International Synchronisation of the Pork Cycle

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1 The 'Pork Cycle' in the literature

The existence of the so called 'Pork Cycle' was first recognized by HANAU (1927) for the German pork market and by COASE and FOWLER (1935) for the pork market in Great Britain. These authors hypothesised that a positive shock on the demand side for pork, for example, leads to increasing producer prices for pigs in the short-run because the farmers cannot expand their supply immediately. Assuming the naive expectation that the current observed high prices of pork will persist in the future, farmers will increase pig production because of its higher profitability. This decision to increase production will have an impact on the supply of slaughtered pigs about one year later at the earliest – that is the time it takes to produce piglets and fatten them for slaughter. This larger amount of slaughter pigs reduces the producer price as the supply exceeds the demand of pork meat. This development has a negative impact on the profitability of pig production so that farmers with high marginal costs drop out of pig production. As a consequence of this, the supply of slaughter pigs decreases in the medium-run and the producer price increases again, leading to another round of the pork cycle.

At roughly the same time, RICCI (1930), SCHULTZ (1930), and TINBERGEN (1930) analysed the relationship between supply and demand reactions more generally and formulated own theoretical explanations for cyclical price fluctuations. A few years later, EZEKIEL (1938) combined these explanations and published the so-called 'Cobweb-Theorem'. As an example, he cited self-induced cyclical price fluctuations on pork markets in several countries due to the nearly inelastic supply reaction of the pork producers in the short-run and the highly elastic supply reaction in the long-run.

In the following decades the pork cycle was repeatedly the subject of interest in the agricultural economic literature. HARLOW (1960), for example, determined a length of four years for the fluctuations of pork prices of the USA, which corresponds to the empirical results of HANAU (1927) and COASE and FOWLER (1935). However, this contradicts Ezekiel's Cobweb-Theorem which predicts a cycle length of only two years, i.e. double the length of the time period between the decision to increase production (by producing piglets) and the ensuing effect on the supply side of the market (increasing numbers of slaughtering pigs)

This contradiction has never been resolved in a convincing manner in the literature. Another puzzle is how the pork cycle can be maintained given the fact that countercyclical behaviour on the part of pork producers would be highly profitable (HAYES and SCHMITZ, 1987). Part of the explanation could lie in the fact that the pork cycle does not fluctuate regularly. External shocks, such as increasing feed costs due to poor harvests or an outbreak of the swine fever, periodically disturb the cycle making it impossible to predict. To account for irregular fluctuations, TALPAZ (1974) decomposed a time series of pork prices into component cycles using Fourier methods. Other authors proposed non-linear models and the chaos theory, e.g. CHAVES and HOLT (1991), HOLZER and PRECHT (1993), and STREIPS (1995). Recently, HOLT and CRAIG (2006) test the forecasting ability of a time-varying smooth transition autoregressive model (TV-STAR) of pork prices.

In our study we take the existence of cyclical pork price fluctuations as given, whether they are due to the 'classic' cobweb proposed by EZEKIEL (1938) or some other (combination) of explanation(s). The focus of our analysis is the question whether the pork cycle in different international markets has become more or less synchronised over time. Specifically, we hypothesise that as a consequence of the ongoing liberalisation of agricultural markets in many countries, and of the ensuing increases in pork trade, pork price fluctuations in different countries will have become increasingly synchronous over time.

To test this hypothesis we draw on two separate types of analysis. In Chapter 2 we analyse the correlation of pig price data from over 100 countries. In Chapter 3 we analyse 36 years of monthly data on producer prices and numbers of slaughtered pigs in the USA and Germany – the second and the third largest pig producing countries in the world after China. We apply the Hodrick-Prescott-Filter (HODRICK and PRESCOTT, 1997) to isolate countercyclical movements of prices and slaughtered volumes in both countries, and to provide evidence that pork price fluctuations in these two markets are indeed becoming increasingly synchronous. The paper closes with conclusions in Chapter 4.

