Studies on the Agricultural and Food Sector
in Transition Economies

Aaron Grau

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Abstract

The German dairy supply chain is one of the most important agrifood supply chains in Germany. In 2015, raw milk production accounted for 19.2% of the total domestic agricultural production value and dairy products summed up 8.0% of total German agrifood exports. Nevertheless, the economic success of the supply chain is overshadowed by reports on market power abused by dairies and retailers. Fueled by complaints of dairy farmers and dairies on non-competitive behavior of downstream supply chain agents, the German anti-trust agency conducted a sector analysis between 2008 and 2012. In its final report the anti-trust agency acknowledged the threat of oligopsony power at both markets, raw milk and dairy output market, but could not find any evidence. Thus, the main premise of the presented work is to empirically investigate the German dairy supply chain for the existence of oligopsony power at the raw milk and dairy product market.

Three approaches, structure-conduct-performance paradigm (SCPP), new empirical industrial organization (NEIO), and asymmetric price transmission (APT), are revised and their suitability for the empirical application discussed. The theory review shows that none of the discussed approaches provide a model that fits the structure of the German dairy supply chain of oligopsonistic threat on two vertically integrated markets. Additional characteristics of the theoretical frameworks limit their suitability for the study further. Either the data requirements are high and the models highly complex, like in the case of NEIO, but an index of market power can be measured, or the data requirements are rather low and the theoretic models rather simple, like in the case of APT, but market power or its extent are not clearly identified. Consequently, a modification of one of the approaches is not sufficient and a new theoretical model merging aspects of NEIO and APT had to be developed.

In a first step the two markets for raw milk as the material input and dairy product as the material output to the transformation process are modeled structurally in the spirit of the NEIO framework. However, the system of derived supply and demand equations is then used to obtain explicit solutions of the endogenous variables, the material input and output prices as well as their quantities. After rearrangement and substitution, two pricing equations, one depicting the farm-processor relation, and the other depicting the processor-retailer relation, are found which only depend on material input and output prices as well as the non-material input prices, technological change, and the measures for oligopsony power. Consequently, quantity data is obsolete. Unfortunately, the market

power indices cannot be uniquely identify from this two pricing equations with the use of standard estimation techniques.

In order to be able to evaluate the extent of market power a new estimation strategy was developed that links the methods vector error correction model (VECM), Kalman-Filter, and dynamic factor analysis (DFA) together. The VECM accounts for stationarity in combinations of the variables, commonly found between price series of integrated markets, and allows estimating the two pricing equations simultaneously as cointegration vectors. The error correction representation is transformed via the simple two step estimation technique of Lütkepohl and Krätzig (2004) in order to be able to apply the Kalman-Filter and to obtain time-varying parameters. The time-variation is assumed to be caused solely by changes in oligopsony conduct and is extracted in form of dynamic factors through the application of the DFA. The results of the DFA do not only permit to uniquely identify the time-varying market power indices, but also the price elasticities of supply. With knowledge of these elasticities as well as the market power indices the so-called buyer power indices can be calculated which measure the relative effects of the oligopsony conduct on the prices.

The derived theoretical model and the estimation strategy were applied to the German dairy supply chain using monthly data over the time horizon from January 2003 to December 2015. The data consisted of price time series comprising the price for raw milk, a dairy output price derived by share-weighting the prices of important dairy products, as well as prices of other cost variables involved in the product transformation process along the chain. The initial statistical analysis revealed non-stationary of the variables and two long-rung cointegration relationships among them, justifying the theoretical model and the use of a VECM. The estimation strategy was applied to a total of nine different VECM specifications differing in lag length and assumptions on the other cost variables. The specification with a lag length of two and weakly exogenous variables was the best fit for the data.

The empirical application was successful and revealed theoretically consistent and statistically significant market power indices on the German raw milk market and dairy output market for the entire time period. While the raw milk market is close to perfect competition with a market power index value range of 0.038 to 0.048, the dairy output market is subject to larger market imperfections with a value of 0.14 to 0.22 and reaches Cournot level at times. The rather inelastic supply of raw milk and dairy products due to asset specificity and high investment costs lead in collaboration with the derived market power indices to large mark-downs. While the German raw milk price was marked-down by

21% to 48%, the mark-down of the share-weighted dairy output price ranges between 49% and 82% over the analyzed time period. Overall, large rents were shifted in disadvantage of dairies and in particular of dairy farmers downstream the supply chain and overall welfare was reduced.

To overcome the market imperfections on each market of the German dairy supply chain different steps can be taken. While low levels of oligopsony conduct are observed on the raw milk market, the inelastic response of raw milk supply to price changes causes the rather large mark-downs. Consequently, policies that enhance the responsiveness of supply, e.g. credit availability and technology transfer to dairy farmers, should be implemented. For the dairy output market, the extent of market power and, because of a similar inelastic supply, the mark-downs are larger. Consequently, measures to decrease market power need to be promoted. One possibility is to increase the number of buyers of dairy products and thus the marketing options for dairies. This could be done in the case of the German dairy supply chain by promoting exports or dissolving procurement alliances between larger and smaller retailers.

Several innovations make the presented approach a novelty in the field of market power studies. To our knowledge no attempts to model oligopsony power on two vertically integrated markets exist so far in the economic literature. While the markets are model in the fashion of NEIO, the derivation of partial equilibrium equations and the final pricing equations significantly lower the data requirement and the necessary number of equations for estimation. Moreover, by assuming time-variation in the oligopsony conduct and applying the developed estimation strategy, the market power indices are adaptive rather than ‘static’.

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List of abbreviations

AC	Average cost
ADF	Augmented Dickey Fuller Test
AIC	Akaike Info Criterion
AICc	Akaike Info Criterion with correction
APT	Asymmetric price transmission
BPI	Buyer power index
CE	Conjectural elasticity
CPI	Consumer price index
CPM	Conduct parameter method
CRS	Constant returns-to-scale
CV	Conjectural variation
DFA	Dynamic factor analysis
ECM	Error correction model
ECT	Error correction term
EDM	Equilibrium displacement model
EM	Expectation-maximization algorithm
EU	European Union
FP	Final Prediction Error
FPE	Farm-processor equation
GIM	General identification methodology
HQC	Hanna-Quinn Criterion
MARSS	Multivariate autoregressive state-space
MFC	Marginal factor cost
MC	Marginal cost
ME	Milk equivalent
ML	Maximum likelihood
MR	Marginal revenue
MRP	Marginal revenue of product
MS	Markov-switching
NEIO	New empirical industrial organization
OLS	Ordinary least squares
PCM	Price-cost margin
PRE	Processor-retailer equation
PTA	Production-theoretic approach
S2S	Simple two step estimation procedure
SC	Schwarz Criterion
SCPP	Structure conduct performance paradigm
SMP	Skim milk powder
UK	United Kingdom

USA	United States of America
VC	Variable cost
VECM	Vector error correction model
VMP	Value of marginal product

1 Introduction

The study of market power in agri-food supply chains possesses a long history in economic literature. However, it has been primarily dominated by oligopoly studies. For a long time agricultural markets were even regarded as prime example of perfect competition (Sexton, 2013). The reason that the threat of seller power by the food processing industries was early identified as plausible and a rich field for empirical application is that heavy concentration and consolidation processes shaped most agri-food supply chains in developed countries into a form of an hour glass until the 1950s and 1960s. In the U.S. food processing sector, for example, 50% of the value added in this sector was achieved by only 20 manufacturers in 1995, while in 1954 they already accounted for half of the share (Sexton, 2000).

On the head and tail of agri-food supply chains concentration remained low. Agricultural producers persisted to be atomistic and retailers heterogeneous. This structure allowed the processing sector to gain a dominant position and to drive distribution with the development of strong brands and the use of wholesalers and retailers as a link to consumers (Dobson et al., 2003). Consequently, research until the 1980s focused more and more on the food processing sector as a possible source of oligopoly power with welfare loss implications, in particular, for retailers and final consumers. The notion of competitive farm commodity markets persisted (Swinnen & Vanderplas, 2010).

In the late 1980s and 1990s research focus shifted slowly towards the idea of oligopsony power on the raw agricultural commodity markets. Finally, the possibility of buyer power of a concentrated processing sector towards the atomic farm sector was acknowledged (e.g. Muth & Wohlgenant, 1999; Schroeter, 1988). Apart from different levels of concentration, further sector specific characteristics of the agricultural sector were quickly found that promote the threat of buyer power. Agricultural products are often less ‘mobile’ due their perishableness, processors are highly depended on non-substitutable, specialized agricultural inputs, and farmers are highly specialized in the production of specific goods through extensive investment, which represent exit barriers for farmers and cause raw supply to be inelastic (Rogers & Sexton, 1994).

Starting in the 1990s, mergers and acquisition activities have heavily promoted concentration at the retail level in the EU and the USA. By mid-1990 retail concentration in the EU surpassed food sector concentration, and today is much higher than concentration in the food processing industry has ever been (Swinnen & Vandeplas, 2010). As a result, the TOP 20 retailers in the EU accounted for 40%

of the total revenue at the beginning of the 2000s. In comparison, the TOP 20 food processor only accounted for 15% (Clarke et al., 2003). By the mid-2000s, in some EU countries, such as Germany or the UK, the five largest enterprises encompass more than 70% of retailers' total turnover (Consultative Commission on Industrial Change, 2008).

These rather new developments at the retail level seemed to have reshaped the nature of agri-food supply chains. Apart from the concentration processes at this stage, retailers have frequently integrated wholesaling into their business, thus extinguishing this stage, and further taken control over the upstream stages by demanding specific products and creating own brands (Dobson et al., 2003). Consequently, the manufacturers were replaced by retailers as driver of the agri-food supply chain (Bell et al., 1997).

The new structure of agri-food supply chains has caused a debate in economic literature whether the growing power of retailers might be welfare enhancing or diminishing. A series of authors (e.g. Chen, 2003; Dobson & Waterson, 1997) argue that the growing buyer power in form of bargaining power allows retailers to countervail the original oligopoly of the food sector and extract beneficial conditions for retailers, which ultimately are passed on to consumers. However, for countervailing power to be applicable to the food sector must actually earn rents above the competitive level (Chen, 2008).

Consequently, other authors argue that the retail sector might really exert oligopsony power and push the procurement price by buying less. This does not only harm the food sector, but also consumers, since it has quantity distortion effects (OECD, 2008). However, even if higher concentration in the retail sector might increase oligopsony power it is argued by some authors that gains in efficiency (Demsetz, 1973; Guy et al., 2004; Swinnen & Vanderplas, 2010), reduction in market failures through vertical integration (Slade, 1998), or increasing innovation activities, since firms in an highly concentrated sector benefit from R&D and thus are more inclined to invest (Pray et al., 2005), could offset the negative welfare effect of oligopsony.

