A decomposition analysis of the EU farm gate milk price

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Abstract

The increased price variability of the EU farm gate milk price in recent times makes it necessary for farmers as well as policy makers to analyze which factors attribute to this variability. In this study the EU, German and Irish farm gate milk price is therefore decomposed into its trend, seasonal and cyclical components using state space models. The decomposition results are used to analyze which components attribute to the huge price variability observed in recent times and how the Common Agricultural Policy (CAP) changed the price dynamics. They show that the dynamics of the EU, German and Irish series converged after the CAP 2003 reform. The dynamics are also compared to the US market. Another main result is that most of the observed price volatility in recent times is attributed to the cyclical component. Price volatility is therefore to some degree predictable and intrinsic to the dairy industry.

Keywords Milk price, forecasting, Kalman filter, State Space models, Cycle estimation

JEL code **C10, Q11**

1 Introduction

Changes in the common agricultural policy (CAP) of the EU dairy industry play an important part in examining milk price dynamics. Especially the CAP Luxembourg agreement in 2003 marked a major change in the EU dairy sector policy. Prior to this the focus was on maintaining high and stable prices through a suite of market intervention tools. This agreement saw the focus shift to greater market orientation which in turn led to greater volatility. This is not well documented by the existing literature but the study of Kelly et al. (2012) confirms that this holds for the Irish milk price. In addition O'Connor and Keane et al. (2012) show that there is evidence of increased volatility in SMP and butter prices for the EU in recent times. However even if the studies mentioned above quantify volatility they do not seperate it into its different components. In this study the average EU, German and Irish milk price series are therefore divided into their trend, seasonal and cyclical components. Estimates of these components can give hints as to which factors contribute to the increased price variation or volatility respectively and are thus important for policy makers as well as farmers to base their decisions.

Beside its effect on volatility the cyclical component plays an important role in agricultural commodities. As theoretical economic models like the Cobweb suggest cycles in commodity prices can arise because of delays between supply and demand and are thus an inherent feature of these series. Different methods for extracting this components exist. Classical methods depend on detrending. Examples include differencing, spectral analyis, exponential smoothing and ARIMA or the Baxter and King (1999) and Hodrick and Prescott (1980) filter. Most of these methods were widely applied to macroecomomic time series with infrequent applications to agricultural commodities. An exception from that is the famous pig cycle which has been widely analysed. For example Dawson (2009) uses spectral analysis and Meadows (1971) uses system dynamics to

study the behaviour of the pig cycle. Criticisms of some of these classical approaches can be found in Harvey (1989), Harvey and Jaeger (1993) and Murray (2002). As further argued in Labys and Kouassi (1996) only the structural time series models proposed by Harvey (1989) can capture the underlying stochastics of a time series. This approach is therefore used in this study.

Another method of estimating cycles is peak to peak (or trough to trough) analysis. In a recent study by Hunt and Kern (2012) this was used to analyse the US dairy price cycle. While the method used is very basic and drawing of peaks is to some degree arbitrary. The study concludes that the old price cycle died and that cycles will not occur in regular patterns in the future. Structural time series models allow for this fact as the framework allows cycles to change over time and they also try to identify the data generation process.

Structural time series models have been used for analyzing commodity price series. Labys and Kouassi (1996) use structural time series models for modeling price cycles for agricultural, metal and petroleum commodities. In Labys et al. (1998) the approach is used for modeling cycles of metal commodities and Alagidede (2009) uses it for metal and agricultural price indices. However an application of structural time series models for the decomposition of commodity prices in the dairy industry or the milk price is limited to the study of the US market Stephenson (2011) and Nicholson and Stephenson (2011). An application to the EU market is to the authors knowledge new.

2 Some aspects of the EU dairy industry

The EU dairy industry is higly regulated and subject to the CAP. In recent times the CAP moved away from price support (intervention buying, import tariffs and export refunds) to income support via the Single Payment Scheme (SPS). This reorientation began in the 1990s with decreases in the intervention buying prices of Butter and SMP (Skimmed milk powder) and really gathered pace

with the Luxembourg agreement in 2003. Though the cuts were not implemented in full until 2007. Also a supply quota was introduced in 1984 and, as confirmed under the "2008 Health Check" agreement, will expire the quota in 2015. The objective of these recent policy changes was to realign EU dairy prices with world prices with the SPS as compensation for farmers.

Also while most of the EU regulations focused on intervention in the SMP and butter markets the analysis in this paper is done on the CIRCA[1] raw milk price paid to milk producers in the EU, Germany and Ireland. This price is collected by the EU Commission from its member states at the end of each month. The EU price represents a weighted average price of the member state prices. Further information on how the data is collected can be found in Commission Regulation (EU) No 479/2010. In figure 1 these raw milk prices are shown for the period from January 1990 to October 2012[2]. The EU and German price are very similar although the German price is slightly more volatile. The Irish price is below the other prices until 2003 and then converges to a level similar to the other series. It is the most volatile price of the series. This is also confirmed by the highest Coefficient of Variation in table 1. It can also be seen that the Coefficient of Variation almost doubled for the period post 2003 confirming the believe of increased volatility in recent times.