2 Pork price developments in different countries

Prior to recent decades, most farmers produced only a few pigs and sold them on regional markets. Trading over long distances and especially across borders was not common. Besides the problems of transporting live or slaughtered pigs and the lack of information about the price developments in neighbouring countries, import barriers for pigs and pork meat (tariffs and various veterinary restrictions) prohibited many trading activities. As a result, markets were not integrated and a specific pork cycle could be observed for each country – even for neighbouring countries.

To study whether this has changed, we use the annual producer prices for slaughter pigs (in US-$) collected by the FAO. All in all the FAO provides data for 122 countries between 1991 and 2008 (18 years). We exclude 9 countries with more than two missing values from further calculations, leaving 113. The heterogeneity of the remaining countries is very high. Besides large pork producing countries such as China and the USA, it includes, for example, a number of small island states in the Pacific or the Caribbean, as well as a number of predominately Islamic states where pork production and consumption presumably play a negligible role.

HARDING and PAGAN (2006) suggest analysing the synchronisation of the minima and maxima of time series to generate insights into the similarity of price developments. Therefore, we generate the first differences of all price data series and create a dummy variable (1/0) to distinguish between increasing (first difference is positive) and decreasing (first difference is negative) slaughter pig prices. If two countries have identical series of increasing and decreasing prices, the coefficient of correlation between their dummy variable series will equal one. Of course, perfect positive correlation could occur by chance. But since a series of 17 price changes allows for $2^{17} = 131,072$ permutations, the probability of a perfect positive correlation occurring by chance among 6,328 pairwise correlations ($[113^2-113]/2$) is low.

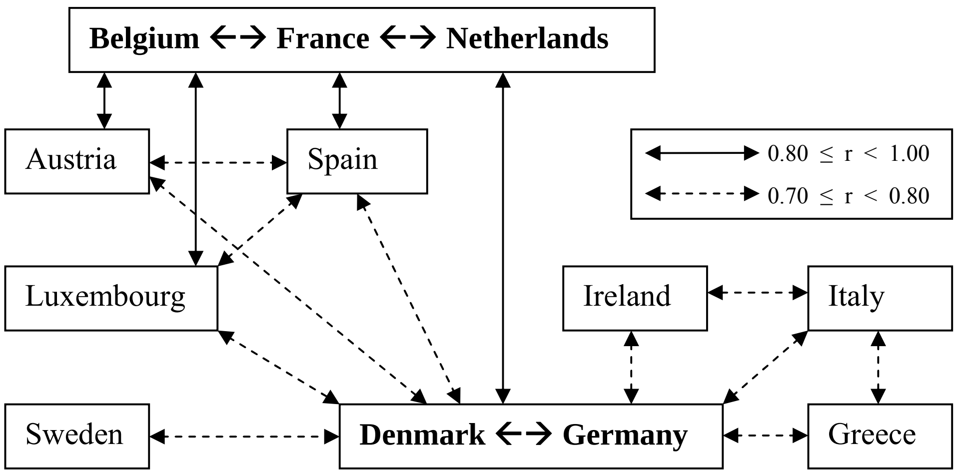
The results indicate that several groups of countries do display identical price annual price movements over the sample period. These groups are:

- Belgium, France, the Netherlands and the Czech Republic;
- Denmark and Germany;
- Togo and Niger;
- Cameroon and Equatorial Guinea; and
- Macedonia and Cape Verde.

With the exception of Macedonia and Cape Verde, all the other pairs involve direct or close neighbours. Common price movements are observable between locally integrated markets, such as between Togo and Niger or between Cameroon and Equatorial Guinea. The group comprising Belgium, France, the Netherlands and the Czech Republic differs from the pair Denmark and Germany by the direction of only one price change, from 2006 to 2007. So the pairwise correlation coefficient between these country groups is also strongly positive (r = 0.87). It comes as no surprise that pork price fluctuations within the European Union are highly synchronised. This applies especially to the old member states Belgium, Denmark, France, Germany and the Netherlands, as all of these countries have traded pigs and pork with each other for a long time. Indeed, nearly all countries of the EU-15 are positively correlated with each other (Figure 1). Only Great Britain, Portugal and Finland have shown pork price developments during the last two decades which are not very similar to rest of the EU-15 (pairwise correlation coefficients less than 0.70).

