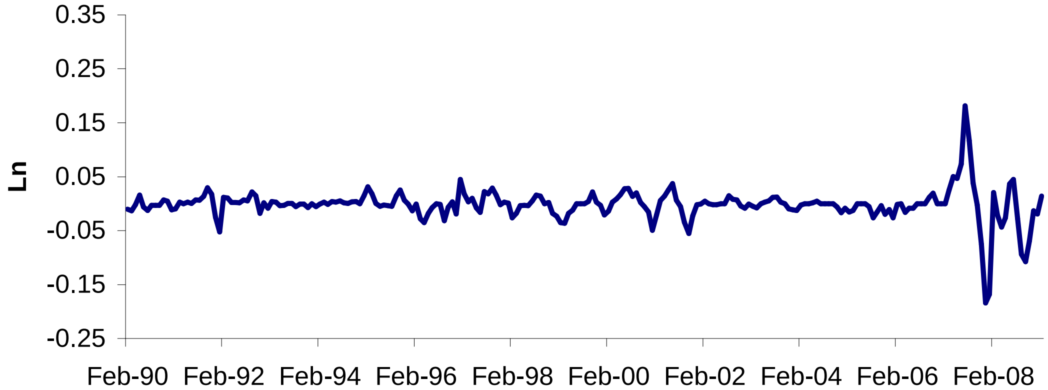
(b) EU SMP Price Growth Rate 1990-2009



(c) World Butter Price Growth Rate 1990-2009



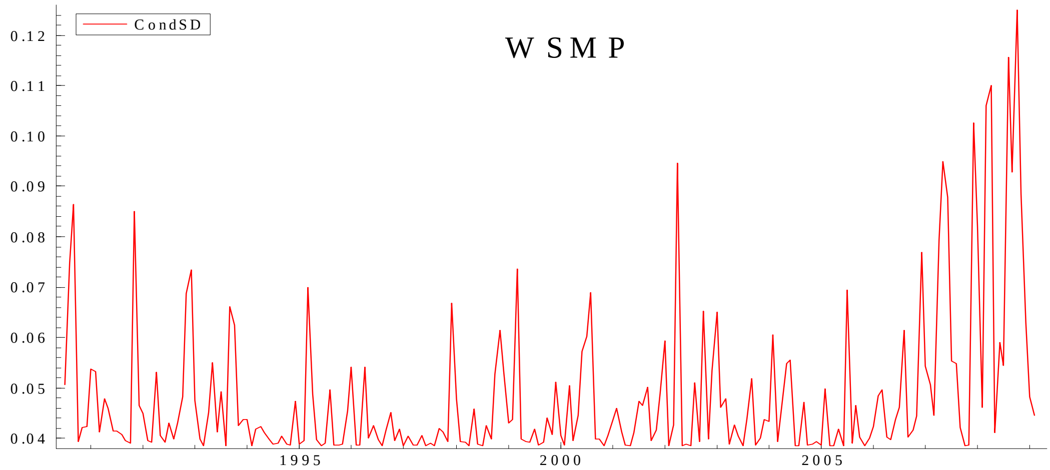
(d) EU Butter Price Growth Rate 1990-2009



Appendix 2 GARCH Specifications and Volatility Charts

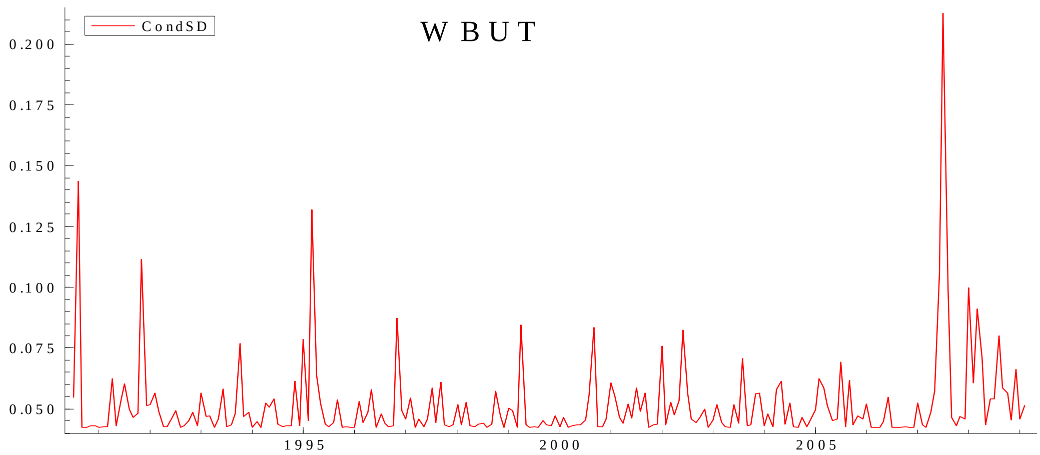
Modelling **WSMP** by restricted GARCH(0,1)
The estimation sample is: 1990 (7) to 2009 (2)