The debate of buyer power of retailers was ultimately shifted into the public domain in the year 2009. While consumer food prices and agricultural producer prices experienced a similar trend of rapid growth over the years 2007 and 2008, producer prices quickly dropped below the pre-2007 level in 2009 but consumer prices remained high. Apart from farmers protesting in front of retailers' branches in several EU countries (Swinnen & Vanderplas, 2010), also the European Commission (EC) warned of negative long-term effects of the oligopsony power of retailers for the entire agri-food sector. The caused reduced profitability and quantity distortions limit food processors' incentives to invest in improved product quality and innovation of production process and consequently lower the future efficiency and competitiveness of the entire chain (EC, 2009).

Nevertheless, research on oligopsonistic behavior of retailers remains scarce. Only a few studies have factored in this development and the possible threat of retailers' buyer power on the food industry output market in their empirical applications (i.e. Fałkowski, 2010; Gohin & Guyomard 2000; Lloyd et al., 2009; Madau et al., 2016). The primary cause for this is the availability of data. Even though, data at the producer and consumer level are frequently publicly available, the terms between retailers and food processors remain mostly in the dark (Lloyd et al., 2009; Sexton, 2013).

The aim of the following work is to overcome this deficit and add to the literature. However, in contrast to the before mentioned studies on oligopsony power by retailers, also oligopsony behavior of food processors towards farmers is considered to approximate the structure of modern agri-food supply chains in developed countries as accurate as possible. In addition, the data prerequisite is significantly lowered by deriving a model that does not require any kind of quantity data, but only requires data on prices, for outputs and inputs along an agri-food supply chain. To our knowledge we are not aware of any similar approach in the economic literature so far.

For empirical application the German dairy supply chain was selected due to characteristics, which make it a primary target for the study of subsequent oligopsony along an agri-food supply chain. As mentioned before, the retail sector is dominated by a handful of firms which generate the major share of food retailing revenue. These retailers face around a hundred dairy companies on the markets for dairy products. Nevertheless, also the dairy stage can be considered as highly concentrated with up to 50% of German raw milk processed by only five companies (Loy et al., 2015). German dairies, on the other hand, source raw milk almost entirely from a domestic and atomistic primary production consisting of ten thousands of dairy farmers. Not surprisingly, the German anti-trust agency has received a growing number of complaints by dairy farmers and dairies on the procurement behavior of downstream buyers, respectively the dairies and retailers, since the start of the 2000s. While dairy farmers have been criticizing that dairies abuse their buyer power by asymmetrically transmitting prices, price decreases on the dairy output market are faster transmitted to the upstream stage than prices increases, dairies have been accusing retailers to abuse their market position to lower the prices for dairy products by colluding. As a result an official investigation was started by the anti-trust agency in 2008 with its final report published in 2012. The German anti-trust agency stated that even though procurement prices are low and the structure along the chain seems to favor the position of buyers, no evidence on the abuse of market power was found (Bundeskartellamt, 2009).

With the model developed we are able to identify market power and its level along the German dairy supply chain. For this purpose, the time horizon January 2003 to December 2015 was chosen, since it does not only cover the period under investigation by the German anti-trust agency, but also phases of heavy structural change, in particular at the farm and processing level, the EU policy reforms attempting to liberate the milk market, and the before mentioned growing asymmetry in producer and consumer price between 2007 and 2009. The ending date was chosen to also uncover the effects of the recent final abolishment of EU milk quota system in April 2015 on the entire dairy supply chain and possible market power distribution along the chain.

The work is structured in the following way. Chapter 2 provides a description of the German dairy supply chain and its recent developments, also covering vertical and horizontal relationships between chain agents and latest policy changes. From its characteristics and the comment of the German anti-trust agency it is assumed that the supply chain is affected by subsequent oligopsony conduct on the raw milk and dairy product market. The adjacent Chapter 3 delivers an overview of relevant theoretic models in economic literature that have been developed to investigate market power so far. It will become apparent that no theoretic model of subsequent oligopsony has been developed so far. Chapter 4 presents an overview of all known empirical applications of the theoretic models of Chapter 3 to the dairy sector. Chapter 5 derives a theoretic model of oligopsony on two vertically integrated markets and the partial equilibrium equations that only consist of price data. The methodology applied to estimate an index of oligopsony power of the dairies and retailers respectively is introduced in Chapter 6. Chapter 7 presents the empirical application to the German dairy supply chain with its various steps and the obtained results for the level of oligopsony and the actual price mark-down for both markets due to the oligopsony conduct. Chapter 8 gives explanations for the estimated level of market power and lists shortcomings of the approach. Chapter 9 provides final conclusions.

2 German dairy supply chain

The German dairy supply chain is one of the most important branches of the German food industry. German dairy farmers generated around 10.1 billion € of production value in 2015, which accounted for about 19.2% of the total domestic agricultural production value (52.6 billion €). The dairy industry itself created revenue of 23.7 billion € in the same year. 28% of its revenue was generated outside the domestic market and the total share of milk and dairy products in overall German exports made up 0.7% and of total agri-food exports 8.0%. The German dairy supply chain is also of great significance to global dairy production. In 2015 around 20.0% of all EU's raw milk (163.2 million t) was produced in Germany (32.8 million t). This production volume makes Germany the 5th largest producer after the USA and three of the BRIC countries (Brazil, China, and India). Furthermore, German dairies ranked 6th in fresh milk, 5th in butter, and 2nd in cheese production worldwide (AMI, 2016).

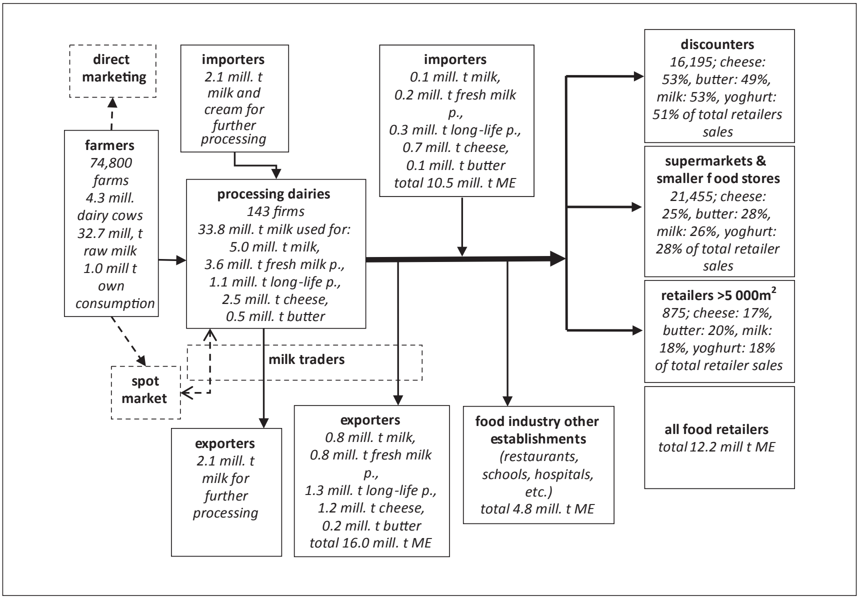
The following sections will give an overview over the German dairy supply chain. First, the structure of the chain and each level directly involved in the transformation of the product from production over processing to marketing will be discussed. In this context also relevant policy changes affecting the structure of each level and the chain will be depicted. Second, the economic interactions between the stages will be briefly portrayed. And last but not least, a summary will merge all subsection to deduce a coherent picture of the entire chain and possible market power distribution along the chain.

2.1 Dairy supply chain

The German dairy supply chain with data from the years 2014 and 2015 is schematically illustrated in Figure 1. German dairy farmers almost exclusively deliver their output product raw milk to German dairies. In 2015, 96.3% of the raw milk produced was delivered to dairies operating in Germany. The rest of raw milk is either directly marketed, used for the production of around 0.1 million t of butter or used for own consumption by farmers (AMI, 2016). This is a consequence of delivery obligations, defined in contracts towards their dairy cooperatives or investor-owned dairies (Bundeskartellamt, 2012). Most raw milk is contracted over an average period of 3 years, if delivered to cooperative dairies, and 3 years and 9 months, if delivered to investor-owned dairies (Bundeskartellamt, 2009).

The raw milk is picked up by dairies at the farm gate on a frequency of 1 to 3 days (Bundeskartellamt, 2009). The amount of raw milked delivered to German dairies increased by 18.3% compared to 2003. Furthermore, around 2.1 million t were imported. Overall, German dairies processed approximately 33.8 million t in 2015. The costs of purchased raw milk accounts for about 55% of the dairies' total costs (Bundeskartellamt, 2012).

Figure 1: Structure of the German dairy supply chain (2014/15).



Source: own illustration based on data from BMLEV, 2015; Bundeskartellamt 2009/2012; MIV, 2016.

Only small amounts of raw milk, 1% to 6% of total production, and other fast perishable, unprocessed dairy products, are traded on spot markets by milk traders and dairies, in most cases to balance short-time oversupply and undersupply of dairies. Milk traders mostly act as an important export agent for dairies (Bundeskartellamt, 2009).

The raw milk is then processed into a diverse number of products, most importantly milk for consumption, fresh milk products (e.g. yoghurt), cheese, long-life milk products (such as milk powder), and butter. The produced products are mainly sold to a small number of retailers (around 37% of ME in 2015), especially discounters, or exported (around 49% of ME in 2015). The remaining 14% of ME are delivered to wholesalers, large consumers, or the food industry.

2.1.1 Raw milk production

In Germany the stock of dairy cows declined by around 2.0% from 2003 to 2015 (see Table 1). However, since the milk output per cow increased by approximately 21.4%, the overall raw milk production grew by around 4.8 million t (+17.4%) (see Table 1). Thus, Germany was the largest producer of raw milk in the European Union in 2015 with approximately 32.7 million t, of which only around 2.3% was produced organically in 2015 (BMLEV, 2006-2015).

Table 1: Total stock of dairy cows, average milk production per cow, total milk production, milk delivered to dairies, average fat and protein content of delivered milk, and average milk price at farm gate in selected years.

	2003	2006	2015	change 2003-2015	in %
total stock of dairy cows (in 1,000)	4,373	4,054	4,285	-182	-2.0%
avg. milk production per cow (in kg)	6,272	6,849	7,616	1,344	21.4%
total milk production (in 1,000 t)	27,874	27,995	32,721	4,847	17.4%
milk delivered to dairies (in 1,000 t)	26,621	26,876	31,495	4,874	18.3%
share of total milk production	95.5%	96,0%	96.3%		0.8%
avg. milk fat content	4.20%	4.16%	4.09%		-0.1%
avg. milk protein content	3.42%	3,40%	3.42%		0.0%
avg. milk price (€/100 kg) at farm gate	31.4	27.4	29.1	-2.3	-7.3%

Source: own illustration based on data from BMLEV, 2006-2015.