Table 1: Summary statistics

1990-2012	**EU Average**	**Germany**	**Irish**
Mean	30.6055	30.5968	28.5320
Standard Deviation	2.4539	2.9567	3.8624
Coefficient of Variation	8.0178	9.6636	13.5369
1990-2003	**EU Average**	**Germany**	**Irish**
Mean	30.6963	30.9471	27.1196
Standard Deviation	1.6043	1.8017	2.1782
Coefficient of Variation	5.2263	5.8218	8.0318
2003-2012	**EU Average**	**Germany**	**Irish**
Mean	30.4855	30.1337	30.3993
Standard Deviation	3.2581	3.9647	4.7272
Coefficient of Variation	10.6873	13.1569	15.5503

[1] Source: http://circa.europa.eu/

[2] The most recent period at the time of the analysis

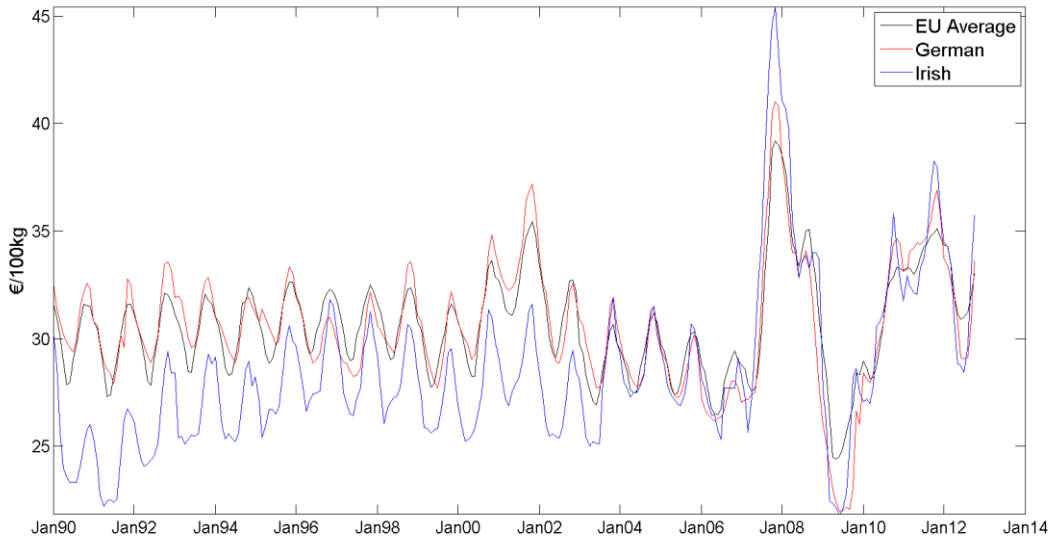

Figure 1: EU, German and Irish original series 1990-2012

3 Methodology

The structural time series approach by Harvey (1989) is used for the decomposition of the price series into its trend, seasonal and cyclical components. The time series is divided into two periods, pre and post 2003, to test how the CAP reform in 2003 has changed the milk price dynamics although not all CAP measures were fully implemented until 2007.

For the decomposition an additive structural model is used whereby the notation follows Durbin and Koopmann (2012):

$$y_t = \mu_t + \gamma_t + c_t + \varepsilon_t \qquad t = 1, \ldots, n \tag{1}$$

Where μ_t is the trend, γ_t the seasonal, c_t the cycle component and ε_t is white noise. In general the trend, seasonal and cyclical component can not be observed directly therefore the Kalman filter is

used to estimate this components. The model formulations for the components are given in the next sections.

3.1 The trend

The trend is the slowly varying component of a time series. As in Durbin and Koopmann (2012) the trend is modeled as random walk with linear drift, whereas the drift itself may be time varying and random. The model is called a local linear trend model and is formulated as:

$$\begin{aligned} \mu_{t+1} &= \mu_t + \nu_t + \xi_t \qquad & \xi_t &\sim N(0;\sigma_\xi) \\ \nu_{t+1} &= \nu_t + \zeta_t \qquad & \zeta_t &\sim N(0;\sigma_\zeta) \end{aligned} \tag{2}$$

where μ_t is the trend, ν_t is the slope of the trend, ξ_t and ζ_t are normal distributed disturbances.

3.2 The seasonal

The seasonal component is modeled as a seasonal dummy model[3]. The idea behind this is that over a full period (e. g. a year) all seasonal components (e. g. monthly) γ_t add to 0. This idea and the possibility of letting the seasonal pattern change over time gives the formulation:

$$\gamma_{t+1} = \sum_{j=1}^{s-1} \gamma_{t+1-j} + \omega_t \qquad \omega_t \sim N(0;\sigma_\omega) \tag{3}$$

where γ_t is the seasonal component, s is the number of periods per year ($s = 12$ for monthly data) and ω_t is a normal distributed disturbance term to let the seasonal pattern change over time.