		Coefficient	Std.Error	robust-SE	t-value	t-prob
WSMP_1	Y	0.306072	0.06608	0.1077	2.84	0.005
WSMP_3	Y	0.208133	0.05396	0.07222	2.88	0.004
WSMP_5	Y	-0.109334	0.05414	0.04732	-2.31	0.022
alpha_0	H	0.00147904	0.0001985	0.0002729	5.42	0.000
alpha_1	H	0.422738	0.1245	0.1249	3.39	0.001



Modelling **WBUT** by restricted GARCH(0,1)
The estimation sample is: 1990 (7) to 2009 (2)

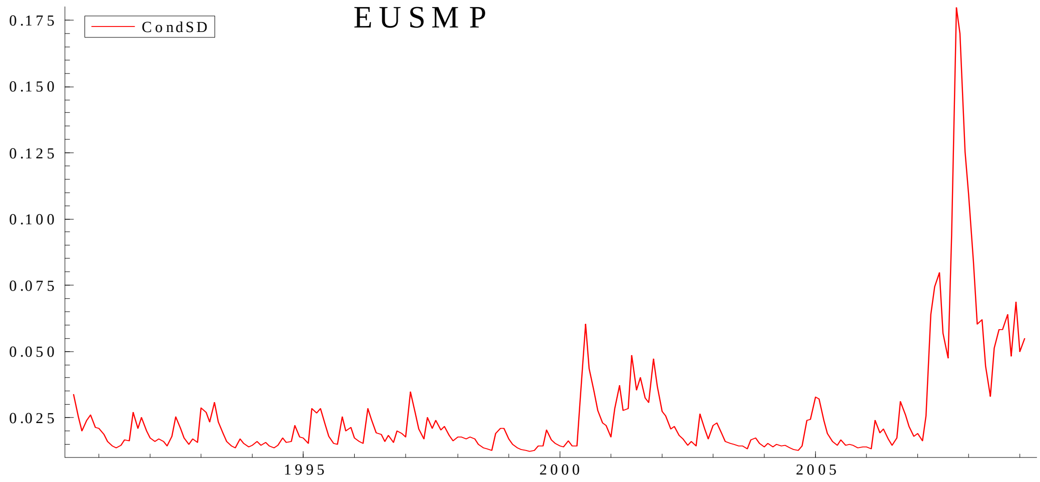
		Coefficient	Std.Error	robust-SE	t-value	t-prob
WBUT_1	Y	0.322282	0.07283	0.09257	3.48	0.001
WBUT_3	Y	0.0860846	0.05478	0.04244	2.03	0.044
WBUT_5	Y	-0.197504	0.05109	0.09525	-2.07	0.039
alpha_0	H	0.00179056	0.0002351	0.0003257	5.50	0.000
alpha_1	H	0.422387	0.1381	0.2064	2.05	0.042



Modelling **EUSMP** by restricted GARCH(1,1)

The estimation sample is: 1990 (7) to 2009 (2)

		Coefficient	Std.Error	robust-SE	t-value	t-prob
EUSMP_1	Y	0.573138	0.07903	0.08233	6.96	0.000
EUSMP_2	Y	-0.223628	0.07303	0.08499	-2.63	0.009
EUSMP_5	Y	-0.151037	0.05120	0.06055	-2.49	0.013
alpha_0	H	7.29770e-005	2.624e-005	3.502e-005	2.08	0.038
alpha_1	H	0.454464	0.1228	0.1782	2.55	0.011
beta_1	H	0.495433	0.09554	0.1323	3.75	0.000



Modelling **EUBUT** by restricted GARCH(1,1)
The estimation sample is: 1990 (7) to 2009 (2)

		Coefficient	Std.Error r	robust-SE	t-value	t-prob
EUBUT_1	Y	0.767340	0.07746	0.06576	11.7	0.000
EUBUT_2	Y	-0.230737	0.07680	0.06758	-3.41	0.001
alpha_0	H	1.84080e-005	6.902e-006	7.288e-006	2.53	0.012
alpha_1	H	0.409981	0.1035	0.1853	2.21	0.028
beta_1	H	0.589816	0.07456	0.1100	5.36	0.000