A fierce structural change affected German dairy farmers over the analyzed period. The number of dairy farmers dropped by around 38.4% between the years 2003 and 2015. Only 74,800 farms were still producing in 2015, which implies that around 46,700 farms stopped producing since 2003. Furthermore, more and more cows are held on average by a single farm (on average 54.0 in 2015 compared to 36.0 in 2003). The number of dairy farms holding 100 to 199 cows grew approximately by 121.5% between 2003 and 2015. The stock of dairy cows living on farms with less than 50 animals decreased, while the stock held on farms with more than 50 animals increased (see Table 2).

Over the period 2003 to 2015 policy changes occurred that heavily affect raw milk production. Since its introduction in 1984 the EU milk quota system regulated the maximum amount of raw milk a member state was allowed to produce. Each farm was assigned a quota of milk production. However, in 2015 the national raw milk quota system was abolished to liberalize the market. The available quota had been annually increased, from 2006 to 2008 by 1.5% and from 2008 on by 1.0%, to help the dairy sector to adjust slowly to a completely liberalized market (Gerlach et al., 2006; Fahlbusch et al., 2009).

To allow individual firms to expand their production, a milk quota exchange was introduced in the fall of 2000. Prior to this, EU dairy farmers were only permitted to increase their production capabilities on agricultural land that was originally covered by the quota restricting the trade to be rather local if dairy farmers

Table 2: Structure of German dairy cow farming in 2003 and 2013.

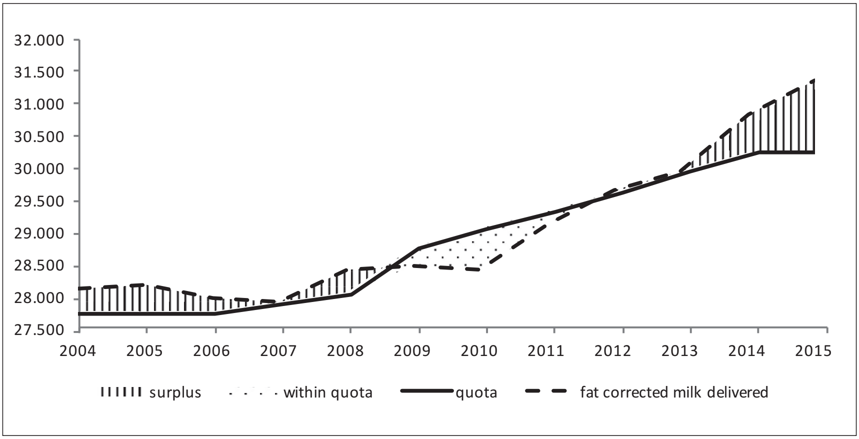
	dairy farms			**share of total**		
distribution of stocks	2003	2013	Change	2003	2013	Change
1 to 9	20,433	9,800	-52.0%	16.8%	12.4%	-4.4%
10 to 19	27,694	12,700	-54.1%	22.8%	16.1%	-6.7%
20 to 49	49,666	28,400	-42.8%	40.9%	36.0%	-4.8%
50 to 99	19,069	19,900	4.4%	15.7%	25.3%	9.6%
100 to 199	3,160	7,000	121.5%	2.6%	8.9%	6.3%
more than 200	1,502	2,200	46.5%	1.2%	2.8%	1.6%
total dairy farms	121,524	78,800	-35.2%	100.0%	100.0%	0.0%
	dairy cows (in 1,000)			**share of total**		
distribution of stocks	2003	2013	Change	2003	2013	Change
1 to 9	109	50.7	-53.5%	2.5%	1.2%	-1.3%
10 to 19	400.6	186.5	-53.4%	9.2%	4.4%	-4.8%
20 to 49	1,556.6	921.4	-40.8%	35.6%	21.7%	-13.9%
50 to 99	1,257.4	1,314.7	4.6%	28.8%	30.9%	2.2%
100 to 199	406.7	909.7	123.7%	9.3%	21.4%	12.1%
200 and more	641.7	868.3	35.3%	14.7%	20.4%	5.7%
total dairy cows	4,372.0	4,251.4	-2.8%	100.0%	100.0%	
avg. dairy cows per farm	36.0	54.0	50.0%			

Source: own illustration based on data from BMLEV, 2006 and 2015.

wanted to avoid geographic dispersion. Even though the quota exchange lifted this requirement, firms were still restricted to trade quota within their own region. 21 of these smaller dairy regions existed until 2007 in Germany and limited expansion regionally. In 2007, the number of dairy regions was decreased to two, and thus quota could be traded across larger distances. As a consequence, quota was mainly transferred from the states of Baden-Württemberg and Lower Saxony to North Rhine-Westphalia, Mecklenburg-West Pomerania, and Bavaria (Bundeskartellamt, 2009). Bavaria was the largest raw milk producer of the German federal states in 2015 with around 8.1 million t (AMI, 2016).

Figure 2 displays the quota assigned to the German dairy farmers by the EU and the milk, corrected for the actual fat content, delivered to dairies since 2004. While between 2004 and 2008 more milk was delivered to dairies than allowed, the annually increasing quota allowed German farmers to expand production within the growing quota regime until 2013. In the last two years of the quota policy, German farmers were increasing their production vastly (see Figure 2), and large fees had to be paid to the EU, alone 0.3 billion € in 2015 (AMI, 2006-2016).

Figure 2: German milk quota and raw milk delivered to dairies from 2004 to 2015.



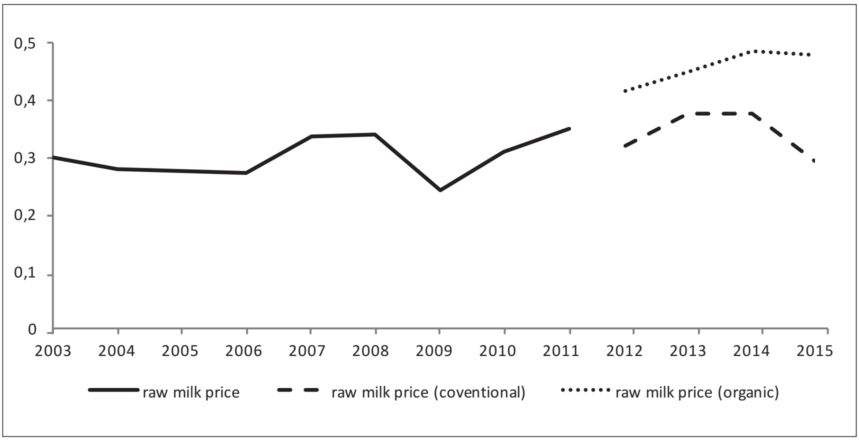
Source: own illustration based on data from AMI, 2010-2016.

Many mid-sized dairy farms tried to prepare for the abolishment of the quota by increasing their economies of scale and thus their stock of dairy cows (see Table 2). The number of farms with 50 or more dairy cows grew by more than 20%. Consequently, smaller-sized dairy farms (< 20 dairy cows), which lack capital or even space to grow further, were forced to shut down their production. More than 50% of these farms quit the dairy business.

Apart from the abolishment of the quota, dairy farmers saw other forms of government intervention in their favor vanish. Gradual reductions in the intervention levels for dairy products, which are now quantity bound, and the expiration of dairy export subsidies were implemented (Bouamra-Mechemache et al., 2008). The intervention prices for butter and skim milk powder (SMP) can be seen as a minimum price for producers at which a government agency clears the market for these products to reduce supply. Since 2003, the raw milk price has never fallen below the intervention level and thus lost its meaning as a raw milk target price. However, in 2009 the intervention regime stabilized prices at the intervention level. For butter the invention price is currently at 2.22 € per kg and for SMP at 1.75 € per kg with a maximum intervention quota of 30.000 t and 109.000 t respectively (Fahlbusch et al., 2011).

Overall, the economic situation for dairy farmers, especially smaller ones, was rather insecure over the period from 2003 to 2015. Figure 3 illustrates the annual average German raw milk price. Drastic drops in the price after peaks, e.g. 2007/2008 and 2013/14, hit small German dairy farmers particularly hard and many had to give up producing. During those brief periods of high prices many small farmers loaned money to increase their production capacities, since they saw only one possibility to survive in a liberalized market setting by growing.

Figure 3: German annual averaged raw milk price from 2003 to 2015.



Source: own illustration based on data from AMI, 2009-2016.

When prices dropped, these farmers lacked financial liquidity and had to declare bankruptcy, further promoting structural change (see Table 2) (Lfl & LEL, 2015; 2016).

Even though prices for organically produced raw milk continued to increase after 2012, while the price for conventionally produced milk declined, switching the production to organic was not seen as a possibility as a result of strict regulations, i.e. in form of a two year transition period, lack of dairies with organic production or the necessary capital (Bundeskartellamt, 2009). In 2015 only 2.3% of all raw milk delivered to German dairies was produced organically (AMI, 2016), and demand for organic dairy products remains marginal (Bundeskartellamt, 2009).

2.1.2 Milk processing

Around 33.8 million t of raw mild were processed by 143 German dairies in 2015. This is an increase of 18.6% compared to 28.5 million t in 2003. As mentioned before, almost all the raw milk was sourced from German dairy farmers (around 93.8%). Nevertheless, raw milk imports from neighboring countries have become more important, since domestic production accounted for 96.5% of dairies' total procurement in 2003.

In 2014, the processing of raw milk into dairy products split as follows (for further details see Table 3):

- 5.0 million t of milk for consumption (-13.6% compared to 2003)
- 2.9 million t of fresh milk products (e.g. yoghurt) (+11.0% compared to 2003)
- 1.4 million t of long-life milk products (e.g. milk powder) (+12.0% compared to 2003)
- 2.5 million t of cheese (+24.7% compared to 2003)
- 0.5 million t of butter and milk fat products (+8.2% compared to 2003)

In four of these five dairy product groups Germany was self-sufficient in 2014 and exported large amounts of these products. Only for butter and other milk fat products Germany was not 100% self-sufficient. However, its self-sufficiency rate was raised to 99.0% in 2014 and grew by 15.4%-points compared to 2003 (see Table 3).