[3] The seasonal component could also be modeled as trigonometric. Tests showed that both formulations yield similar results.

3.3 The cycle

Different formulations of a cycle (e. g. Butterworth) exist. The interpretation of a cycle in time series is that of a recurring pattern but not in a periodic way. In this paper the cycle is modeled as in Durbin and Koopmann (2012) in the form:

$$\begin{aligned} c_{t+1} &= \rho(\cos\lambda + \sin\lambda)c_t + \varpi_t \qquad & \varpi_t &\sim N(0;\sigma_\varpi) \\ c^*_{t+1} &= \rho(-\sin\lambda + \cos\lambda)c^*_t + \varpi^*_t \qquad & \varpi^*_t &\sim N(0;\sigma_\varpi) \end{aligned} \tag{4}$$

where ρ is a dampening factor with $0 < \rho < 1$ and the λ frequency. The period of the cycle is $2\pi / \lambda$. Including more than one cycle is straightforward but it has to kept in mind that each cycle adds three more parameters to estimate.

3.4 A note on volatility

Volatility is commonly used as a measure for price variation. As in O'Connor and Keane et al. (2012) volatility may be defined as substantial variation from the long term trend. The exact definition of volatility is usually model dependent e.g. it is measured as the standard deviation from the mean of returns or log returns. Also GARCH models are commonly used to measure volatility. However using the definition of volatlity as variation from the long term trend it is clear that γ_t, c_t and ε_t from the model in equation 1 are part of volatility. The seasonal γ_t and the cyclical c_t components are model inherent components and thus can be seen as variation or volatility which can be explained by the model e. g. volatility from usual business cycles. The noise term ε_t can not be explained by the model and thus can be seen as a measure of unexplained volatility e. g. volatility from shocks. The terms volatility and price variatiton are used interchangeably in this study.

4 Empirical Results

The model described in section 3 is applied to the average farm gate raw milk price for the EU, Germany and Ireland. The model results are presented in the following subsections.

4.1 Decomposition results prior to CAP 2003 reform

Figure 2 shows the price of the EU, German and Irish milk price paid to producers for the period January 1990 to December 2002. It can be seen that all series exhibit a strong seasonal pattern whereas the absolute price level of the Irish series is well below the EU and German series.

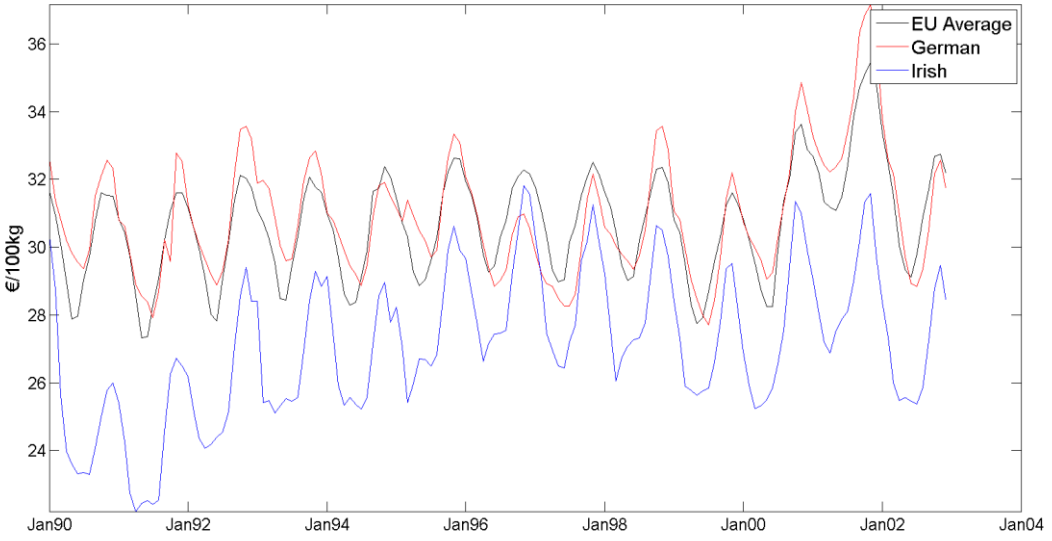

Figure 2: EU, German and Irish original Series 1990-2003

The trend, seasonal and cyclical components as described in section 3 are estimated by maximum likelihood using the Kalman filter[4]. The parameter estimates are shown in table 2. A graphical represenation of the smoothed components for the EU, German and Irish series is given

[4] The implementation is done in Matlab using the SSMATLAB Toolbox by Victor Gómez

in figure 3, 4 and 5, respectively. Goodness of fit statistics of the residuals are shown in table 3. Intervention variables as described in Commandeur and Koopmann (2007) for outliers are added. The table shows that the assumption of normality and independance can not be rejected for all series at least at the 1 % level.