The positive correlation coefficients shown in Figure 1 indicate a common 'pork cycle' which is confined to Europe. This cluster of countries with similar pork price developments is unique in the data we study. Only Eastern Europe also shows many positive correlation coefficients – but these are all smaller. Therefore we can conclude that there is regional market integration between the following countries: Russia, Armenia, Republic of Moldova, Latvia, Lithuania, Estonia, Poland and the Czech Republic. Note that the Czech Republic displays the same price movements as Belgium, France and the Netherlands; this suggests some similarities in pork price developments in Eastern and Western Europe. Since the period after 1990 has been characterised by increasing trade and integration between the EU and these Eastern European countries, with some of them becoming full EU members themselves in 2004, this result also comes as no surprise.

Figure 1. Correlation coefficients for the pork price development of EU-15 countries



Source: Own calculations based on FAO (2011)

To test whether these positive coefficients of correlation between pork price movements are statistically significant we generate a distribution of correlation coefficients under the assumption of independent pork price developments. We create 100,000 pairs of times series of price increase/price decrease dummies for two countries and calculate the corresponding correlation coefficients. When generating these series we account for the fact that the probability of a price increase changes from year to year in our FAO sample: for example from 2007 to 2008 the pork prices increased in 87.3% of the 113 countries (the highest such proportion in the FAO sample), and from 1997 to 1998 this proportion was only 24.8% (the lowest such proportion). Hence, the median of the simulated distribution of correlation coefficients equals 0.169, and only less than one quarter of the values are negative. Based on this distribution we would expect a perfect coefficient of correlation (r = 1) in only 0.8 of 6,328 cases, and a coefficient between 0.8 and 1.0 in 10.4 cases. In fact, many more high correlations are observed (Table 1), and most of these are between countries in Europe, with twelve members of the EU-15 being responsible for nearly half of the expected correlation coefficients more than 0.80.

Table 1. Expected and observed correlation coefficients

	expected number	observed number	thereof Western and Eastern European countries	thereof only EU-15 members
r = 1	0.8	10	7	4
$0.80 \leq r < 1.00$	10.4	32	24	15
$0.70 \leq r < 0.80$	61.0	94	27	18

Source: Own calculations based on FAO (2011)