Table 3: Total German production of dairy products, import and export, consumption and self-sufficiency rate in selected years.

	milk for consumption				fresh milk products (e.g. yoghurt)			
in 1,000 t	2003	2014	change	2003	2014	change		
production farmers	174	125	-49	-28.2%	0	0		
production dairies	5,821	5,030	-791	-13.6%	2,688	2,984	296	11.0%
total production	5,996	5,155	-841	-14.0%	2,688	2,984	296	11.0%
import	27	87	60	222.2%	176	169	-7	-4.0%
import/total production	0.5%	1.7%		1.2%	6.5%	5.7%		-0.8%
export	840	759	-81	-9.6%	513	746	233	45.4%
export/total production	14.0%	14.7%		0.7%	19.1%	25.0%		5.9%
consumption	5,183	4,493	-690	-13.3%	2,351	2,407	56	2.4%
self-sufficiency rate	115.7%	111.9%		-3.8%	114.3%	124.0%		9.7%
	long-life milk products (e.g. milk powder)				**cheese**			
in 1,000 t	2003	2014	change	2003	2014	change		
total production	1,245	1,395	150	12.0%	1,984	2,475	491	24.7%
import	236	390	154	65.3%	576	727	151	26.2%
import/total production	19.0%	28.0%		9.0%	29.0%	29.4%		0.4%
export	761	1,216	455	59.8%	701	1,188	487	69.5%
export/total production	61.1%	87.2%		26.1%	35.3%	48.0%		12.7%
stock change	-45	39			69	22		
consumption	765	530	-235	-30.7%	1,790	1,992	202	11.3%
self-sufficiency rate	162.7%	263.2%		101.5%	110.8%	124,2%		13.4%
	butter and milk fat products							
in 1,000 t	2003	2014	change					
production farmers	1	0.1	-0.9	-90.0%				
production dairies	452	490	38	8.4%				
total production	453	490	37	8.2%				
import	168	148	-20	-11.9%				
import/total production	37.1%	30.2%		-6.9%				
export	89	149	60	67.4%				
export/total production	19.6%	30.4%		11.8%				
changes in stock	-10	-5						
consumption	542	495	-47	-8.7%				
self-sufficiency rate	83.6%	99.0%		15.4%				

Source: own illustration based on data from BMLEV, 2005 and 2015.

While the output in general increased, the domestic consumption decreased. Except for cheese products (+11.3%) and fresh milk products (+2.4%), which experienced small level of growth in consumption, smaller amounts of milk (-13.3%), long-life milk products (-30.7%), and butter and milk fat products (-8.7%) were consumed (see Table 3).

Due to the growth in production more dairy products had to be exported. Overall, exports grew drastically compared to 2003: exports of fresh milk products by 45.4%, exports of long-life milk products by 59.8%, exports of cheese by 69.5%, and exports of butter and milk fat products by 67.4%. Only exports of milk for consumption declined by 9.6%, however, relatively less than the overall production. Consequently a larger share of domestic fresh milk production was exported in 2014 than 2003. Imports of some dairy product groups also grew tremendously percentagewise, but in all Germany evolved as a net exporter of dairy products (see Table 3).

149 dairies, with more than 50 employees, operated in Germany in 2014 (see Table 4). This is a decline of around 39.7% compared to 2003. The dairies earned approximately 26.1 billion € of revenue, a little bit more than ¼ of it outside of Germany. The total revenue increased by around 27.0%, while the number of employees increased by 12.5%. Thus the average revenue per firm (+110.6%) and per employee (+36.8%) increased considerably from 2003 to 2014.

Table 4: Number of German dairies, total dairy employees, (domestic and external) revenue of German dairies, and average revenue per dairy and employee in selected years.

	2003	2014	Change	Change in %
dairies[1]	247	149	-98	39.7%
total number of employees	34,238	38,532	4,294	12.5%
total revenue (in million €)	20,555.8	26,104.0	5,548.2	27.0%
domestic revenue (in million €)	16,879.5	19,067.9	2,188.4	13.0%
revenue on external markets (in million €)	3,677.3	7,036.1	3,359.8	91.3%
avg. revenue per dairy (in 1,000 €)	83,170	175,195	92,025	110.6%
avg. revenue per employee (in 1,000 €)	600	821	221	36,8%

Source: own illustration based on data from BMLEV, 2005 and 2016.

Notes: [1] With more than 50 employees.

The structure of German milk processing is dominated by large dairies. In 2012, 25 dairies processed annually more than 300,000 t of raw milk (see Table 5). In total, these 25 firms processed more than 70% of the entire milk processed in Germany. Their share of total milk processed increased by around 8.2%-points between 2003 and 2012. In the meantime, around 17.7% of German dairies processed less than 5,000 t per year, but accounted only for 0.2% of German overall milk production. 96.1% of all German raw milk was processed in 2014 by firms with more than 50,000 t annual processing capacities, in total 78 dairies.

Table 5: Structure of German milk processing in 2003 and 2012.

	dairies			**share of total**		
processed milk in 1,000 t	2003	2012	Change	2003	2012	Change
less than 5	47	26	-44.7%	24.1%	17.7%	-6.4%
5 to <50	35	43	22.9%	17.9%	29.3%	11.3%
50 to <300	84	53	-36.9%	43.1%	36.1%	-7.0%
300 and more	29	25	-13.8%	14.9%	17.0%	2.1%
total	195	147	-24.6%	100.0%	100.0%	
	amount of milk (in 1,000 t)			**share of total**		
processed milk in 1,000 t	2003	2012	Change	2003	2012	Change
less than 5	66	53	-19.4%	0.2%	0.2%	0.0%
5 to <50	1,594	1,095	-31.3%	4.3%	3.7%	-0.6%
50 to <300	12,399	7,585	-38.8%	33.1%	25.5%	-7.6%
300 and more	23,400	21,021	-10.2%	62.5%	70.6%	8.2%
total	37,459	29,754	-20.6%	100.0%	100.0%	

Source: own illustration based on data from BMLEV, 2003 and 2015.

The concentration of the German dairy industry can further be observed in the list of the TOP 10 German dairy companies (regarding revenue) in 2015 (see Table 6). Four of them are cooperatives, one being a Danish-Swedish cooperative (Arla Foods). Overall, these 10 companies accounted for approximately 11.0 billion € of domestic revenue, around 41%. Table 6 also illustrates that the TOP 10 dairies earn less than 50% of their revenues domestically and their main income source are foreign markets. Thus the export business on external markets was becoming more essential to large dairy companies' performance.

Table 6: Revenue of the TOP 10 German dairy companies in 2015.

	domestic revenue	total revenue
DMK Deutsches Milchkontor	3.18	5.30
Unternehmensgruppe Theo Müller	1.60	3.70
Arla Foods	1.55	10.61
FrieslandCampina	1.37	11.35
Hochwald Foods	0.68	1.59
Bayernland	0.63	0.90
Hochland	0.58	1.28
Savencia	0.50	4.60
Meggle	0.47	1.00
Zott	0.43	0.96

Source: own illustration based on data from Lfl & LEL, 2015 and 2016.

Overall, concentration has increased in the German dairy industry through mergers and acquisitions tremendously from 2003 to 2015. However, in comparison to some other food processing industries the share of the ten largest dairy enterprises in the sector's total revenue still remains rather low. While in poultry meat processing the ten largest firms account for 70.6% of the total revenue, the ten largest dairies accumulated 43.3% of total revenues in 2012. Nevertheless, in meat processing in general, pastry production, and the overall food industry the TOP 10's share is significantly smaller than in the dairy industry with 25.8%, 22.3%, and 12.3% respectively. Thus the dairy industry's concentration can be seen as a concern (BMLE; 2016).

Even though the domestic market for dairy products grew only slightly or in some product groups even decreased, dairy companies increased their processing capacities and thus their demand for raw milk. The demand for raw milk actually outpaced the growth in production, which was enabled by the annually increasing quota, and was covered by increasing raw milk imports. The growing possibility to market the extra production through exports gave the German dairy industry a window of growth.

2.1.3 Marketing

In 2015, the output of the dairies was primarily exported (49% milk equivalent) or sold to retailers (37%), and other larger consumers (14%) including wholesalers, large costumers, and the food industry for further processing (MIV, 2016). Even though a large share of the processed milk was exported, exports only accounted for approximately 28.0% of dairies' revenue. More than half of the revenue from exports was generated with cheese products, followed by long-life dairy products with around 31.3%. While cheese is almost exclusively sold to EU member countries, more than 90%, around 40% of long-life dairy products were marketed to a diverse number of non-EU countries, primarily located in the Middle and Far East (AMI, 2016). Nevertheless, only 17.6% of export revenue from dairy products was earned outside the Common Market (BVE, 2016).

2.1.3.1 Retailers

The main income for the German dairy industry is earned domestically. The primary outlets on the domestic markets are retailers with approximately 76.3% of all milk equivalent marketed in Germany. The structure of the German food distribution sector is characterized by a dominance of small-to-medium sized stores. Table 7 substantiates a dominance of small stores measured by square meter per shop. In 2014 small shops with less than 200 m², in particular discounters, were the dominant form of food distribution in Germany. As a counterpoint, 874 large retailers with more than 5,000 m² were counted in 2014. In German

Table 7: Structure of German food retailing in 2003 and 2014.

	number of stores		revenue in € billion		revenue per store in € million	
	2003	2014	2003	2014	2003	2014
retailers >5000m²	2,688	874	32.9	18.9	12.24	21.62
discounters	14,214	16,195	50.1	66.9	3.52	4.13
supermarkets	8,620	11,855	29.7	55.5	3.45	46.86
other food stores	37,350	9,600	13.8	4.9	0.37	0.51
overall	62,872	38,525	126.5	146.2	2.01	29.75

Source: own illustration based on data from BMLEV, 2006-2015.

national statistics discounters accounted for 16,195 stores (no breakdown by size is available) (BMLEV, 2015).

The highest revenue per store (21.6 million €) in food retailing was generated by large retailers in 2014. However, their overall revenue declined by 14 billion € between 2003 and 2014. Discounters generated 66.9 billion €, around 45.7% of the total food retailing revenue, but in comparison to large retailers and supermarkets with a fairly low revenue per shop of 4.1 million €. Table 7 displays that other and in most cases smaller shops accounted for a large number of stores, but their overall revenue was marginal (3.3% of total revenue) and they earned only 0.5 million € per shop in 2014 (BMLEV, 2006-2015).

Additionally, discounters in Germany are expanding. In 2004 discounters opened 401 new stores which were 2.8% more than in 2003. Between the years 2003 and 2014 the number of discounter stores increased by about 13.9%. While large retailers are becoming fewer but earn more on average per unit, smaller retailers who do not co-operate to achieve scale effects have competition disadvantages and are less economically viable. Alone between 2003 and 2004 7.8% of the small retailers (<100m²) exited the food retailing market (BVE, 2016; BVE, 2007).Despite the dominance of small units, food retailing in Germany is heavily concentrated. The five largest food retailers achieved a market share of 72.3% of 191 billion € total revenue in grocery sales in 2015 (BVE, 2016). A series of mergers and acquisitions, e.g. the Edeka Group bought the discounter Plus in 2007, resulted in this fast growing and high concentration ratio. The five largest food retailers in Germany were the Edeka Group (25.3% of food revenue in 2014), Rewe Group (15.0%), Schwarz Group (14.7%), Aldi Group (11.9%), and Metro Group (5.4%) in 2015 (BVE, 2016; BVE, 2007).

