British Food Journal

Seasonal and cyclical behaviour of farm gate milk prices

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Introduction

Changes in the common agricultural policy (CAP) play an important part when examining milk price dynamics in the EU dairy industry. In particular the Luxembourg agreement in 2003 marked a major change in EU dairy sector policy. Prior to this the focus was on maintaining high and stable prices through a suite of market intervention tools. The Luxembourg agreement saw the focus for dairy shift to greater market orientation with the introduction of income support via the Single Payment Scheme (SPS) and the reduced use of market intervention tools which in turn led to greater price variability. A similar effect could be observed on the US milk price after the product purchase prices were reduced under the Dairy Price Support Program in the mid 1980s.

The increased price variability at EU farm level is not well documented by the existing literature however the study of Kelly et al. (2012) confirms that the Irish milk price displays greater variability in more recent years. In addition O'Connor and Keane (2011) show that there is evidence of increased volatility in EU wholesale skim milk powder (SMP) and butter prices in recent times[1]. However even if the studies mentioned above quantify variability they do not separate it into its different components. In this study the German, Irish and average EU farm gate milk price series are therefore decomposed into their trend, seasonal and cyclical components. Estimates of these components can give insights as to which factors contribute to the increased price variation and are thus important for policy makers as well as farmers to base their decisions. In addition the decomposition results for the European farm gate milk prices are compared with that of a US farm gate milk price. The comparison with the US milk price can help to identify if there are common factors driving the trend, seasonal and cyclical components or if price is mainly driven by regional factors.

Different methods for analysing cycles or similar components exist. These can simply be divided into statistical models which decompose a time series into its components to infer something about the underlying structure of the series or methods which try to explicitly capture the underlying system structure. Examples for the former type of methods include peak to peak analysis, exponential smoothing, ARIMA models, spectral analysis, Baxter and King (1999) filter or Hodrick and Prescott (1997) filter. For example Dawson (2009) uses spectral analysis to study the pig cycle whereas in a recent study by Hunt and Kern (2012) peak to peak (or trough to trough) analysis was used to analyse the US dairy price cycle. An example for the second type of methods is system dynamics which is used by Meadows (1971) to model and capture the behaviour of the pig cycle.

Criticisms of many of the time series approaches mentioned above can be found in Harvey (1989), Harvey and Jaeger (1993) and Murray (2002). Labys and Kouassi (1996) further argue that 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.

Structural time series models have been used for analyzing commodity price series. Labys and Kouassi (1996) use these models when modeling price cycles for agricultural, metal and petroleum commodities. In Labys et al. (1998) the approach is used for modeling cycles in prices of metal commodities. In Fadiga and Misra (2007) the structural time series approach is used to identify common trends and cycles in the fiber market whereas in Kapombe and Colyer (1998) it is used to model supply in the US broiler market. 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 in Nicholson and Stephenson (2014). An application of this methodology to the EU dairy market is to the authors knowledge new.

In summary this paper addresses the following questions:

- What is the effect of trend, seasonal and cyclical component on selected European farm gate milk prices?
- How much of the variation in the selected milk prices are accounted for by these components?
- Does the impact of these components on price change in time due to for example policy changes in the CAP?
- Is the evolution of these components mainly driven by regional factors or may there be some fundamental factors underlying the evolution of prices in the dairy industry?

Answering these questions has important consequences for farmers as well as policy makers. If milk prices exhibit strong seasonal and/or cyclical behaviour farmers need to factor this into their planning and investing decisions. Policy makers should also account for this cyclical nature if considering policy measures and counter cyclical measures in particular . At a minimum they must be careful that policies may have unwanted pro cyclical effects on milk prices. Finally the existence of cycles also has consequences for forecasting and policy analysis (Nicholson and Stephenson, 2014).

The remainder of the paper is organised as follows. The next section summarises the economic theory of why seasonality and cycles may exist in agricultural commoditities, the following section outlines the EU and US dairy industry. The two following sections introduce the methodology and data used. The results section presents the results of the models and the final section concludes.

On seasonality and cycles in agricultural commodities

Economic theory suggests that seasonality and cycles are common features in agricultural commodity prices (Tomek and Robinson, 2003 or Piot-Lepetit and M'Barek, 2011). Seasonality can arise because of seasonal patterns in supply and demand. The timing of seasonal effects in commodity prices is thus usually highly predictable whereas the effect may be stochastic. In the case of the dairy industry seasonality in prices may be explained by the biology of the livestock, seasonal production costs and demand changes throughout the year.

Cycles in prices of agricultural commodities and the dairy industry in particular can arise because of lags between decisions to increase or decrease supply and the actual period the commodity becomes available. Cycles can last much longer than one year and are not as predictable as the seasonal component because neither the timing nor the effect on prices is known exactly. One popular explanation for cycles is the classical cobweb theorem presented by Ezekiel (1938). The cobweb theorem suggests that farmers set supply for the next period based on the price of the current period. Criticism and extensions of the simple cobweb theorem and its application to the pig cycle can be found in Dawson (2009) and the references therein. Another generalisation is the dynamic cobweb theorem developed by Meadows (1971) using the system dynamics methodology.

Transferring these theories to the dairy industry implies that cycles in supply and prices can easily arise. These may be the result of the lag between the decision to change milk supply which may be based on current price and the actual availability of this milk on the market because of the time it takes to expand or contract supply. It should be noted that milk supply in the short run can be adjusted to some degree by feeding and herd management, however significant increases in production often require a relatively long time to bear results.