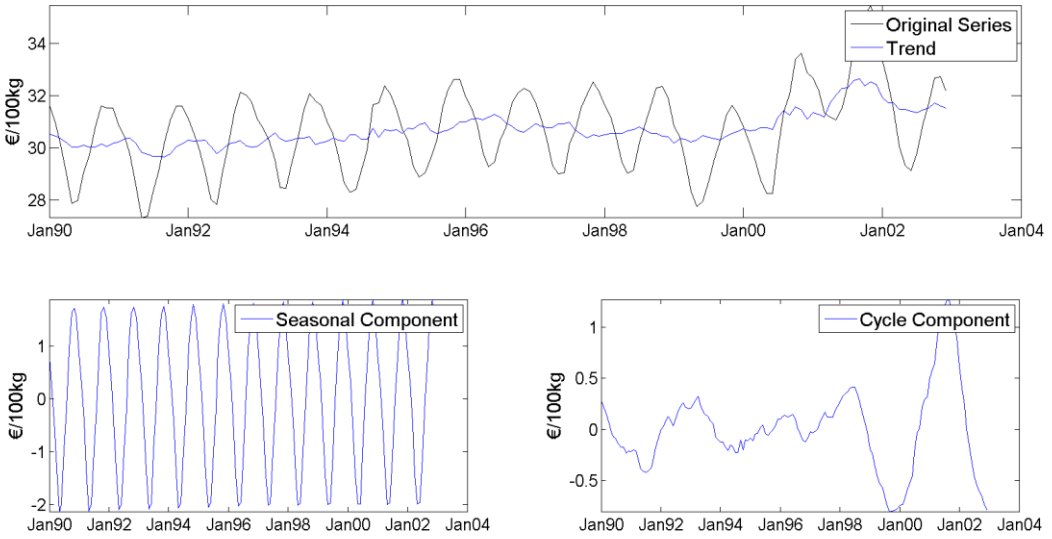

Figure 3: Decomposition estimates of the EU series

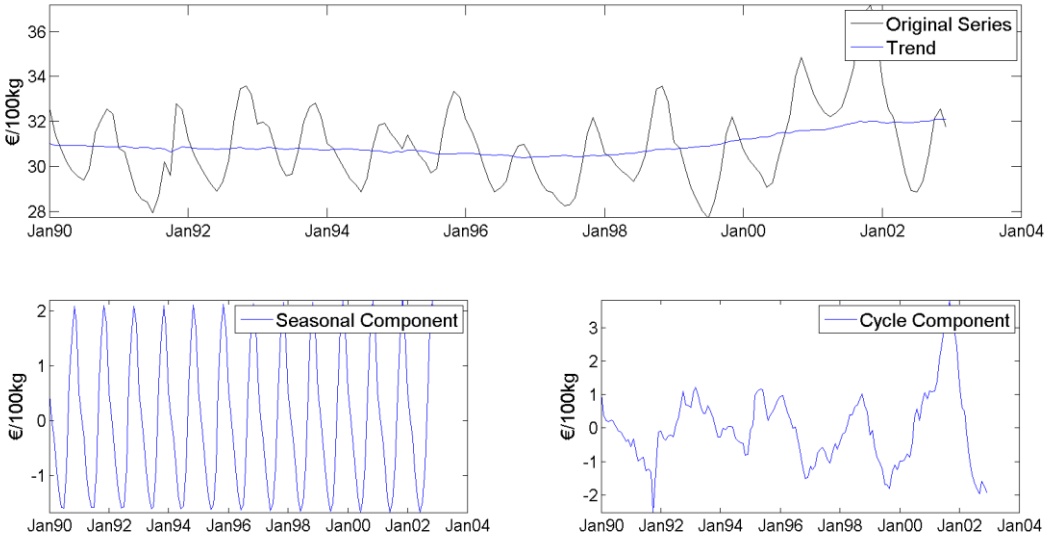

Figure 4: Decomposition estimates of the German series

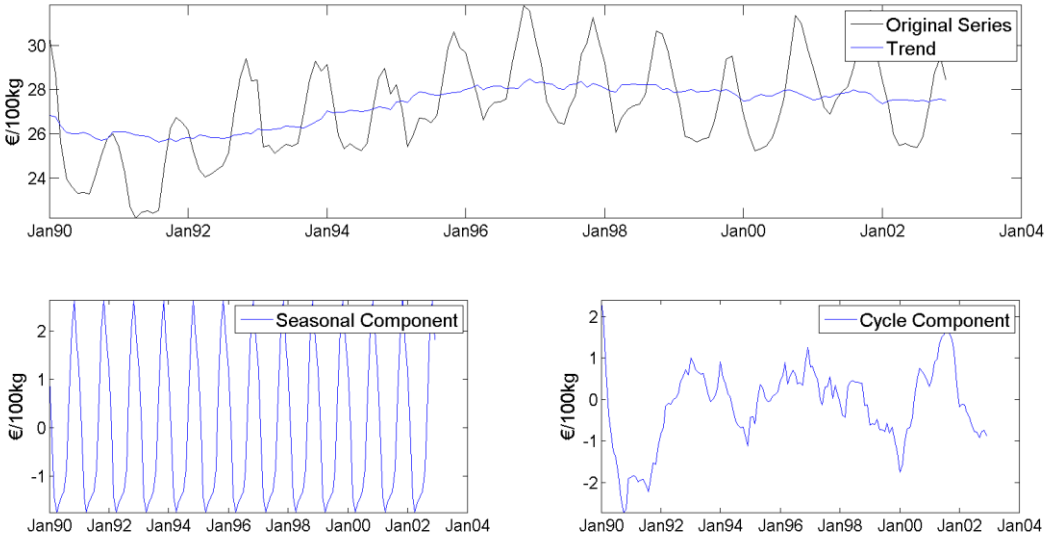

Figure 5: Decomposition estimates of the Irish series

As in Harvey (1989) the trend represents the long term movement of a time series. For the EU and German series the trend evolution over time is similar. It is relatively flat around 31 EUR per

100 kg. For the Irish series trend is below the other two series at a level of 26 EUR to 28 EUR per 100 kg.

The seasonal and cyclical components and the error term play an important role in analyzing the price dynamics. Short run variations around the trend are measured by these components. As can be seen from table 2 the standard deviation σ_{ε}^{2} of the error term is small meaning that the data is nearly fully explained by the trend, seasonal and cyclical components. The cycle length ranges from 39 months for the German, 42 months for the EU to 46 months for the Irish series what can also be seen in table 2. From the graphs it can also be observed that the general pattern and magnitude of price variation of the cycle is different for all series. The maximum magnitude of the cycle is largest for the German series and lowest for the Irish series. The magnitude of price variation from the seasonal component is biggest for the Irish series. This confirms the general belief that the Irish price is more seasonal than the German price. Also while the seasonal component is allowed by the model to change over time the graphs suggest that it is almost constant over this time period for all series.