2.1.3.2 Consumers

Most consumers buy dairy products in discounters (see Table 8). Around half of the amount of dairy products was sold to consumers via discounters in 2014. While larger retailers account for a bit less than 1/5 of total dairy sales in the individual product categories, supermarkets market more than ¼. Less than 5% of dairy products were sold in other establishments. The shopping habits of German consumers didn't change much between 2003 and 2014. Discounters and supermarkets increased their shares of total sales slightly, while larger retailers lost some.

The overall consumption of dairy products in Germany decreased between 2003 and 2014 (see Table 9). Germans consumed on average around 127.6 kg of dairy

Table 8: Share of total sales for selected dairy products for discounters, larger retailers, supermarkets and other establishments in 2014.

	discounters	retailers >5000m²	supermarkets	other establishments
cheese	53.1%	17.2%	25.2%	4.5%
butter	49.0%	20.3%	28.1%	2.5%
milk	53.1%	18.0%	26.0%	2.9%
yoghurt	51.3%	18.4%	27.9%	2.4%

Source: own illustration based on data from BMLEV, 2015.

products in 2014 (a decrease of 17.4 kg compared 2003). Some dairy products are more and more popular among consumers, e.g. cheese (see Table 9). Other products, such as buttermilk (-31.3%), cream (-21.6%), and butter (-13.6%) were consumed less than in 2003.

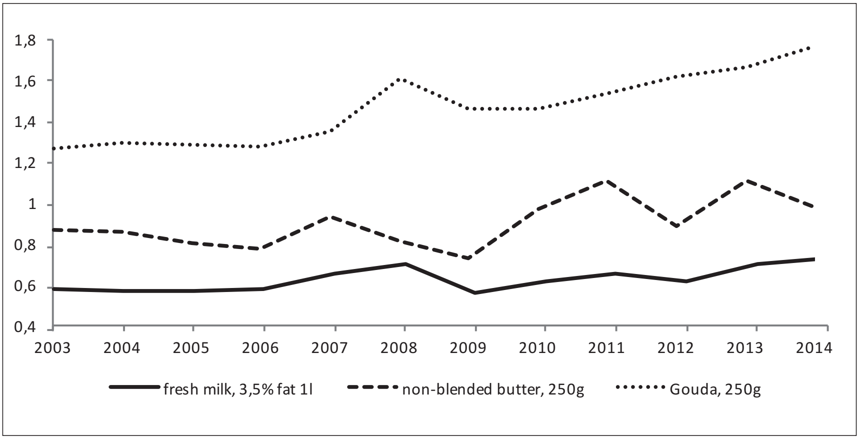
Table 9: Per capita consumption of selected dairy products in Germany in 2003 and 2014.

kg per capita	2003	2014	Change 2003-2014	
milk	65.1	53.2	-11.9	-18.3%
butter milk	1.6	1.1	-0.5	-31.3%
mixed milk products	12.0	12.9	0.9	7.5%
yoghurt	17.6	17.0	-0.6	-3.4%
cream	7.4	5.8	-1.6	-21.6%
other fresh milk products	4.8	1.6	-3.2	-66.7%
cheese	21.3	24.2	2.9	13.6%
butter	6.6	5.7	-0.9	-13.6%
long-life milk products	8.6	6.1	-2.5	-29.1%

Source: own illustration based on data from BMLEV, 2015.

Figure 4 presents the consumer prices for fresh milk, non-blended butter and Gouda from 2003 to 2015. While the price for Gouda almost steadily increased over the period, the price of butter fluctuated heavily. In 2006, consumers paid less than 80 € cents; in 2013 it was more than 1.10 €. The price for fresh milk did

Figure 4: German consumer prices (in €) for fresh milk, non-blended butter and Gouda cheese in selected years.



Source: own illustration based on data from BMLEV, 2005-2015.

not fluctuate heavily, but increased by about 15 € cents between 2003 and 2014. However, in 2012 consumers only paid 6.9% more for fresh milk than in 2003.

2.2 Economic relationships

After describing the structure of dairy farmers, milk processors, and food retailers in the previous section, the following section depicts existing forms of vertical and horizontal economic relationships and issues arising from these.

2.2.1 Vertical relationships

The bargaining power of dairy farmers towards dairies is seen as relatively low. Because of recent concentration processes at the processing level, often only a small number of large-scale dairies or even only one dairy exist in the region - a radius of around 200 km due to transport costs and the perishableness of raw milk - and are the only buyers for raw milk, while there exist hundreds of small to medium-sized dairy farmers (Bundeskartellamt, 2009). Furthermore, long-lasting contracts with long cancelation periods of up to 12 months and the low number of dairies in the region limit the ability to change processing partners and thus strengthen the position of dairies. After ending contractual relationships with one dairy in the region, dairy farmers reported to the German anti-trust agency that others would refuse to accept them as suppliers (Bundeskartellamt, 2009).

To determine the price of raw milk most commonly investor-owned, but also more and more cooperatives, German dairies observe the prices of surrounding dairies and pay an average of this to dairy farmers, who due to their negligible size have to act as price takers (Bundeskartellamt, 2012). However, a series of extra payment can be added to the standard price, e.g. depending on the fat and protein content of the delivered milk or in form of a loyalty bonus. Payoffs are carried out on a monthly basis (Bundeskartellamt, 2009).

The payment system of cooperatives is slightly different. Cooperatives determine the raw milk price after a purchaser for the final dairy product is found and the dairy product price determined. Not having the price of raw milk fixed, gives cooperatives less incentives to include the raw milk price as a cost in their negotiations with possible buyers. Thus, it can be argued that cooperatives are less eager to achieve a high price, but rather try to sell all products. In addition to the later determined raw milk price, cooperatives pay their members a bonus at the end of the year, which consist of the entire profits earned (Bundeskartellamt, 2009).

Dairy cooperatives, who are owned by their members, often act as vertical integrated enterprises when they negotiate with the retailing sector. However, most of the cooperatives consist of up to 15% of inactive members. Furthermore, the still large numbers of active members, who have diverse production cost structures, limit the influence that a single small-scaled farmer might have on the board of the dairy and thus on the milk prices paid out. Consequently, many dairy cooperatives have distanced themselves from their active members and optimize the dairies economic performance, thus acting more and more as private companies with the raw milk price being solely a cost variable rather than the income of its members (Bundeskartellamt, 2009).

Due to EU policy changes that promote market liberalization, intrinsic organizational problems to adapt to these, e.g. lack of capital to boost innovations, and driving cost-minimizing strategies, dairy cooperatives are often not able to promote their members' interest in receiving a high raw milk price, but instead fail to pay higher prices than their private competition (Bundeskartellamt, 2009; Fahlbusch, 2013; Grau et al., 2015).

Even though, from a national perspective the dairy stage is heavily concentrated with the six largest dairies accounting for 50% of market share, four of which are cooperatives (Loy et al., 2015), and we could expect an oligopoly, pricing in the German dairy supply chain is mostly characterized by 'top down' negotiations. The dairies negotiate with a very small number of retailers, most often discounters, which purchase the largest share of dairy products, namely the Aldi Group, Schwarz Group, Rewe Group, and Edeka Group. Regarding the product group milk for consumption the Aldi Group, Rewe Group, and Edeka Group cover around 50% to 65% of all domestic demand. Through establishment of procurement alliances between larger retailers and smaller retailers with market shares of less than 5% as well as the fact that retailers manage dairies' milk exports, of which 50% is marketed internationally by only two retailers, at most six retailers market more than 90% of the German dairy industry's milk for consumption output (Bundeskartellamt 2014).

In general, Fahlbusch et al. (2009) and others (e.g. Hellberg-Bahr et al., 2010) stated that large shares of German dairy product exports are actually marketed by German retailers. In their EU campaign, they offer so-called 'Euro contracts' that allow them to procure vast quantities of dairy products, in particular less perishable ones like cheese, through central buying and distribute them to their European subsidiaries.

Regarding contractual arrangements the negotiations with the Aldi Group are often seen as signal negotiations for the rest of the sector, since the Aldi Group in most cases offers the lowest prices to consumers for a variety of basic dairy products (Bundeskartellamt, 2009). Negotiations, in particular have become more frequent. While standard products are negotiated two or more times, e.g. the prices for butter are determined on a monthly basis, brand product contracts are arranged annually (Fahlbusch et al., 2009). Competitors are able to respond quickly to price changes of the discounters and their everyday low pricing strategies due to high information transparency provided by market research institutions, which makes collusion unnecessary (Bundeskartellamt, 2009).

Negotiated contracts are often so large that several dairies have to form production alliances to fulfil the quantity requirement. Through public calls for bids and dairies undercutting each other's offers, retailers are well informed on their suppliers' production costs and consequently marginal costs, and can force dairies more easily to provide the product at these (Fahlbusch et al., 2011). In recent years, private labels of retailers emerged, which allow retailers to have full control over the cost pass-through process and bind dairy companies more tightly to them (Loy et al., 2015). The Aldi Group and Schwarz Group sum up more than 60% in private label cheese and 50% in milk products. All this, high transparency of information and the dominant position of retailers, might lead to fierce procurement strategies and oligopsonistic conduct (Loy et al., 2015).

2.2.2 Horizontal relationships

To increase their bargaining power in negotiations with dairies, German dairy farmers are allowed to form producer collectives and even collaborations of producer collectives. In 2014, around 143 dairy producer collectives existed, but only 2 collaborations (BMLEV, 2000-2012). The largest producer collective was in 2009 Bayern-MeG with around 9,000 members and a milk production of 1.4 million t (Bundeskartellamt, 2009).

More and more dairies form co-operations to use their facilities more efficiently. Examples of cooperation among dairies in Germany are the following: they share the investment risk for new facilities and technologies, they exchange already delivered raw milk and semi-processed goods to optimize the usage of their processing facilities and costs, and they exchange milk delivery contracts to optimize the supply and transport costs. However, co-operations of dairies that constrain the economic competition for raw milk supply or actual divide regional markets among them are prohibited (Bundeskartellamt, 2012). The merger of Nordmilch AG and Humana Milchunion eG in 2011 preceded a joint-venture of the firms in 2005, the wheyco GmbH, a firm that produced specialized dairy products (Grau et al., 2015).