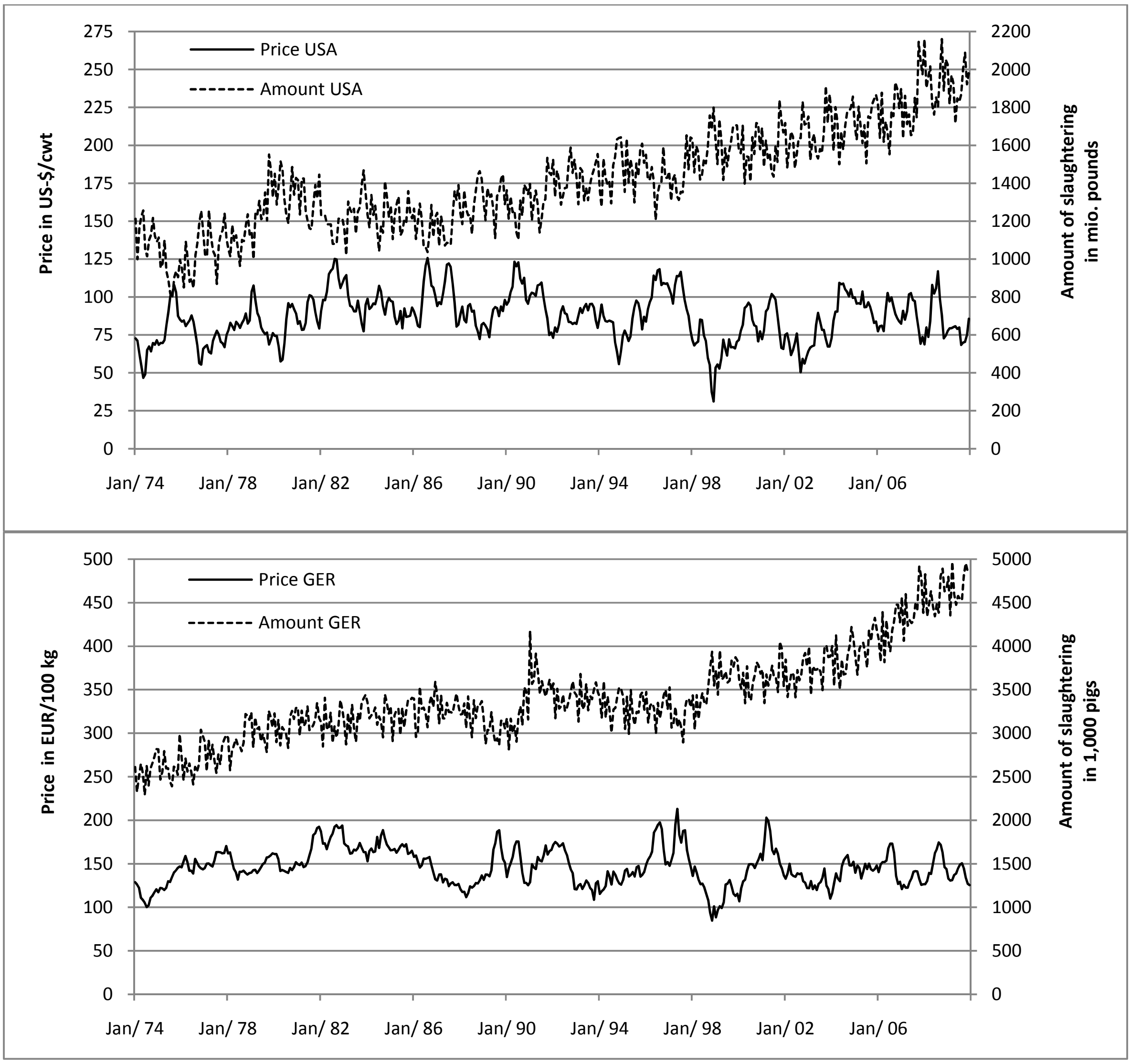
3 Synchronisation of the pork cycle of the USA and Germany

The results presented above suggest pork price movements are synchronised in regions where trade has been liberalised and the infrastructure required to integrate markets for a perishable product such as pork is available. However, these results are based on only 18 years of annual data and are therefore not able to cast any light on whether price movements have become more or less synchronised over time.

We therefore next consider longer, high-frequency pork price series in the USA and Germany. These countries do not trade directly with each other but they are important pig producing countries, accounting for 10 and 5% of world production, respectively (FAO, 2010). China accounts for about 46% of the world pig production, and FENGYING, LING and JIEYING (2009), based on an analysis of monthly data since 1996, find evidence of a pork cycle in China with an average length of 42 months, which corresponds to the cycles lengths observed in Europe and the USA. Hence, it would be interesting to include China in our analysis as well. However, the monthly time series of pork prices and slaughter quantities that are available for China are considerably shorter that those for the USA and Germany, which date back to 1974.

For the USA we use weekly price observations provided by LMIC (2010) for Iowa and South Minnesota hog prices on carcass basis which we aggregate to monthly data by arithmetic averaging of four or five observations per month. Nearly 40 percent of all pigs of the USA are slaughtered in these states. The slaughter volumes are taken from annual reports of the USDA (1974-2009). Monthly producer prices and slaughter volumes for Germany are provided by the national statistical office (STATISTISCHES BUNDESAMT 2010, ZMP 1974-2008). The price and slaughter series employed are presented in Figure 2a and 2b. Cyclical price movements are clearly visible, as are seasonal fluctuations in slaughter volumes and an overall increase in slaughter volumes over most of 1974-2009 period in both countries. The German data prior to reunification in 1990 only apply to the West Germany, and this does lead to a structural break in the data (especially apparent in a jump in slaughter volumes – see Figure 2b) which does not, however, have a major effect on our analysis.