Some aspects of EU and US dairy policies

Within the dairy industry agricultural policies play an import part. The EU dairy industry is subject to the Common Agricultural Policy (CAP). Prior to the Luxembourg 2003 agreement the CAP focused on maintaining adequate and stable prices for particular dairy commodities such as butter and skimmed milk powder (SMP). It was expected that the stable prices from these commodities were to be transmitted to the farm gate price for milk. This aim was mainly achieved by purchasing to intervention stores, setting production quotas, export refunds, import tariffs and subsidized consumption[2]. These measures resulted in EU dairy commodity prices being significantly higher and less volatile than World prices. Additionally it could be argued that these measures can be seen counter cyclical dampening the magnitude of cycles. For example intervention prices which serve as floor prices would be probably only active at the trough of a cycle.

In contrast to that recent changes in the CAP in particular the Luxembourg 2003 agreement, resulted in a greater market orientation with a lower level of price support (intervention buying, import tariffs and export refunds) for EU dairy commodities. As compensation for the resultant losses, income support at farm level was introduced via the Single Payment Scheme (SPS). In addition the supply quota introduced in 1984 will expire in 2015 as confirmed under the “2008 Health Check”[3]. While the aim of bringing EU dairy prices more in line with World prices is witnessed in O’Connor & Keane (2011) these measures can be seen neutral to cyclical beaviour as the SPS is paid regardless of where the cycle is situated.

Like the EU the US government established policy measures for its dairy industry. These measures include price supports, export subsidies and the federal Milk Income Loss Contract (MILC) (USDA, 2011). Price supports set floor prices for dairy products while the MILC program provides income support if milk prices fall below a certain target price. In general both of these measures should have a counter cyclical effect. However cyclical behaviour has been observed in US dairy prices (Nicholson and Stephenson, 2014) over a long period. One explanation might be that floor prices are currently ineffective as current intervention prices are well below market prices. The MILC programm in contrast should reduce cyclical effects of farm income and not necessarily that of farm gate milk prices. It should also be noted that the new farm bill introduced in 2014 introduced a Margin Protection Program for Dairy

Producers (MPP-Dairy) which will compensate dairy farmers if the difference between the national all milk price and a feed cost estimate falls below a certain threshold.

Methodology

The structural time series approach by Harvey (1989) is used for the decomposition of the price series into trend, seasonal and cyclical components. For the decomposition an additive structural model is used which is described in Harvey (1989) and Durbin and Koopmann (2012):

$$y_t = \mu_t + \gamma_t + \psi_t + \varepsilon_t$$

where μ_t is the trend, γ_t the seasonal, ψ_t the cycle component and $\varepsilon_t \sim N(0, \sigma_\varepsilon)$. The model formulations for the components are given in this section.

The trend as in Harvey (1989) represents the long term movement of a series which can be extrapolated into the future. As in Durbin and Koopmann (2012) the trend is modeled as a random walk with drift. In its most general form the drift could be modeled as stochastic but the analysis showed that a constant deterministic drift is sufficient in the current context. The model is thus formulated as:

$$\mu_{t+1} = \mu_t + \upsilon + \xi_t$$

where and μ_t is the trend, υ is the drift of the trend and $\xi_t \sim N(0, \sigma_\xi)$.

The seasonal component is modeled with a seasonal dummy variable[4]. The idea is that over a full period (e. g. a year) all seasonal components (e. g. monthly) γ_t add to 0. This and the possibility of letting the seasonal pattern change over time gives the formulation:

$$\gamma_{t+1} = -\sum_{j=1}^{s-1} \gamma_{t+1-j} + \omega_t$$

where γ_t is the seasonal component at time t, s is the number of periods per year ($s = 12$ for monthly data) and $\omega_t \sim N(0, \sigma_\omega)$ is a normal distributed disturbance term. The seasonal pattern is thus allowed to change over time.

The interpretation of a cycle in time series is that of a non-annual recurring pattern. In this paper a first order cycle as described in Harvey (1989) is used. The cycles have the form:

$$\begin{pmatrix} \psi_{1,t} \\ \psi^*_{1,t} \end{pmatrix} = \rho \begin{pmatrix} \cos\lambda & \sin\lambda \\ -\sin\lambda & \cos\lambda \end{pmatrix} \begin{pmatrix} \psi_{1,t-1} \\ \psi^*_{1,t-1} \end{pmatrix} + \begin{pmatrix} \varpi_t \\ 0 \end{pmatrix}$$

where ρ is a dampening factor with $0 < \rho < 1$, λ the frequency and $\varpi_t \sim N(0, \sigma_\varpi)$. The period of the cycle is $2\pi / \lambda$.

In general the trend, seasonal and cyclical component cannot be observed directly therefore the Kalman filter is used to estimate these components. The model parameters are estimated using the maximum likelihood approach. The implementation is done in Matlab using the SSMATLAB Toolbox by Victor Gomez[5].

Data

This paper considers the raw milk price paid to milk producers in Germany and Ireland as well as the average EU price. These prices are collected by the EU Commission from its member states at the end of each month and were published by the milk market observatory[6]. The average EU price is included as it provides a useful reference price for policy makers. The German price is included as Germany is the largest producer of milk in the EU. Finally the Irish price series is included because of it represents a seasonal and grass based feed system. Irish milk production is far more seasonal than production in Germany and practically all other countries of the EU. This can be seen from Figure 1, where monthly milk collection from 2012-2014 is shown. Thus a priori one would expect that the dynamics of the Irish price might differ from that of the German price and most other major producer countries like France, the Netherlands or Italy.