2.2.3 Anti-trust investigations

With the concentration and consolidation processes at the processing and retail level as well as the vertical relationships in mind, it is not surprising to hear that since the start of the 2000s the German anti-trust agency has received a growing number of complaints by dairy farmers and dairies on the procurement behavior of downstream buyers, respectively the dairy industry and retail sector (Bundeskartellamt, 2009).

Apart from the before mentioned issues regarding changing the buyer, dairy farmers have been criticizing that dairies asymmetrically transmit prices, price decreases on the dairy output market are faster transmitted to them than price increases. However, dairies themselves have been accusing retailers to abuse their bargaining position to lower the prices for dairy products by colluding. As a result an official investigation was started by the anti-trust agency in 2008 with its final report published in 2012. The German anti-trust agency stated that even though procurement prices are low and the structure along the chain seems to favor the position of buyers, no evidence on the abuse of market power was found (Bundeskartellamt, 2009; 2012).

2.3 Summary

The German dairy supply chain is one of the, if not the most important agri-food supply chain in Germany. Even though, restricted by the milk quota and a saturated domestic market for dairy products, the chain has boosted production at every level since the early 2000s. Primary destination for the surplus is the Common Market and in particular EU neighbor states. Nevertheless, the home market is still the dominant outlet for German dairy products.

The growth in production was accompanied by heavy structural change and concentration processes at every level of the supply chain. While dairy farmers declined drastically in number, around 1/3, and grew tremendously on average in size, by 50%, they remain atomistic with around 74,800 dairy farms still being active in raw milk production. The processing level experienced a similar decline percentagewise and is showing alarming levels of concentration with six dairies dividing up 50% of the raw milk market. Nevertheless, through a series of mergers and acquisitions the number of possible buyers at the retail level has declined to about five, which control almost the entire dairy product supply via procurement alliances and central buying for their European campaign. High levels of information transparency allow retailers to harmonize the procurement and prices of dairy products without the necessity of collusion.

Even though, the dairy sector is characterized by cooperative action, four of the six largest dairies being cooperatives, farmers hardly benefit in form of higher raw milk prices. Due to cost-minimizing strategies and production of standard dairy products, these cooperatives are not able to pay higher prices for the milk delivered by their members than the private competition, which earn higher margins with their brand products. Facing a highly concentrated retail sector with good knowledge of the dairies' production cost, it is hard to imagine that dairy cooperatives act as something else than price takers on the dairy output market.

The structure and vertical relationship give suspicion to the subsequent abuse of buyers' market power. Fueled by complaints of dairy farmers and dairies on non-competitive behavior of downstream supply chain agents, the German anti-trust agency conducted a sector analysis between 2008 and 2012. In its final report the anti-trust agency acknowledged the threat of oligopsony power at both markets, raw milk and dairy output market, but could not find any evidence. Thus, the main premise of the presented work is to empirically investigate the German dairy supply chain for the existence of oligopsony power at the raw milk and dairy product market.

3 Theory Review

Throughout the past 100 years several approaches with the aim to analyze market power emerged and partially submerged again. In the following chapter we will present the most notable approaches: the structure conduct performance paradigm (SCPP), the new empirical industrial organization (NEIO) approach, and the price transmission framework. Furthermore, the strengths and weaknesses of any method will be separately discussed. In a concluding summary, the approaches are contrasted to each other and the appropriateness of methods for the field of study is discussed.

3.1 Structure conduct performance paradigm (SCPP)

3.1.1 Methodology

The structure conduct performance paradigm (SCPP) was first introduced by Mason (1939; 1949) more as a case study approach and later augmented by Bain (1951; 1968) through the use of statistical methods (Stiegert et al., 2009). The primary idea of the SCPP is to explain the performance of an industry on the basis of its market structure. It is assumed that market structure causes firms' conduct, which influences the performance of the industry. Consequently, structural variables, such as concentration ratios, are used as explanatory variables for performance, e.g. price-cost margins (PCM) or profits, derived from accounting data. With this thought in mind it appeared now easily possible to explain cross-sectional differences among industries in performance with a relatively low number of structural variables (Bresnahan, 1989).

In the first two decades after the establishment of the SCPP several different measures of market structure, in particular concentration ratios, were tested to explain intra- and inter-industry performance variety (Bresnahan, 1989). Stigler (1964) used the Herfindahl index to explain the rate of return on capital, rate of return on net worth, and ratio of market value to book value. The finding was that the more firms exist the greater the competition is. Later on, Miller (1967) and Kilpatrick (1967), using concentration ratio measures, discovered that the four firm concentration ratio tends to explain the performance of an industry more than higher numbered concentration ratios. Miller even found a negative impact of the eight firm concentration ratios on industry's profit, thus counterbalancing the effect of the four largest firms (Miller, 1967). Collins and Preston (1969) also stated that higher PCMs in industries with a higher four firm concentration ratio exist. Analyzing 94 industries and using data for the years 1958, 1963, and 1968, Cowling and Waterson (1976) emphasized that changes in the Herfindahl index are associated with changes in the PCMs.

In general, the SCPP studies found a positive relationship between firm concentration and performance in industries, mainly PCMs, what motivated anti-trust agencies around the world to take an offensive stand against mergers, predatory pricing, and resale price maintenance, throughout the 1960s and 1970s (Stiegert et al., 2009).

3.1.2 Criticism

Following the primary successes of the SCPP, criticism regarding its main assumptions emerged. While the SCPP assumes an unidirectional link between market structure and industry conduct, a series of studies argued and proved that industry conduct and market structure actually mutually influence each other (Marion et al., 1979: Martin, 1979; Clarke & Davies, 1982; Schaffer, 1982). Apart from the theoretical concerns, the endogeneity of conduct can lead to issues in the empirical application. When the exogeneity assumption does not hold, the ordinary least squares (OLS) regression estimates of the reduced-form between structural and performance variables are biased, since the structural variables are correlated with the error term and inference based on these estimates is invalid (Bresnahan, 1989; Kadiyali et al., 2001).

Confronted with the criticism, the SCPP has been altered to overcome partially its original limitations. Martin (1979) focuses on the endogeneity problem between profitability, seller concentration, and advertising demand. The methodology comprises three equations with PCM, concentration ratio, and advertising-sales ratio as endogenous variables that depend on each other and other structural, performance, and explanatory variables, including lags of the endogenous variables. For 209 industries in the year 1967, the author reports that conduct is determined by market structure and performance, higher advertising intensity in concentrated and more profitable industries, and that concentration follows dynamic adjustment processes (Martin, 1979). Another, more recent example is the study of the U.S. food manufacturing sector by Stiegert et al. (2009). By applying simultaneous estimations technique to the approach of Martin (1979), a positive relationship between industry structure and profits is identified. However, it is further elaborated that the differences between industries in performance can not only be explained by the market structure, but also other determinants, such as the regionalism of the market, and have to be accounted for (Stiegert et al., 2009).

Apart from the exogeneity issue, the SCPP was also heavily criticized for its use of accounting data and the choice of concentration ratio to represent market structure. Many authors applying SCPP used accounting data to calculate PCMs. Since economic marginal costs (MC) are not observable from accounting data, often average cost (AC) across products was used as a proxy, however with only limited explanatory power (Perloff et al., 2007). Fisher and McGowan (1983) criticized that in general accounting data poorly represent economic variables due to practices of the accounting department of firms like 'creative accounting', delayed reporting, and limited disclosure statements of firms (Blanck & Bahrs, 2011).

Concentration ratios do not only neglect the importance of imports and exports for an industry, but often overstate the level of competition when a closely related industry exists. Furthermore, most concentration ratios are calculated at the national level and disregard firm concentration on local markets and thus underestimate concentration (Perloff et al., 2007). In addition, the cross-sectional character of many SCPP studies has been criticized. Bresnahan (1989) and Kadiyali et al. (2001) doubt that comparison among industries with highly idiosyncratic characteristics are valid on the basis of a small number of structural variables and rather the distinctive characteristics cause the industries' outcome.

Due to the critic and hence dissatisfaction, the SCPP, even though still applied today, see for example Stiegert et al. (2009) and Bhuyan (2014), has lost significance, and other approaches have emerged. In particular, NEIO can be regarded as an answer to the shortcomings of the SCPP.

3.2 New empirical industrial organization (NEIO)

NEIO emerged in the late 1970s out of dissatisfaction with the SCPP. The new approach addresses the main issues of SCPP, non-observable economic MC, endogeneity of variables, and cross-sectional comparison. Advances in game theory improved the understanding of firms' conduct and allowed to treat it as an unknown parameter. Unfortunately, frequently no unique equilibrium solution exists for game theoretic models, but rather multiples. As long as firms consider future benefits strongly for their decision process in a repeated game, a countless number of subgame perfect Nash equilibria exist. NEIO approaches circumvent the issue in most cases by focusing on a single industry and thereby restricting the possible outcome set (Kreps, 1990; Sperling, 2002). The focus on the single industry case is opposed to the cross-sectional character of SCPP studies.

The invisibility of economic MC is dealt with by NEIO approaches either by estimating firms' conduct, i.e. market power, without measuring costs at all or by deriving a measure of MC from firm behavior. In general, the market is modeled with demand and supply equations, deduced from firms' profit, production, and cost functions. Due to the endogeneity of prices and quantities in this setup, most NEIO studies rely on simultaneous estimation techniques (Bresnahan, 1989). The two most applied NEIO approaches will be discussed in detail in the following sub chapter.

3.2.1 Methodology

Bresnahan (1982) and Appelbaum (1979; 1982) presented the most common applied NEIO methodologies, the general identification methodology (GIM) and the production-theoretic approach (PTA) in their seminal works respectively. Price and quantity are determined by the intersection of supply relation and demand function in a market. In a perfectly competitive market the price is determined by the MC of the marginal producer, thus *price* (*P*) = *MC*. In the case of a non-competitive market setting, where sellers have market power, suppliers will equate their 'perceived' marginal revenue (MR) to MC to maximize their profits. A monopoly pricing behavior is present when the *'perceived' MR* = *MR*, and competition prevails when *'perceived' MR* = *P*. In cases of *'perceived' MR* < *P* some form of oligopoly pricing exists (Bresnahan, 1982).