Due to the different results from the decomposition especially in the cycle component it can be concluded that the EU, German and Irish prices show different dynamics prior to the CAP 2003 reform.

4.2 Decomposition results post the CAP 2003 reform

In figure 6 the EU, German and Irish price series for the period January 2003 to October 2012 are shown. The most striking feature of the series is the huge price jump at the end of 2007 followed by the milk crisis and deep trough in 2009. Also it can be observed that the series still exhibit a seasonal pattern although this pattern is not as clear to see post 2007.

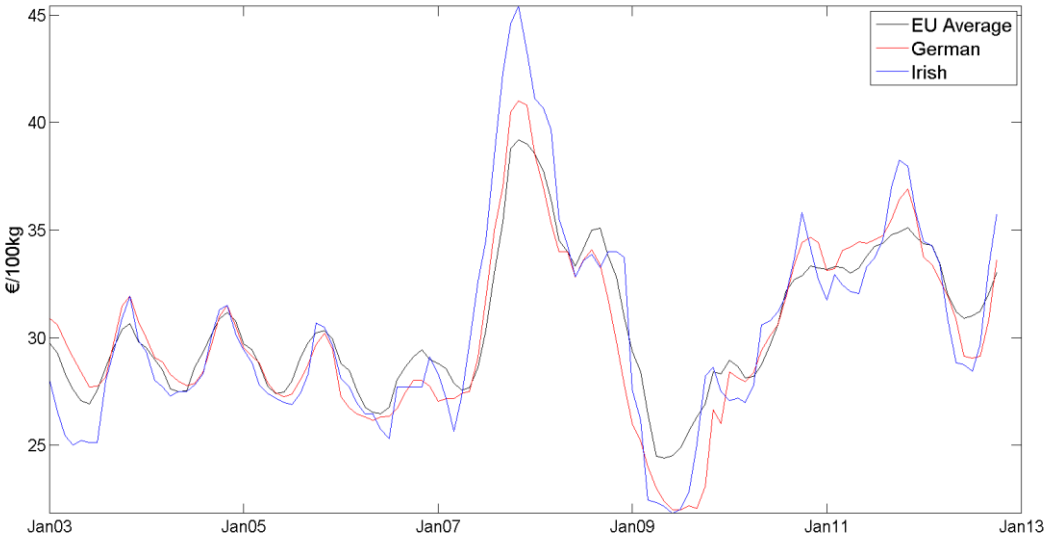

Figure 6: EU, German and Irish original series 2003-2012

As before the series are decomposed into trend, seasonal and cyclical components by maximum likelihood estimation and the Kalman filter as described in section 3. The parameter estimates are shown in table 2. The smoothed estimates of the trend, seasonal and cyclical components for the EU, German and Irish series are given in figure 7, 8 and 9, respectively. Goodness of fit statistics of the residuals for the period 2003 to 2012 are shown in table 3. The table shows that the assumption of normality and independence cannot be rejected for all series at least at the 1 % level.