<Figure 1>

The EU price represents a weighted average price of the member state prices. The weight of each country is measured by its quota divided by the total quota of the EU with Germany accounting for circa 23.5% and Ireland 4.5% in 2000 compared to 19.7% for Germany and 3.8% for Ireland in 2013. As the quota increase in both countries over the years is inline with general quota increases of the total EU quota the decrease in weight is mainly due to the EU east enlargements in 2004 and 2007. In Figure 2 these monthly raw milk prices are shown for the period from January 1995 to December 2013. For the current analysis this period is divided into two periods, pre and post 2004, in order to examine how the milk price dynamics have changed post the CAP reform of 2003[7]. For the first period all series exhibit a clearly observable seasonal pattern. In the second period the most striking feature of the series is the large price jump at the end of 2007 followed by the deep trough in 2009. Also it can be observed that the series still exhibit a seasonal pattern although this pattern is not as obvious post 2007.

The EU and German prices appear to be very similar which is not surprising as Germany is the largest producer of milk in the EU. However the German price is slightly more variable which seems reasonable assuming offsetting effects of averaging over all member states. The Irish price is below the other price series until 2003 and then converges to a similar level. It appears the most variable 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 more than doubled for all three series in the period post 2004 confirming the belief of increased price variability in recent times.

<Figure 2>

<Table 1>

USD. The comparison with the US price is only done for the period post 2004 therefore only statistics for this period are presented in the table.

To further investigate the question that there are some fundamental factors driving global milk prices the analysis in this paper compares the EU price described above with the average All milk US price[8]. This analysis only covers the second period post the CAP as prior to this prices in the EU were considered to be influenced more by policy interventions rather than market factors. Thus a comparison for the first period might be not applicable.

Figure 3 shows the US price along with the EU price. Like the EU price the US price has a peak at the end of 2007 followed by the trough in 2009. Compared to the EU series the US price seems more variable especially at the beginning of the time series. This is also confirmed by higher Coefficient of variation in Table 2 of about 18% versus 12% for the European series.

<Figure 3>

Results

The model described in the methodology section is now applied to the farm gate raw milk price in Germany, Ireland the average EU price along with the US price. These decomposition results are also presented in this section. The estimated parameters are reported in Table 2 for all series and the respective time period. In addition a maximum of two intervention variables per series for outliers as described in Commandeur and Koopmann (2007) are added.

<Table 2>

Goodness of fit analysis in the context of state space models is conducted on the prediction errors of the Kalman filter. The errors are checked for normality, independence and conditional heteroscedasticity. Therefore the Jarque and Bera (1987) test and Ljung and Box (1978) test are used. In addition the Ljung and Box (1978) test on the squared errors as described in Harvey (1989) is used as test for conditional heteroscedasticity. The results of the tests are shown in Table 3. This table shows that the assumption of normality and independence cannot be rejected at the 5 % level for all tests except for the EU price in the period 2004 to 2013 for which the Ljung and Box (1978) test is only significant at the 1 % level. The test against conditional heteroscedasticity is also significant at the 5 % level for all tests except for the EU price in the period 1995 to 2004 which is again only significant at the 2 % level.

<Table 3>

Figure 4 shows the original price series of the EU, German and Irish milk price paid to producers for both periods along with their respectively smoothed estimates of the trend component. As mentioned the trend represents the long term movement of a time series. For the first period the trend of the EU series is flat between 30 EUR and 31 EUR per 100 kg (panel A) while it is slightly increasing but at a similar level of 31 EUR for the German series (panel B). The Irish trend is below the other two series at a level of 28 EUR per 100 kg with a slight decrease over time (panel C). For the second period it can be seen that the trend for all series is increasing and at a similar level of more than 35 EUR at the end of the series. Given the lower level and downward direction of the Irish trend compared to the other series, it can be concluded that the long term movement represented by the trend converged between the average EU price and its member states Germany and Ireland.

<Figure 4>

As the trend of all series is almost linear for both periods the seasonal, cyclical components and the noise term must account for almost all of variation. These components in general play an important role in analyzing the price dynamics. As can be seen from Table 2 the standard deviation of the error term σ_{ε} is small in both periods for all three series meaning that the data is nearly fully explained by the trend, seasonal and cyclical components. The cycle length ($2\pi / \lambda$) in the first period which ranges from 43 months for the Irish, 47 months for the German to 55 months for the average EU series can be seen in Table 2[9]. From the left part of Figure 5 it can be seen that the general pattern and magnitude of price variation of the cycle varies for all series in the first period with the exception that the cycle has a peak between 2001 and 2002 for all series. To compare the magnitude of price variation attributed to the seasonal and cyclical component across the different series a normalised measure is used. This is calculated as the maximum drawdown[10] (the decline from the peak to trough) divided by the mean of the series in the respective period. Based on this measure the added price variation in the first period from the cycle is largest for the German series account for circa 22% of price variation. The cycle magnitude is comparable for the EU and Irish series which adds about 15% and 13% to variation.

Table 2 shows that post 2004 the cycle length is now almost identical for all three series with 37 months for the average EU, 38 month for the German and 39 months for the Irish series. It should be noted that a 3 years cycle is consistent with the finding of Nicholson and Stephenson (2014) who argue that it takes around 3 years for a dairy producer to expand milk output in a significant manner.

Figure 5 shows that the pattern of the cycle for all series in the second period with a large 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 series and accounts for up to 63% of price variation based on the measure described above. The impact of the cycle in the German price is slightly lower with about 54%. In contrast the EU cycle only accounts for up to 39%. This is not surprising as cyclical effects over all member states may be slightly different and average over all states as the cycle might be positive in one state and negative in another state.

<Figure 5>

In addition the magnitude to price variation from the cycle sharply increased and also helps to explain the huge price movements in recent time as can be seen from Figure 5.

The seasonal component for both periods is shown in Figure 6. In the first period the seasonal component has the largest effect on the Irish price accounting for about 17% of price variation applying the same measure as before. The effects from the seasonal component on the EU and German price are almost identical with 13%. For the second period the magnitude of price variation from the seasonal component is again biggest for the Irish series with about 17% although the graph shows that it slightly increased in absolute terms. The almost constant magnitude in relative terms thus comes from an increase of the mean in the second period which can be seen from Table 1. The effects from the seasonal component on the EU and German series are 11% and 12% which is slightly lower than in the first period.