In a general NEIO oligopoly model based on Bresnahan (1982) with a homogenous product, demand and supply relations have to be formulated and derived. The demand of buyers typically takes the form,

$$Q = D(P, Y) \tag{2.1}$$

where Q is the quantity, P the price, and Y a vector of exogenous demand shifter. In case of oligopoly behavior and quantity as the strategic variable the supply relation of the profit maximizing individual firm i takes the form,

$$P(Q, Y) = \frac{\partial c_i(q_i, W)}{\partial q_i} - \varphi_i \frac{\partial P(Q, Y)}{\partial Q} q_i \tag{2.2}$$

where $P(\bullet)$ is the inverse industry demand, $C(\bullet)$ is the cost function, q_i the individual firm's supply, and W an exogenous cost shifter. The variable $\varphi_i = \partial Q / \partial q_i$ is an index of firm behavior. It can either measure the firm i's conjectural variation (CV), the belief of a firm on how output changes affect industry output, or the wedge between price and MC (Bresnahan, 1989; Sperling, 2002). Nevertheless, φ_i quantifies firm i's ability to mark-up the price from the competitive level and comprises within itself different levels of competition. If φ_i takes a value of zero, price equals MC and perfect competition prevails. In case of a value of one, a monopoly exists. Values between zero and one represent different intensities of oligopoly with the special case $\varphi_i = 1/n$ being Cournot competition (Bresnahan, 1989). The methodology that estimates φ_i as a continuous variable ranging from zero to one was titled by Corts (1999) as the conduct parameter method (CPM). We therefore stick to this terminology and consequently refer to φ_i as the conduct parameter.

Given (2.2), the identification of φ_i is not straight forward possible as it appears to be. The conduct parameter and the slope of the inverse industry demand, $\partial P(\bullet)/\partial Q$, form a compound parameter and the effects of the individual terms cannot be separated without additional information. The necessary information is normally obtained by estimating the demand and supply equation simultaneously, what quantifies the slope of the demand equation $\partial Q(\bullet)/\partial P$. However, the demand equation has to contain an exogenous variable that through an interaction term with the price is able to alter the demand slope in face of an exogenous change. Otherwise, in case of non-constant MC, it might not be possible to distinguish between perfect competition and monopoly (Bresnahan, 1982; Lau, 1982).

Appelbaum's (1982) seminal work is similar to the isochronal work of Bresnahan (1982) and models a homogenous product market with quantity setting firms. However, after defining the demand function that the industry faces (2.1), input demand for the i^{th} firm are derived by applying Shepard's lemma (Shepard, 1970) to its cost function. In the next step a slight alternative formulation of Bresnahan's supply relation (2.2) is deduced by taking the first-order condition with respect to the output quantity that maximizes profits,

$$P(Q,Y) = \frac{\partial c_i(q_i,W)}{\partial q_i} - \frac{\theta_i}{\varepsilon} P(Q,Y) \qquad (2.3)$$

where $\theta_i = (\partial Q/\partial q_i)(q_i/Q)$ is the conjectural elasticity of total industry with respect to the firm i's output, and $\varepsilon = (\partial Q/\partial P)(P/Q)$ is the market demand elasticity. The conjectural elasticity (CE) θ_i is a compound of the conjectural variation and the firm i's output share. Thus, it nests the same market structures perfect competition to monopoly in the value range 0 to 1 (Appelbaum, 1982). To account for the lack of firm-level data, Appelbaum (1982) aggregates across all firms' cost functions by using a Gorman polar form, which allows firms to have individual, but parallel cost functions and thus marginal cost be equal across firms. Through this industry input demand functions are obtained, whose slopes enter the supply relations (2.3) via the marginal cost term and enable to restrict parameters across the system of equations. The system consists of the demand equation (2.1), the supply relations (2.3), and industry input demand functions. The advantage is that more efficient parameter estimates are obtained (Sperling, 2002).

Appelbaum (1982) argued further that since MC are the same, the 'perceived' MR must be the same as well. Following this thought of line, firms equal their constant MC to the 'perceived' MR in equilibrium, consequently also the conjectural elasticity must be the same across firms in equilibrium, thus $\theta_i = \Theta$ is the equilibrium value (Appelbaum, 1982).

With Θ being the equilibrium value it is now possible to compute a popular measure for monopoly power in the market, the Lerner index L (Lerner, 1934). By subtracting MC from both sides in (2.3) and dividing through the price, the Lerner index is obtained,

$$L = \frac{P - MC}{P} = -\frac{\Theta}{\varepsilon} \tag{2.4}$$

where the Lerner index, the relative difference between industry price and MC, equals the negative elasticity adjusted conduct parameter. Consequently, it lays in the range $0 \leq L \leq -1/\varepsilon$, where zero stands again for perfect competition and $-1/\varepsilon$ would be the relative monopoly price mark-up. The derived formulation allows interpreting the conduct parameter as an elasticity adjusted Lerner index, but in contrast to the classical Lerner index it is able to distinguish between markets with high margins due to inelastic demand or due to uncompetitive behavior (Appelbaum, 1982; Corts, 1999).

While Bresnahan (1982) presented a purely theoretic model and left it to other researchers to apply it empirically, Appelbaum (1982) applied his approach to the U.S. textile and the U.S. tobacco industry for the period from 1947 to 1971 using annual data. While he found rather low levels of oligopolistic behavior by the textile industry (0.0368), the tobacco industry acted rather oligopsonistic (0.4019) during this period (Appelbaum, 1982).

In this section two theoretical approaches for the identification of oligopoly power were presented. The next section presents alteration of these concepts to allow for or identify also oligopsonistic market behavior.

3.2.2 Oligopsony model

The seminal works of Appelbaum (1979; 1982) and Bresnahan (1982) both model the oligopoly case. Nevertheless, due to certain characteristics described in the introduction, agricultural supply chains rather seem to be threatened by oligopsonistic market conduct. Schroeter (1988) was the first to model oligopsony, based on the PTA method by Appelbaum (1982), and apply his model to an agricultural supply chain with input and output markets. Similar to Appelbaum (1982) the i^{th} firm's input demand for j non-material inputs, given a fixed output level q_i and assumed to be procured in competitive factor markets, are derived by applying Sheppard's lemma to the firm's non-material input cost function,

$$x_i^z = \frac{\partial c_i(q_i, W^z)}{\partial W^z} \tag{2.5}$$

where ${x^z}_i$ is a vector of the quantities and W^z is a vector of prices for the j non-material inputs. The function for aggregated demand of the output is according to (2.1), while the aggregated supply of the material input is given by,

$$Q = S(W^M, Z) \tag{2.6}$$

where Q is the quantity of material input supply, W^M price of the material input, and Z a vector of exogenous supply shifters. Since fixed proportion technology is assumed, aggregated supply of the material input and aggregated demand for the output are demarked with the same symbol Q. Given this assumption and (2.5), the profit function of the i^{th} firm can be denoted as,

$$\pi_i = \underbrace{P(Q,Y)q_i}_{Revenue} - \underbrace{\left(W^M(Q,Z)q_i + c_i^z(q_i, W^z)\right)}_{Total\ Cost} \tag{2.7}$$

where the profit of i^{th} firm π_i equals the revenue minus total cost. Maximizing its profit to the chosen level of output, and through the fixed proportions assumption to the level of material input, the first-order condition takes a similar form like in Appelbaum (1982),

$$P(Q,Y)\left(1 + \frac{\theta_i}{\varepsilon}\right) = W^M(Q,Z)\left(1 + \frac{\theta_i}{\eta}\right) + \frac{\partial c_i(q_i, W^z)}{\partial q_i} \tag{2.8}$$

where ε has the same definition as market demand elasticity as in (2.3), $\eta = (\partial S(W^M, Z)/\partial W^M)(W^M/Q)$ is the elasticity of material input supply, and θ_i is here the ith firm's conjectural elasticity of output but also of material input and due to the fixed proportions assumption takes the same value on the material input as well as output market. However, since the relative mark-up ($-\theta_i/\varepsilon$) and mark-down (θ_i/η) of the i^{th} firm are defined over the market demand elasticity ε and material input supply elasticity η, they differ in value. Following Appelbaum (1982), after aggregation across firms with the assumption that marginal costs are constant, an industry average value Θ is obtained (Schroeter, 1988).

The model for the aggregated industry is then estimated using a system of equations comprising the supply and demand relations on the output and input markets as well as the first-order condition of the industry's profit function, here (2.1), (2.5), (2.6), and (2.8). Furthermore, the conjectural elasticity is modeled to vary with market structure. Schroeter (1988) applied his approach to the U.S. beef industry for the years 1951 to 1983 using annual data. The estimated conjectural elasticity value is significant, but close to perfect competition. Moreover, its value is declining over time (1951: 0.0417, 1983: 0.0190), thus the increasing concentration in the industry has not worsened market condition. The relative mark-up of around 3% is larger than the relative mark-down of approximately 1% in the later years of the analyzed period, because of the more inelastic demand elasticity compared to the material input supply elasticity (Schroeter, 1988).

The fixed proportion assumption of Schroeter (1988) was later heavily challenged by studies (e.g. Wohlgenant, 1989; Goodwin & Brester, 1995) that found evidence that the food industry is rather characterized by input substitutability than fixed proportion technology. Azzam and Pagoulatos (1990) modify the PTA approach by using a production function for a single output instead of a cost function as well as allowing for variable input technology by taking j first-order conditions of the profit function for j inputs. Consequently, the output and input conjectural elasticity differ. However, the approach has two weaknesses. For estimation $j+1$ structural equations are required and to identify the conjectural elasticities fixed values for the respective elasticity of output demand and input supply have to be assumed. The latter heavily relies on assumptions and is likely to overstate their significance (Wohlgenant, 2001). Nevertheless, the approach was like in Schroeter (1988) applied to the U.S. beef industry over the period from 1959 to 1982 using annual data. For the beef input market a conjectural elasticity of 0.178 and for the output market of 0.223 are obtained (Azzam & Pagoulatos, 1990). The values are drastically higher than by Schroeter (1988), what confirms Wohlgenant (2001) critic of using fixed elasticities of demand and input supply.