Figure 2a/b. Prices and amount of slaughtered pigs for the USA and Germany



Sources: USDA (1974-2009), LMIC (2010), STATISTISCHES BUNDESAMT (2010), ZMP (1974-2008)

3.1 Methodology

We first decompose the price and slaughter volume series into trend and cyclical components using the filter proposed by HODRICK and PRESCOTT (1997). The Hodrick-Prescott-Filter divides a time series y_t into two parts: a trend component g_t and a stationary rest component r_t (1).

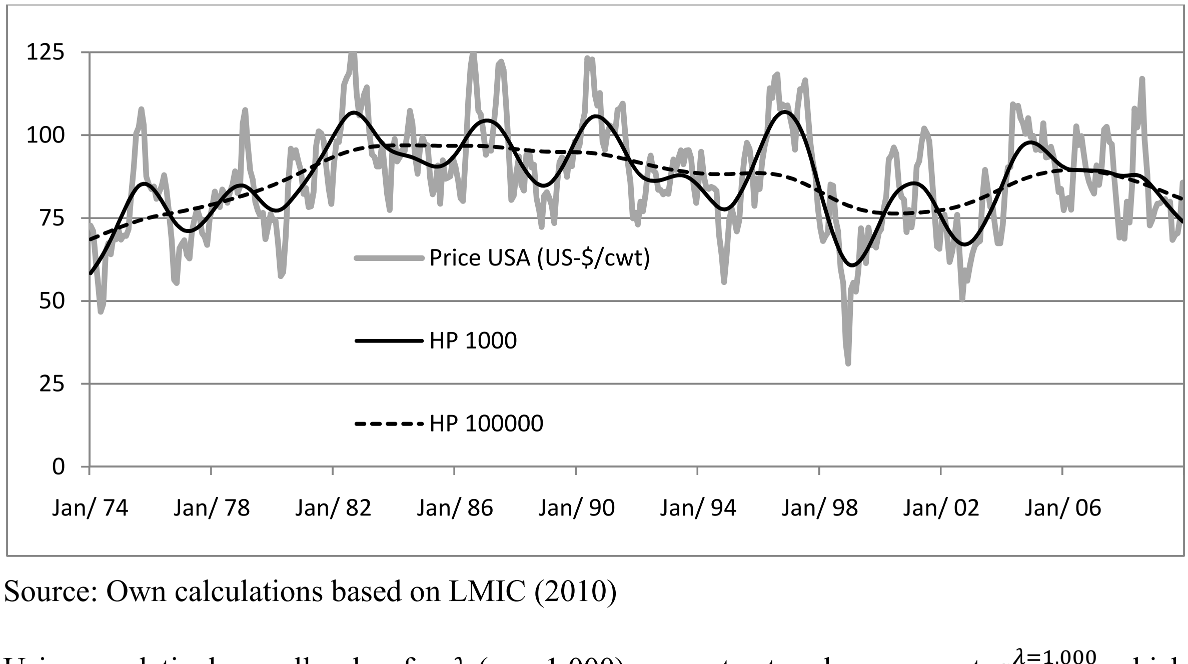
(1) $y_t = g_t + r_t$ for $t = 1, \dots, T$

The decomposition is the result of the following optimization problem (2)

(2) $\min_{\{g_t\}_{t-1}^{T}} \{\sum_{t=1}^{T} r_t^2 + \lambda \sum_{t=1}^{T} [(g_t - g_{t-1}) - (g_{t-1} - g_{t-2})]^2\}$

which depends on the value of a positive parameter λ which could be any positive number. λ penalizes the variability of the time series y_t, so that the higher the value of λ, the smoother the computed trend component. For a very large λ the difference between g_{t+1} and g_t converges to a constant β for the entire data series and the trend component becomes a linear trend $g_t = g_0 + \beta t$. At the other extreme, if λ is set equal to 0, the trend component is the series y_t itself. HODRICK and PRESCOTT (1997) provide guidelines on the λ values that are appropriate for capturing fluctuations of different periodicities. The dependence of the Hodrick-Prescott-Filter on the subjective choice of λ is criticised in literature (see e.g. KAUERMANN, KRIVOBOKOVA and SEMMLER, 2010). However, the method is straightforward and transparent, and the application below produces results which are robust over a range of λ values.