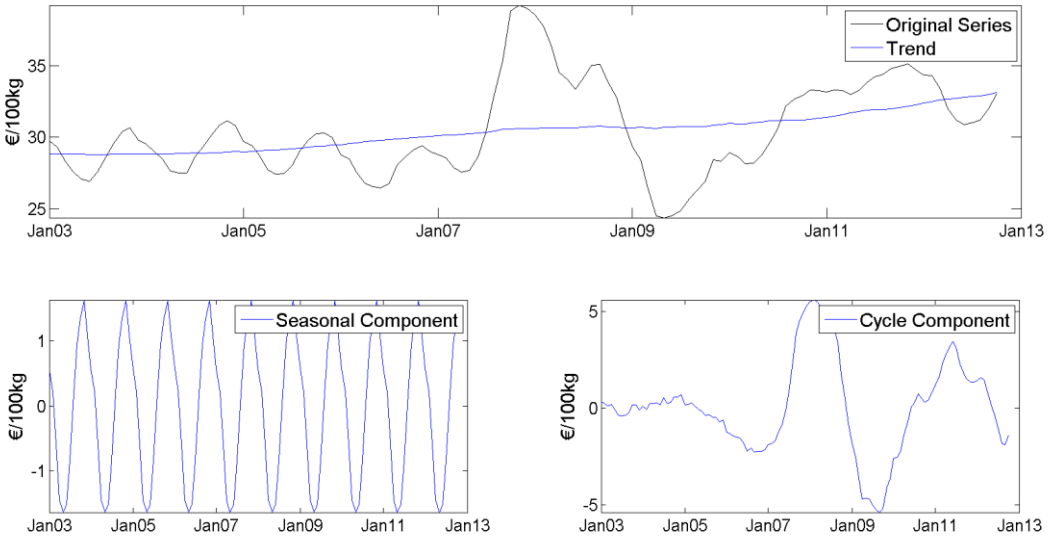

Figure 7: Decomposition estimates of the EU series

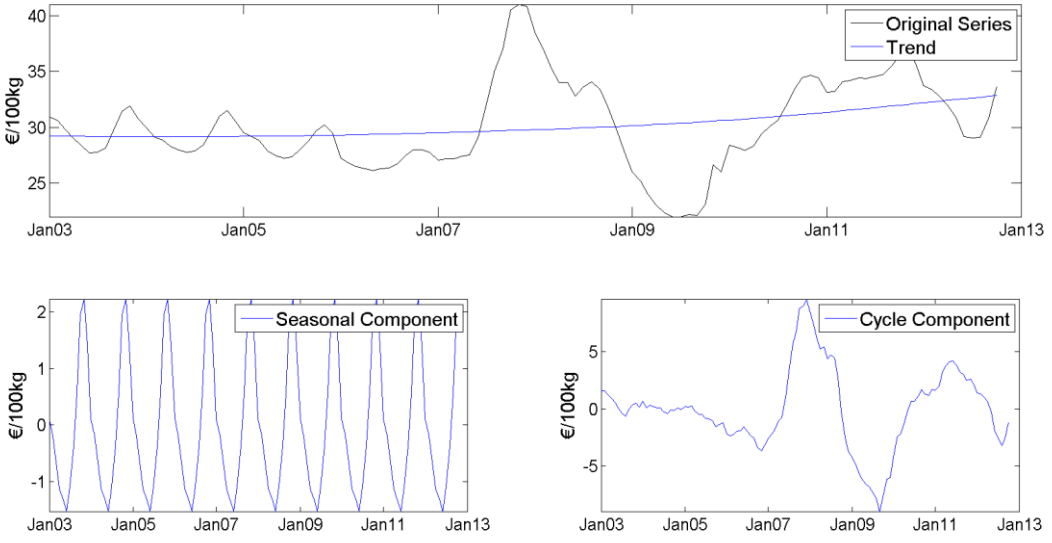

Figure 8: Decomposition estimates of the German series

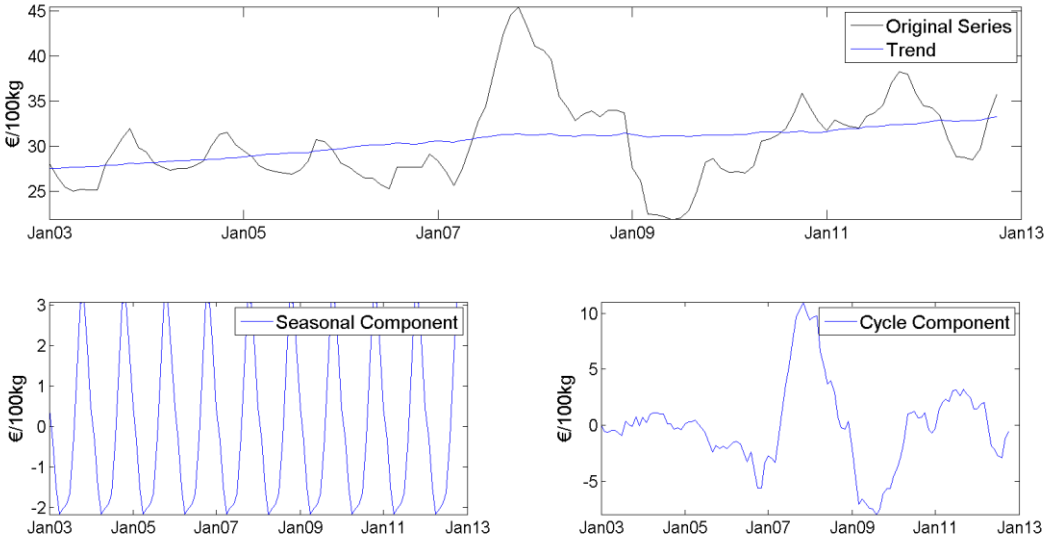

Figure 9: Decomposition estimates of the Irish series

In figure 7 and 8 it can be seen that the trend for the EU and German series are slightly increasing to a level of about 33 EUR at the end of the series. The trend of the Irish series which is shown in figure 9 is slightly increasing, too. The level of the Irish Trend compared to the other two series is lower at the beginning of the sample. Nevertheless at the end of the sample the level is similar to the other series.

Because the trend of all series is relatively stable over time the seasonal and cycle component must account for the huge price jump from the peak at the end of 2007 to the trough in 2009. Table 2 shows that the cycle length is almost identical for all three series with 38 months for the EU and German and 40 months for the Irish series. The graphs show that the pattern of the cycle is similar for all series with a huge peak at the end of 2007 and the trough in 2009, similar to the original series. The impact from the cycle is biggest for the Irish and German price with a total variation of around 19 EUR from the peak to the trough. The cycle in the EU series add a total of 10 EUR to price variation. Given the estimate of the trend, the small standard deviation of the error term and

the cycle it is clear that most of the price variation in recent times is attributed to the cycle. The magnitude of price variation from the seasonal component is biggest for the Irish series. This is similar to the analysis from section 4.1. It is almost constant over time for all three series.

4.3 Comparison of decomposition results pre and post 2003

Next the way in which the price dynamics changed, based on the decomposition results for the periods 1990 to 2003 and 2003 to 2012, is analysed. From the estimates of the trend in section 4.1 and 4.2 it can be seen that the trend for the EU and German series is between 30 EUR and 33 EUR in both periods. The trend evolution of the Irish series differs from that but converges to a level near the EU and German series post 2003. Given this, it can be concluded that the long term movement represented by the trend converged between the EU and its member states Germany and Ireland.