This finding confirms the general belief that the Irish price is somewhat more seasonal than the German price as a consequence of its predominantly grass based feed system. 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.

<Figure 6>

The comparison of the trend, cyclical and seasonal components for both periods showed that the price dynamics for the EU, Germany and Ireland converged for the period post 2004, which is to some point surprising given the different production systems of the individual states in the EU as well as Germany and Ireland in particular. It seems reasonable to assume that this convergence is due in large part to the CAP 2003 reforms and the focus on greater market orientation within the EU dairy sector. The results also show that most of the huge price volatility in recent times is attributed in large part to the seasonal and cycle components. This means that volatility can nearly be fully explained by the model components which confirm the argument of Nicholson and Stephenson (2014) that much of milk price volatility is endemic to the dairy industry.

The dynamics of the EU milk price series is further compared with the average All milk US price from 2004. This analysis will help to identify if there are common factors driving the trend, seasonal and cyclical components or if price is mainly driven by regional factors.

The model described in section 2 is also applied to this US series. Parameter estimates and Goodness of fit statistics of the residuals are shown in Table 2 and Table 3. In order to avoid distorting the milk price dynamics with that of the exchange rate the analysis of the US milk price is in dollar values (USD). From Table 2 it can be seen that 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 (2014) who estimated a 36 month cycle. In addition this cycle length is very close to the estimated cycle length of 37 months for the EU and further strengthens the assumption that a cycle of around 3 years is intuitive for the dairy industry. To compare the magnitude of the cycle in the EU with that of the US a normalized measure is needed which accounts for the different currencies. Figure 7 therefore shows the cyclical component of the EU divided by the mean of the original series along with the same measure for the US cycle. From Figure 7 it can be seen that the impact of the US cycle is higher than that of the EU series which is as anticipated given that the greater variability of the US price around 2004. In addition the US cycle seems to lead the EU cycle by some month. Applying the maximum drawdown measure mentioned above the US cycle adds about 68% to price variation compared to about only 39% for the average EU cycle. The seasonal component adds about 9% to variation which is again similar to the EU series.

<Figure 7>

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. The analysis was done for the periods from 1995 to 2004 prior to the CAP reform and 2004 to 2013 post the CAP reform. Also a comparison with the US market for the latter period was presented. While these datasets may in some cases be considered short for cycle analysis these models have a good fit based on normality, independence and heteroscedasticity tests of the prediction errors. The main results of the decomposition are threefold:

- The comparison of the decomposition for both periods showed that the price dynamics and in particular the length of cycle converged for the period post 2004. One explanation for this convergence could be the market orientated reforms of the CAP post 2003.

- The decomposition results for the latter period showed that most of the recent price variation is attributed to the cycle component. Price volatility for this period seems to be endemic to the dairy industry and to some degree predictable as pointed out in Nicholson and Stephenson (2014).
- 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 Nicholson and Stephenson (2014) who suggested that this is consistent with the time required to expand milk supply based on biological and business factors.

The existence and importance of cycles in milk prices suggests that EU policy makers should consider counter cyclical measures in addition to non-counter cyclical measures when they deem market intervention or income support necessary. Counter cyclical here means measures which are inversely linked to the commodity price. One example of such a measure is the possibility for tax regimes to allow for averaging farm income over several years for tax purposes (Tangermann, 2011). Another example of a counter cyclical measure is the voluntary Cooperatively Working Together (CWT) program in the US developed by the National Milk Producers Federation (NMPF) which aims to reduce milk supply. The program involves payments to producers, who sell their herd for slaughter and subsidies for exports of butter and cheese (FAPRI-UW Dairy Policy Analysis Alliance, 2010). By designing counter cyclical measures policy makers must be careful not to distort market efficiency for example by giving farmers wrong production incentives.

Meanwhile dairy farmers need to factor the seasonal and cyclical nature of milk prices into any financing and budgeting decisions. As the removal of milk quotas approach and some farmers consider expanding production these concerns will be most acute in their case. One counter cyclical strategy for farmers might be a temporary exit from operations anticipating the bottom of the cycle and reentering once prices start to rise again. Nicholson and Stephenson (2014) describe an example where a small number of farms sold their milking cows in early 2008 retained their replacement stock and reentered milk production in late 2010.

Market tools such as efficient future markets could also help to reduce the cyclical impact of milk prices. Individual farmers could use future markets for hedging their exposure to price variations and thus increasing the probability of meeting their planning and budgeting decisions. For the dairy industry as a whole an increased use of future markets could dampen the magnitude of the cycle as a greater portion of milk is hedged with a fixed price. However derivative markets for dairy commodities are still in its embryonic states in the EU with only butter, SMP and whey futures traded. In addition liquidity is fairly thin for these contracts. As there are no contracts on EU milk prices farmers might try to cross-hedge their exposure with butter or SMP contracts or they may use milk derivatives in the US. Although there is a large correlation between these prices and the EU milk prices both methods will give rise to basis risk. It should also be noted that derivative markets can have destabilising effects like strengthen the magnitude of cycles if not tightly regulated and the role of speculators monitored.

Also while the method used in this paper prove that there exist cycles in milk prices and further quantifies the magnitude of these cycles it does not explain why cycles can emerge. Nicholson and Stephenson (2014) provide some possible explanations like the "Bullwhip effect"[11] for this. They further developed a system dynamics based on the commodity model of Sterman (2000) and conclude that supply chain manager in the dairy industry make decisions based on bounded reality, with limited supply chain coordination.