Figure 3. Appliance of the Hodrick-Prescott-Filter for pork prices of the USA



Source: Own calculations based on LMIC (2010)

Using a relatively small value for λ (e.g. 1,000), we get a trend component $g_t^{\lambda=1{,}000}$ which contains the overall long-run smooth trend as well as cyclical fluctuations. If we choose a multiple of this value (e.g. λ = 100,000), the cyclical behaviour of the trend component $g_t^{\lambda=100{,}000}$ disappears and only the long-run smooth trend is left. Figure 3 illustrates the application of the Hodrick-Prescott-Filter for these λ values to the monthly US pork prices.

Altogether we can observe 8-10 cycles of the swinging component – depending on whether the weakly observable maxima in 1993 and 2008 are counted or not – which indicates over the whole time period of 36 years an average length of the pork cycle of around four years.

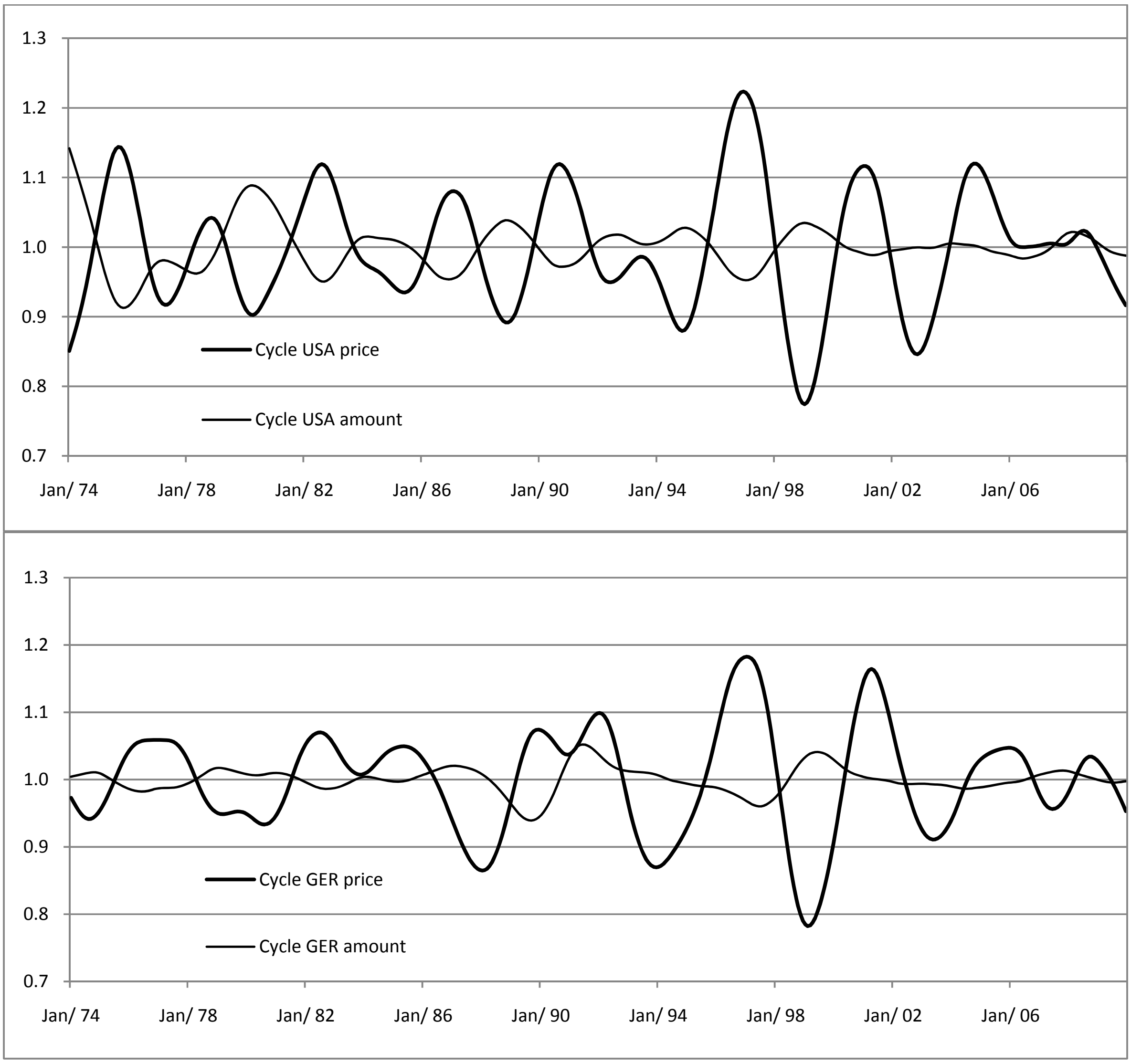
We isolate the cyclical component of the time series by dividing the smooth trend plus cycle component by the smooth trend component:

(3) $$g_t^{cyc.} = \frac{g_t^{\lambda=1,000}}{g_t^{\lambda=100,000}}$$

3.2 Results

The results indicate first that in both the US and Germany price movements and slaughter volumes are cyclical (see Figures 4a and 4b).

Figure 4a/b. Cycles for prices and amounts of slaughtered pigs in the USA and Germany



Source: Own calculations

Furthermore, as predicted by the cobweb theorem price and slaughter volumes fluctuate counter-cyclically to one another. To illustrate this we estimate the following equation:

(4) $$ln\left(\frac{p_{t+1}}{p_t}\right) = \beta_0 + \beta_1 \cdot ln\left(\frac{q_{t+1}}{q_t}\right) + e_t,$$

the results of which are presented in Table 2.

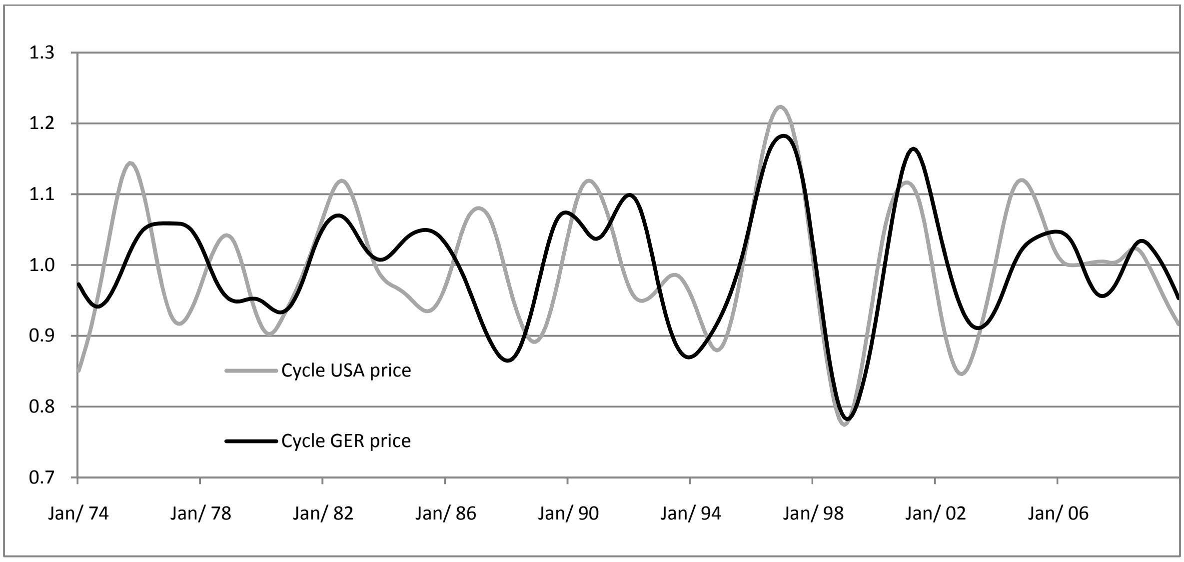
Table 2. Regression of pork price changes on contemporaneous changes in the volume of slaughtered pigs

	USA		Germany	
	coefficient	p-value	coefficient	p-value
$\hat{\beta}_0$	0.001	0.847	0.000	0.986
$\hat{\beta}_1$	-0.332	<0.001	-0.075	0.048

Source: Own calculations

The estimated $\hat{\beta}_1$ coefficients for both the USA and Germany have negative signs and are significantly different from zero at the 5% level, confirming that pork prices fall as slaughter volumes increase, and vice versa.