As mentioned in section 4.1 and 4.2 the cycle length ranges from 39 to 46 months for the period pre 2003 and 38 to 40 for the period post 2003. From that it is clear that the length of the cycle slightly shortened and converged between the EU, Germany and Ireland. In addition the cycle accounts for the huge price movements in recent time what can be seen from the figures 7, 8 and 9. The 38 to 40 month cycle seems reasonable as it is argued in Stephenson (2011) that it takes around 3 years for a dairy producer to expand milk output.

The comparison of the decomposition results for both periods showed that the price dynamics for the EU, Germany and Ireland converged for the period post 2003. It seems reasonable to assume that this convergence is due in large part to the CAP 2003 reforms. The results show also that most of the huge price volatility in recent times is attributed to short run fluctuations as measured by the seasonal and cycle components. This means that volatility can nearly be fully explained by the

model components which confirms the argument of Stephenson (2011) that much of milk price volatility is something endemic to the dairy industry.

4.4 Comparison with the US market

In this section the dynamics of the EU milk price series is compared with that of the US market[5]. Figure 10 shows the decomposition results for the US[6]. As can be seen in the graph the US like the EU has a peak at the end of 2007 followed by the trough in 2009. In contrast to the EU series the US has another high at the end of 2011. The trend of the US milk price is rising from 14 USD to 18 USD. Due to the different currencies the comparison between the EU and US is done only on the cyclical component. Table 2 shows the cycle length of the US milk price is 36 months. This is consistent with the length of the largest estimated cycle in Nicholson and Stephenson (2010) and Stephenson (2011) which estimated also a 36 month cycle. In addition this cycle length is consistent with the estimated cycle length of 38 months for the EU and further strengthens the assumption that a cycle of around 3 years is intrinsic to the dairy industry.