Notes

1. The terms variability and volatility are used as synonyms throughout the paper.
2. Since 2006 the use of subsidised internal disposal measures in the dairy sector has been curtailed. However Schemes still exist for the subsidised use of milk in schools and for the sale of subsidised dairy products to charities (Donnellan et. al, 2015 p. 11).
3. The recent policy changes are spelt out in more detail in Jogeneel (2011) or O'Connor and Keane (2011).
4. The seasonal component could also be modeled as a trigonometric function. Tests during the analysis showed that both formulations yield nearly identical results.
5. http://www.sepg.pap.minhap.gob.es/sitios/sepg/en-GB/Presupuestos/Documentacion/Paginas/SSMMATLAB.aspx
6. Source: http://ec.europa.eu/agriculture/milk-market-observatory/index_en.htm
7. Also bearing in mind that not all measures of the CAP 2003 reform were fully implemented until 2007.
8. Source: http://future.aae.wisc.edu/
9. Additional cycles were considered. The analysis showed that they were generally small in magnitude and the model was displaying unstable characteristics.
10. The maximum drawdown measure is often used in finance (Magdon-Ismail and Atiya, 2004).
11. The "Bullwhip Effect" is described in Nicholson and Stephenson (2014) as "when small changes (often, in demand), cause alternating over-ordering and under-ordering on the part of supply chain agents, and the supply chain never stabilizes or adjusts to a new equilibrium"

Acknowledgments

The authors are grateful to Charles Nicholson and two anonymous referees for comments on an early version of the paper. Declan O'Connor gratefully acknowledges the support received through the Stimulus Fund of the Irish Dept. of Agriculture and Food for this research.

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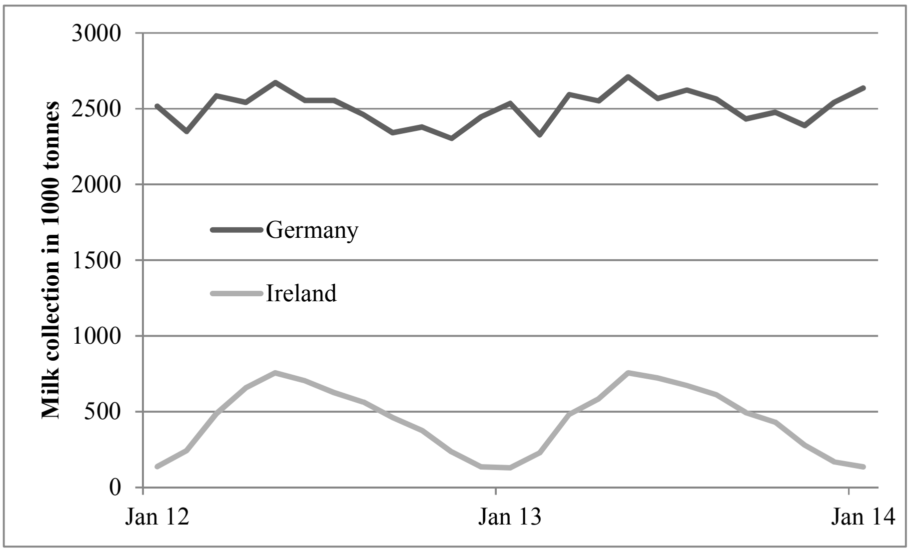

Figure 1: German and Irish monthly milk collection from 2012-2014 Source: Eurostat

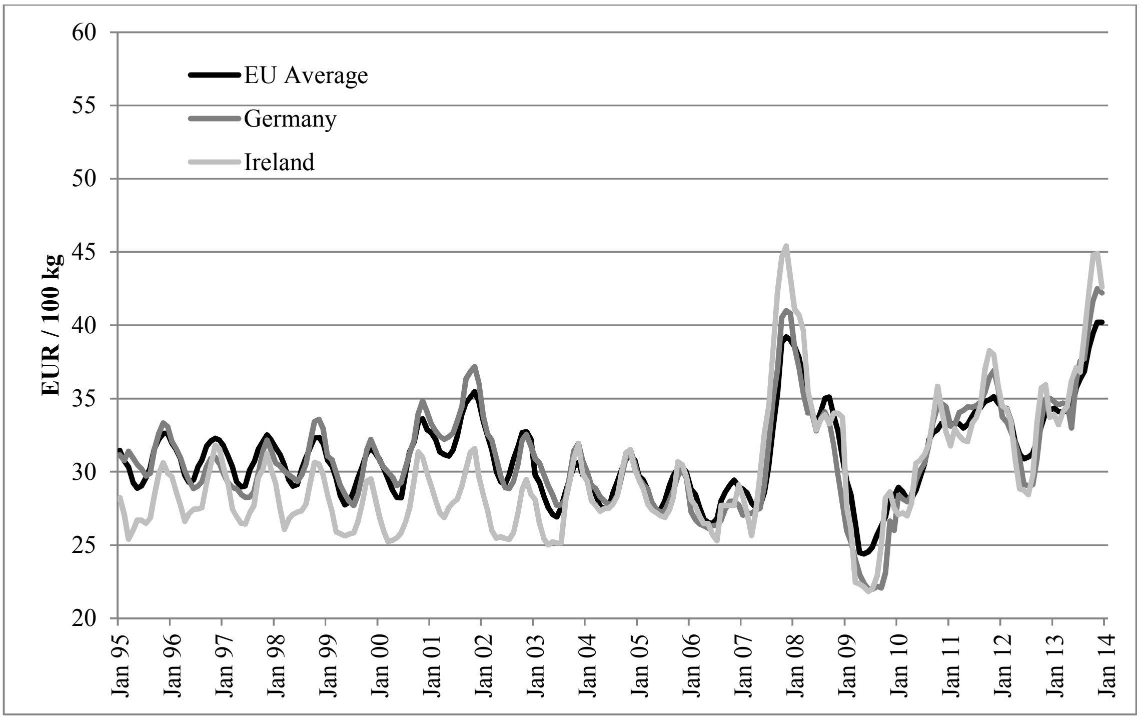

Figure 2: EU, German and Irish original Series 1995-2013. Source: European Milk Market Observatory