Figure 5. Comparing the price cycles for slaughtered pigs in the USA and Germany



Source: Own calculations

We next compare the cyclical components for the producer prices in the USA and Germany. The visual evidence in Figure 5 suggests that there was no synchronisation between the cycles during the first half of the time series, with prices in the US sometimes increasing while those in Germany were decreasing, and vice versa. However, there appears to be evidence of increasing synchronisation since the early 1990s. While the directions of the price changes from one month to the next in the US and Germany are identical only in 41% of the observations (r = -0.16) between 1974 and 1994, this share increases to 76% (r = 0.52) between 1995 and 2009.

We test whether there is an increasing synchronization of the pork cycles in the USA and Germany by estimating the following double-logarithmic model (5) using the data in Figure 5 for different sub-periods between 1974 and 2009.

$$(5) \qquad ln\left(\frac{g_{t+1}^{cyc.,USA}}{g_t^{cyc.,USA}}\right) = \beta_0 + \beta_1 \cdot ln\left(\frac{g_{t+1}^{cyc.,GER}}{g_t^{cyc.,GER}}\right) + e_t.$$

The results are presented in Table 3. While there is no evidence of synchronisation of the cyclical components of pork prices in the USA and Germany between 1974 and 1994, we can reject the null hypothesis of no synchronisation between 1995 and 2009. Moreover, the estimated coefficient of 1.022 is not significantly different from one, which is the value we would expect in the case of perfect synchronisation.

Table 3. Synchronisation of the pork price cycles in the USA and Germany

	1974-1994			1995-2009		
	coefficient	std. dev.	p-value	coefficient	std. dev.	p-value
$\hat{\beta}_0$	0.000	0.001	0.209	0.000	0.000	0.084
$\hat{\beta}_1$	-0.052	0.091	0.571	1.022	0.041	0.000

Source: Own calculations

4 Discussion and Conclusions

The evidence presented in this paper suggests first that the development of pork prices is very heterogeneous in different countries of the world, although there are clusters of countries, in particular the members of the European Union, in which pork prices do move together. Second, cyclical pork price movements in the USA and Germany have become increasingly synchronous since the middle of the 1990s.

The following facts provide possible explanations for this development: First, during the last decade the USA has become a net exporter of pig meat. While only 2% of US production was exported in 1990, this share increased to 21% in 2008. Therefore, over time the USA has increasingly had to compete with the exporting countries of the European Union for world markets. As a result, US markets have become increasingly exposed to the effect of price fluctuations on world markets. Although Germany itself has only recently become a net exporter of pork, the strong market integration in the EU-15 that was illustrated above means that Germany is essentially part of a large net exporting region that includes such major exporters as Denmark and the Netherlands. Second, the so-called MacSharry reform of the EU's Common Agricultural Policy in 1993, and subsequent reform steps in 2000 and 2003 have led, among other things, to reduced price support for grains in the EU. Today, grain prices in the EU are directly linked to world market prices. As a result, beginning in the 1990s and increasingly until today farmers in the EU and the US face similar prices for all the major feed components in pork production (oilseed and other grain substitute prices in the EU have always followed world market levels due to the EU's GATT/WTO commitment to import these duty free).

Future work could consider a number of factors. First, the analysis could be extended to other major pork producers such as China and Brazil, subject to data limitations. Second, we have neglected the influence of exchange rates on the synchronisation in our study. While local currency prices are important from the producer's point of view, trade flows and prices are influenced by exchange rates. Third, we have focused on producer prices for slaughter pigs, but producer behaviour will be driven not by pork prices alone but rather by the profitability of pork production. Profitability depends on pork prices but also prices for inputs such as piglets, feed and energy which could be considered in a more comprehensive analysis. Finally, alternatives to the Hodrick-Prescott-Filter could be employed to address the concern that this filter is subjective.

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