[5] The monthly All Milk price is used. Source: http://future.aae.wisc.edu/

[6] Table 3 shows that the hypothesis of normality and independence for the residuals can not be rejected at the 5 % level and 1 % level, respectively

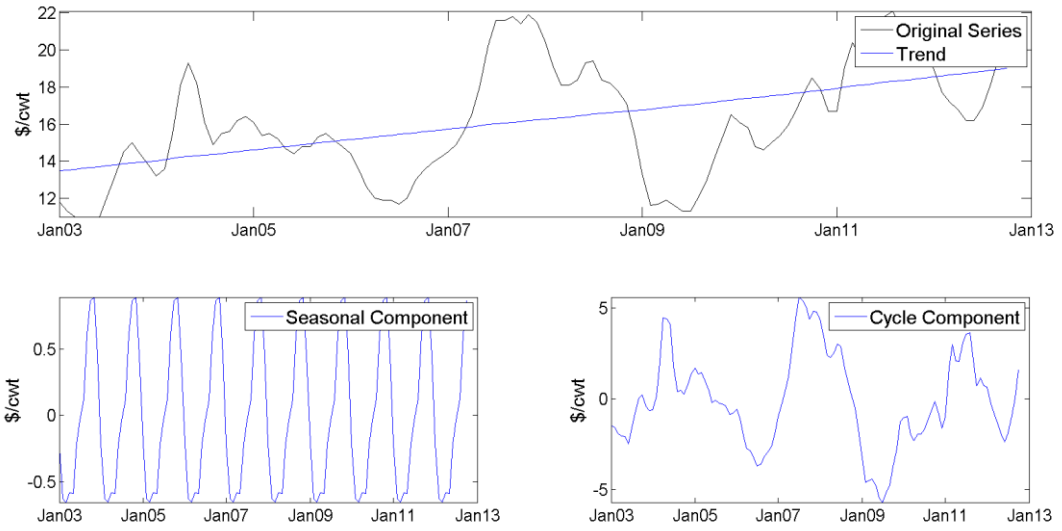

Figure 10: Decomposition estimates of the US series

5 Concluding remarks

In this paper the EU, German and Irish farm gate milk price time series were decomposed into trend, seasonal and cyclical components using the structural time series method by Harvey (1989). The analysis was done for the periods from 1990 to 2003 prior to the CAP reform and 2003 to 2012 post the CAP reform. Also a comparison with the US market was completed. The main results of the decomposition are threefold:

- The comparison of the decomposition for both periods showed that the price dynamics in particular the length of cycle converged for the period post 2003. One explanation for this convergence could be the CAP reforms of 2003.
- The decomposition results for the latter period showed that most of the recent price variation is attributed to the cycle. Price volatility for this period seems to be endemic to the dairy industry and to some degree predictable as pointed out in Stephenson (2011).

- A comparison of the decomposition with the US market shows that the length of the cycle is similar, around 3 years for the EU and US series. This confirmed the results in the study of Stephenson (2011) who assumes that it takes around 3 years to expand milk supply.

In a further analysis the decomposition will be completed for dairy commodities. At the commodity level a comparison between the EU and World prices will be completed. Also the out of sample forecasting quality of the model will be tested in a further study.

Appendix

Parameter estimates

Table 2: Estimated parameter

	1990 - 2003			2003 - 2012			
Parameter	**EU**	**German**	**Irish**	**EU**	**German**	**Irish**	**US**
σ_{ξ}^{2}	0.1935	0.0102	0.0251	0.0033	2.85E-04	0.0066	0.0011
σ_{ζ}^{2}	4.01E-06	6.27E-06	1.51E-05	6.50E-05	1.06E-05	2.76E-05	8.07E-07
σ_{ω}^{2}	0.004	7.65E-04	6.23E-07	6.61E-07	4.72E-06	4.30E-05	1.41E-05
σ_{ϖ}^{2}	0.0507	0.0806	0.0512	0.0332	0.047	0.0622	0.0907
σ_{ε}^{2}	1.78E-08	1.07E-05	7.01E-05	9.65E-06	2.50E-06	2.64E-06	4.42E-05
ρ	0.9743	0.9588	0.9741	0.9833	0.9762	0.9684	0.9536
λ	0.1497	0.1592	0.1378	0.1636	0.1644	0.1577	0.1732
Cycle length	41.976	39.4574	45.6095	38.4145	38.2166	39.853	36.4767

Goodness of fit statistics

Table 3: Goodness of fit statistics of the residuals

	1990 - 2003			2003 - 2012			
p-Values	**EU**	**German**	**Irish**	**EU**	**German**	**Irish**	**US**
Jarque-Bera	0.0433	0.1753	0.0606	0.5	0.1274	0.5	0.0980
Ljung-Box	0.0625	0.8135	0.0779	0.0393	0.0170	0.0989	0.0177

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