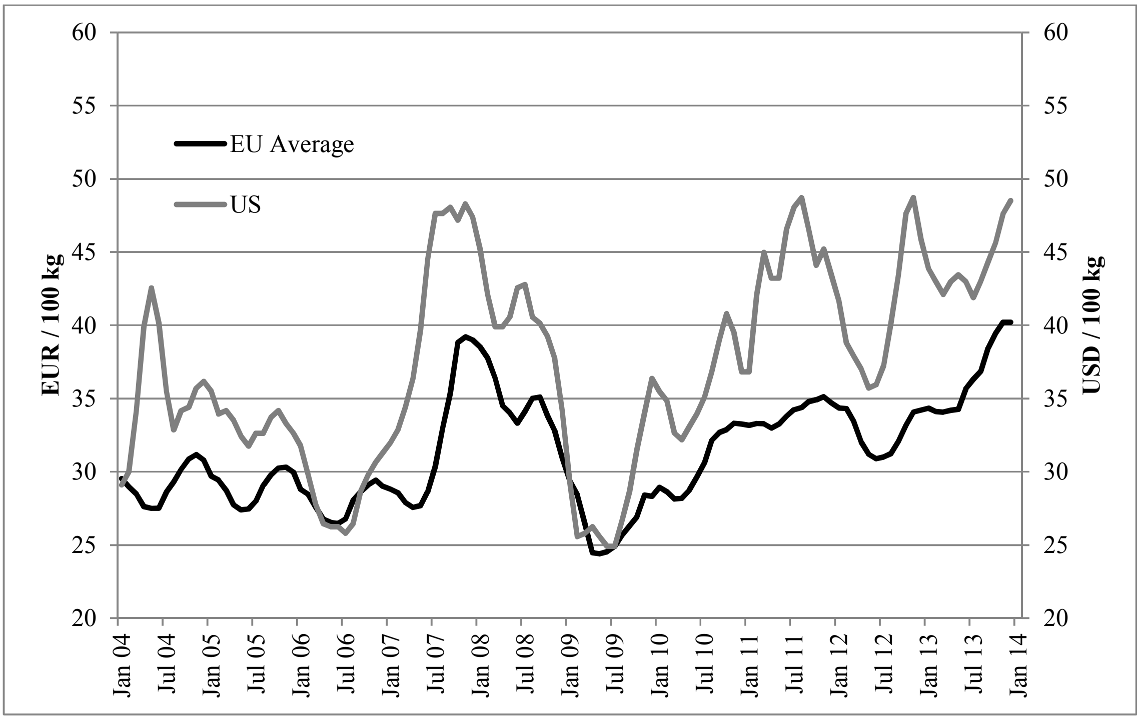

Figure 3: EU original Series and US original Series in USD 2004-2013. Source: European Milk Market Observatory and University of Wisconsin

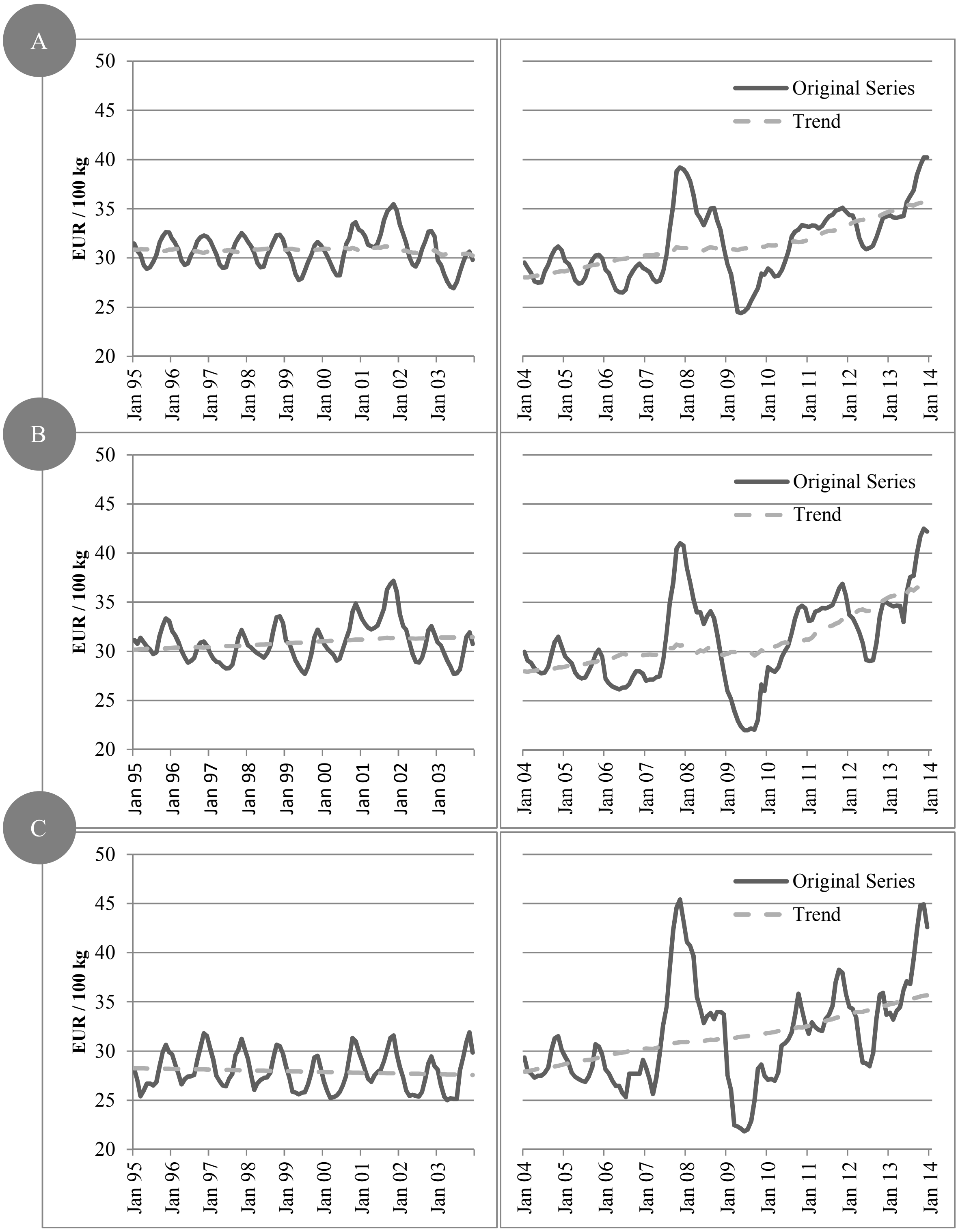

Figure 4: Original Series along with the trend estimate for the periods 1995-2004 and 2004-2013: (A) EU series (B) German Series (C) Irish series. Source: European Milk Market Observatory and own calculations

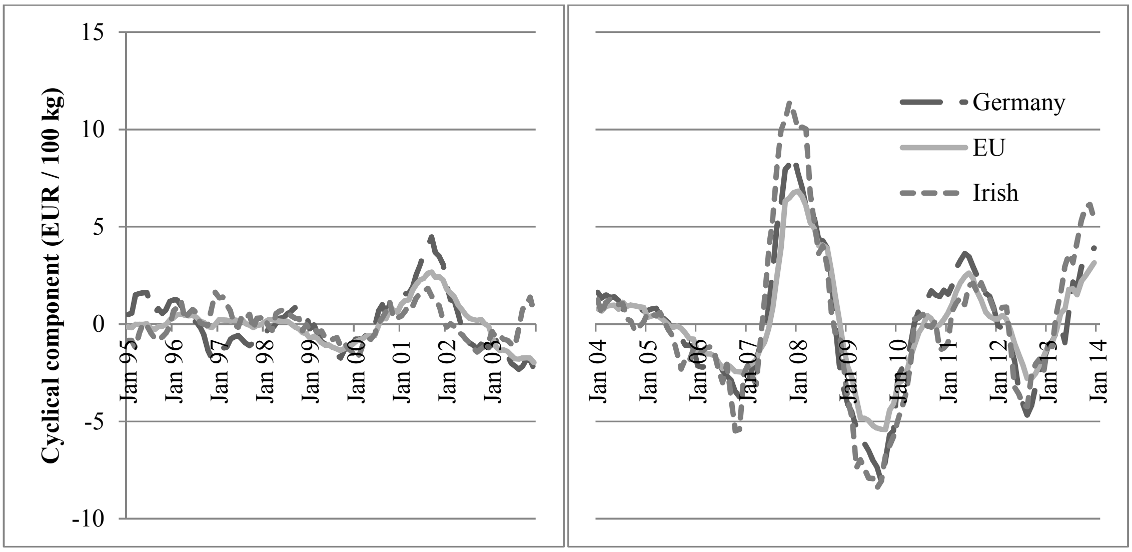

Figure 5: Cyclical components of EU, German and Irish milk price for the period 1995-2004 and 2004-2013. Source: own calculations

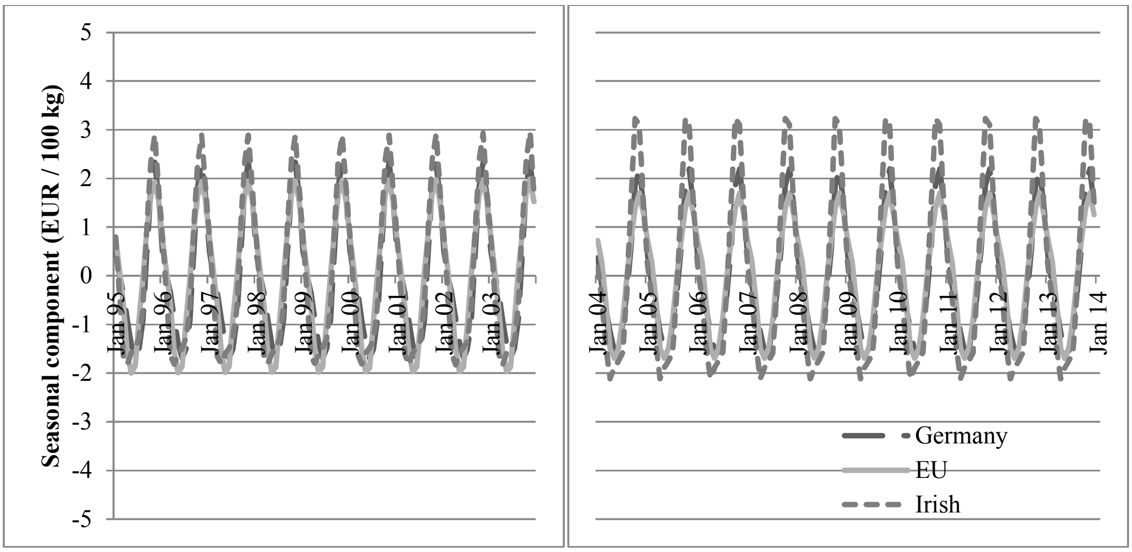

Figure 6: Seasonal components of EU, German and Irish milk price for the period 1995-2004 and 2004-2013. Source: own calculations

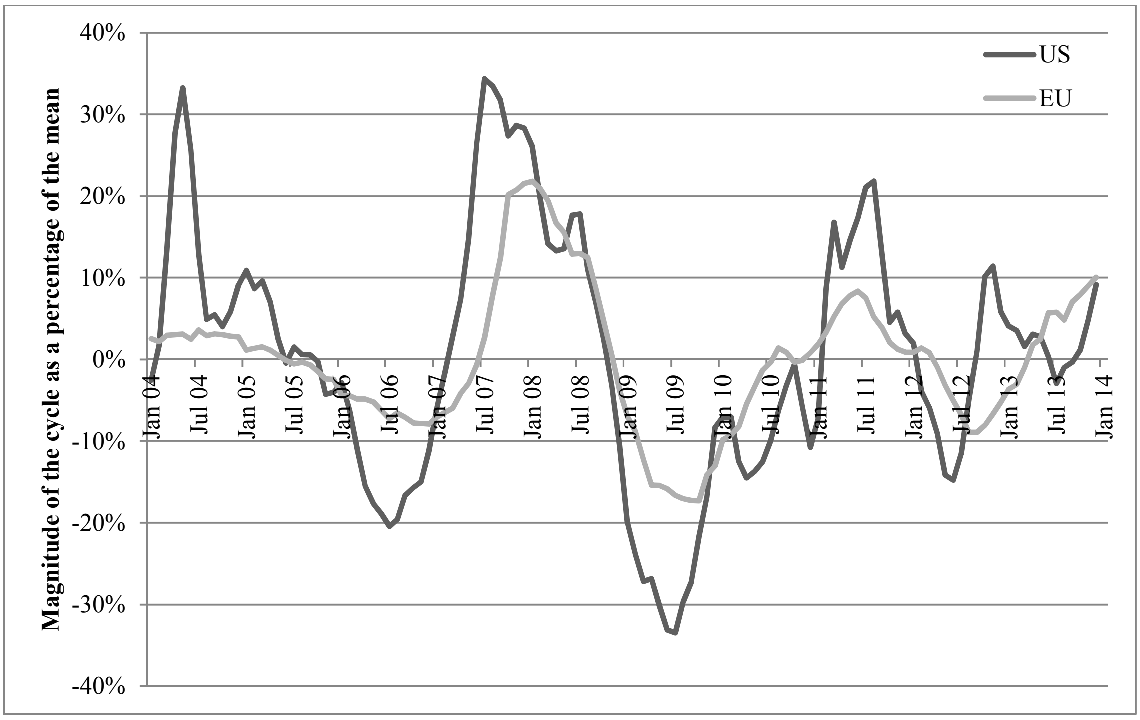

Figure 7: Cyclical component for the US all Milk price and EU price as a percentage of the respective means for the period 2004-2013. Source: own calculations

Table 1: Summary statistics. Source: own calculations

1995-2013	EU Average	Germany	Irish	
Mean	31.0665	30.9612	29.8349	
Standard Deviation	2.9510	3.6140	4.4058	
Coefficient of Variation	0.0950	0.1167	0.1477	
1995-2003	**EU Average**	**Germany**	**Irish**	
Mean	30.7848	30.9279	27.9303	
Standard Deviation	1.7405	1.9915	1.8658	
Coefficient of Variation	0.0523	0.0582	0.0803	
2004-2013	**EU Average**	**Germany**	**Irish**	**US**
Mean	31.3201	30.9911	31.5490	37.3206
Standard Deviation	3.7083	4.6201	5.2577	6.6915
Coefficient of Variation	0.1184	0.1498	0.1667	0.1793

Note: The EU Average, Germany and Irish statistics are in EUR while the US statistics is in USD. The comparison with the US price is only done for the period post 2004 therefore only statistics for this period are presented in the table.

Table 2: Parameter Estimates. Source: own calculations

	1995 - 2004			2004-2013			
Parameter	**EU**	**German**	**Irish**	**EU**	**German**	**Irish**	**US**
σ_ξ	0.0173	0.0035	5.19E-07	0.0068	0.0138	3.47E-04	4.37E-04
σ_ω	5.04E-04	9.26E-07	0.001	5.36E-06	1.09E-06	2.11E-06	2.29E-05
σ_ϖ	0.0287	0.055	0.1871	0.0295	0.0390	0.0646	0.0882
σ_ε	1.80E-07	3.68E-07	1.12E-05	1.58E-06	1.72E-07	1.95E-04	3.89E-08
ρ	0.9856	0.9721	0.9016	0.9852	0.9803	0.9671	0.9549
λ	0.1134	0.133	0.1455	0.1690	0.1673	0.1619	0.1757
$2\pi/\lambda$	55.4093	47.2577	43.1755	37.1886	37.5632	38.8082	35.765

Note: σ_ξ, σ_ω, σ_ϖ and σ_ε are the standard deviation of the trend, seasonal, cyclical and irregular components. ρ and λ are the damping factor and frequency of the cyclical component while $2\pi/\lambda$ is the length of the cyclical component.

Table 3: P-Values of Goodness of fit statistics of the prediction errors. Source: own calculations

	1995 - 2004			2004 - 2013			
p-Values	**EU**	**German**	**Irish**	**EU**	**German**	**Irish**	**US**
Jarque-Bera-Test	0.0772	0.5	0.5	0.1094	0.0525	0.5	0.0677
Ljung-Box-Test	0.073	0.4152	0.6282	0.0210	0.1087	0.1282	0.0746
Ljung-Box-Test on squared errors	0.0142	0.9335	0.464	0.6289	0.1109	0.3691	0.1757