In contrast to Azzam and Pagoulatos (1990) the method developed by Murray (1995) does not assume values for the elasticities of output demand and input supply. The supply of j material input is assumed to be a function increasing in input price ($X^M = S(W^M,Z)$). Accordingly, differentiating this supply relation with respect to the material input price W^M allows obtaining the material input supply elasticity η. Assuming competitive output markets and differentiating an i^{th} firm's profit function (2.7) with respect to the level of material input choice ${x^M}_i$, gives the following profit-maximizing material input demand equation,

$$\underbrace{P(Q,Y)\frac{\partial Q(X^M,X^z)}{\partial x_i^M}}_{Value\ of\ Marginal\ Product} = \underbrace{W^M(X^M,Z)\left(1+\frac{\xi_i}{\eta}\right)}_{'perceived'\ Marginal\ Factor\ Cost} \tag{2.9}$$

where $Q(\bullet)$ is the total output quantity produced, $\xi_i = (\partial X^M/\partial x^M{}_i)(x^M{}_i/X^M)$ is the i^{th} firm's conjectural elasticity of material input supply or accordingly applied to an oligopsonistic market setting the gap between value of marginal product (VMP) and actual marginal factor cost (MFC) and X^M the total quantity of material input supply (Murray, 1995). Aggregating across firms again results an industry measure. The material input demand equation is then not typically estimated directly like in the approaches described previously in a system of demand and supply equations, because it still involves the marginal product term $\partial Q/\partial x^M{}_i$, but instead a shadow price (λ^M) equation is formulated,

$$\lambda^M = W^M(X^M, Z)\left(1 + \frac{\Xi}{\eta}\right) = \frac{\partial \Pi(P,Q,X^M,X^Z,W^M,W^Z)}{\partial X^M} \tag{2.10}$$

where λ^M is the shadow price and Π is industry's aggregated profit function, that equates 'perceived' MFC to VMP, i.e. $\partial \pi(\bullet)/\partial X^M$, represented by λ^M. The shadow price can then be calculated from the estimated industry's profit function. The profit function is estimated along with output supply and j input demand equations, obtained by applying Hotelling's lemma (Hotelling, 1932) to the industry's profit function, as a system of equations. With knowledge on λ^M and η, it is now possible to infer Ξ after solving (2.10) for it. Murray (1995) empirically investigated separately the U.S. markets for pulpwood and sawlogs, both input markets for the wood-processing industry, for the period 1958 to 1988 using annual data. For the sawlog market a mean value of 0.042 and for the pulpwood market of 0.174 for Ξ is derived (Murray, 1995).

In contrast to Murray (1995), Morrison Paul (1999; 2001) derives the industry's aggregated demand for the material input from its cost function. The cost function $C(\bullet)$ takes in Morrison Paul (2001) the form,

$$\underbrace{C(Q, W^M, W^Z, R)}_{Total\ Cost} = \underbrace{VC\ (Q, W^M, W^z, R)}_{Variable\ Cost} + \underbrace{\textstyle\sum_k W^R\, R_k}_{Fixed\ Cost} \tag{2.11}$$

where the total cost consists of variable cost $VC(\bullet)$ and fixed cost, R is a vector of k control variables, and W^R a vector of prices of k control variables. By applying now the 'inverse' Shepard's lemma optimization condition (Morrison Paul, 2001) the industry demand for the material input has the following formulation,

$$\frac{\partial C(\bullet)}{\partial X^M} = W^M\left(1 + \frac{\Xi}{\eta}\right) = -\frac{\partial VC(\bullet)}{\partial X^M} = \lambda^M \tag{2.12}$$

Where $\partial C(\bullet)/\partial X^M$ is the MFC of the material input, and $\lambda^M = -\partial VC(\bullet)/\partial X^M$ is the shadow price. The shadow price λ^M is the "dual equivalent of the primal-based VMP" (Morrison Paul, 2001). Consequently, the expression MFC of the material input equaling the shadow price is the cost-side equivalent of the approach of Murray (1995) profit maximization condition $'perceived'\ MFC = VMP$ (see equation (2.10)).

Morrison Paul (2001) also applied the developed method to the U.S. beef industry in a similar fashion as Murray (1995) by estimating a system of equations comprising, the variable cost function, variable input demand equations, derived via Shepard's lemma, the optimal material input pricing equation, i.e. (2.12) solved for W^M, an output pricing equation, and a functional specification of Ξ that depends on structural variables, e.g. the number of cattle buyers. By assuming fixed proportions technology and oligopoly power on the output market, Θ also enters the output pricing equation. Consequently, the elasticities of supply and demand (ε and η) cannot be easily distinguished from Θ and Morrison Paul (2001) had to assume values for these. In contrast to the other empirical application on the U.S. beef industry, firm-level data for 43 plants in 1992-1993 were available. The results suggest very low levels of oligopsonistic behavior on the cattle input market.

For proper estimation of the method developed by Murray (1995) and Morrison Paul (1999; 2001) quantity data on non-material inputs are required, because they are part of the profit function (cost function), which in most cases are hard to obtain, and endogenous choice variables. Muth and Wohlgenant (1999) solved this issue and presented a model that allowed the estimation of oligopsony power with only two equations and without the requirement of quantity data on non-material inputs by applying the envelope theorem to the production function of a redefined profit function. Therefore, the authors use a slight different representation of the industry's profit function,

$$\Pi(P, X^M, Z, W^M, W^Z) = P \cdot f\left(X^M, X^{Z^*}\right) - W^M X^M - W^Z X^{Z^*} \quad (2.13)$$

where $f(X^M, X^{Z^*})$ is the production function and $X^{Z^*} = X^Z(X^M, W^Z, P)$ is a vector of the optimal quantities of j non-material inputs conditional on the level of the material input X^M. The first-order condition with respect to the chosen level of material input is,

$$\frac{\partial \Pi(\bullet)}{\partial X^M} = P\frac{\partial f(\bullet)}{\partial X^M} + P\frac{\partial f(\bullet)}{\partial X^{Z^*}}\frac{\partial X^{Z^*}}{\partial X^M} - W^M(\bullet)\left(1 + \frac{\Xi}{\eta}\right) - W^Z\frac{\partial X^{Z^*}}{\partial X^M} = 0 \quad (2.14)$$

where the symbol definition is according to the previous equations. With the assumption that the non-material inputs are procured in competitive markets, rearranged (2.14) reduces to,

$$W^M(X^M, Z)\left(1+\frac{\Xi}{\eta}\right) = \underbrace{P\,\underbrace{\frac{\partial f\left(X^M, X^Z(X^M, W^Z, P)\right)}{\partial X^M}}_{Marginal\ Product}}_{VMP} \tag{2.15}$$

where the marginal product term does not depend anymore on the quantities of the non-material inputs, but rather their prices, and the reduced-form VMP equals the ‘perceived’ MFC. Solving (2.15) for W^M and estimating this material input demand equation simultaneously with the inverse supply equation $S^{-1}(X^M, Z)$, which gives a value for η, results in an estimate of Ξ (Muth & Wohlgenant, 1999). As Schroeter (1988) and Azzam and Pagoulatos (1990) before, the elaborated framework was applied to the U.S. beef industry over the period from 1967 to 1983. Results of a constant estimate of the conjectural elasticity and a time trend adjusted one were presented. The revealed values are very close to zero and statistically insignificant (Muth and Wohlgenant, 1999).

3.2.3 Criticism

After the introduction through Bresnahan (1982) and Appelbaum (1979; 1982) NEIO quickly established itself as one of the most dominant approaches to the investigation of market power. Not even one decade after his seminal work Bresnahan (1989) reviewed 68 NEIO studies. Nevertheless, with its growing popularity criticism arose. In the following sections the limitations of NEIO framework as illustrated in the literature will be discussed.

One of the most obvious drawbacks of NEIO is that even though an estimate for the market power can be obtained, the source of the market power is never identified. Surely, as described in the previous section, some authors (e.g. Murray, 1995; Morrison Paul, 2001) tried to model the CPM as a function of exogenous variables, e.g. the number of cattle buyers, but never justified their choice of variables through economic theory. Lacking a clear idea on the market power source, NEIO empirical findings are heavily constrained in their ability to contribute to competition policy recommendations (Bresnahan, 1989).

Frequently data limitations and complexity of the model force NEIO researchers to formulate strong assumptions on technology, competition on other markets and market stages, as well as the type of competition (Wohlgenant 1989; Morrison Paul, 1999; Sexton, 2000). Even though NEIO studies mostly are restricted to the single industry case and thus can use knowledge of industry to approximate more closely the technology, still they repeatedly make questionable assumptions on the underlying technology, e.g. in the NEIO studies of the previous subsection. While Schroeter (1988) assumes fixed proportions technology, Morrison Paul (2001) on the other hand assumes values of the elasticity of input supply and output demand to be able to estimate the model. Furthermore, most NEIO studies heroically exclude the possibility of market imperfections on other input and/or output markets, even though market power on these markets might have a strong influence on the investigated markets (Sexton, 2000). NEIO models a priori always make a decision on the type of competition in the market, whether it is price-setting (Bertrand) or quantity-setting (Cournot), and exclude other forms, thereby strongly restricting themselves from the start and limiting their explanatory power (Sexton, 2000).

Looking past these common limiting assumptions, concerns regarding the validity of NEIO estimation results have been frequently stated. Corts (1999) demonstrated that, in a dynamic oligopoly, the conjectural elasticity is correlated with the instruments applied to identify it, unless the data is truly generated by an equilibrium outcome of firms that behave according to the imposed theoretical model of conjectural variations (Sexton, 2000). Consequently, the estimate of the mean conjectural elasticity is in most cases biased. Perloff and Shen (2012) further proved that the choice of functional form can be essential. While the choice of linear functional forms results in unreliable estimates due to multicollinearity issues, flexible functions circumvent this problem (Sexton & Lavoie, 2001). However, not only the choice of functional form, but also the choice of approach, GIM or PTA, leads to significantly different results, as shown by Perekhozhuk et al. (2016).

Apart from the importance of the choice of functional form or approach for the validity of results, the strongest critic concerning the CPM has been that even though the model assumes dynamic concepts, like conjectures, the behavior of firms is estimated as static and firms maximize one-period profits instead of a continuous discounted stream of profits over a given period (Dixit, 1986). Consequently, the obtained static estimates do not adequately represent conjectural variations or elasticities, which are in reality formed and adjusted repeatedly (Richards et al., 2001). Furthermore, the static NEIO model neglects strategic variables, such as advertising and product quality, which are tools of interfirm competition and have long-term effects, and thus possible adjustment costs (Roberts & Samuelson, 1988).

3.2.4 Dynamic models

In the static framework, as described in the previous subsection, firms maximizes profit by taking the belief on how rivals react as given, and form their decision on price or quantity solely on observations on demand, supply, and cost shifters (Karp & Perloff, 1993a). Actions preceding this period do not affect behavior, in other words history is no concern (Perloff et al., 2007). In contrast to this so-called one-shot game, firms, which interact repeatedly, also consider the history of past actions to form their decision-rule and optimal response (Karp & Perloff, 1993a). Consequently, in a dynamic framework a firm does not just maximize its current profits but rather the discounted-profit stream,

$$\Pi_i = \sum_{t=0}^{\infty} \delta \pi_{it} \tag{2.16}$$

where Π_i is the stream of discounted profits of firm i over an infinite time horizon, δ a discount factor common to all firms in the range of $0 < \delta < 1$, and π_{it} the firm i's profit at time t (Slade, 1989). The i^{th} firm now uses a set of strategies formed from a function of the observable history. If all firms apply this equilibrium decision rule at all times, the arising equilibrium of the industry is the Nash equilibrium solution to the dynamic game (Perloff et al., 2007).

The cause of interfirm dynamics can be either strategic or fundamental. If rivals respond in the future to current actions by observing the history of the game, the source is strategic, while if the current action affects a stock variable that again influences future profits the source is fundamental (Perloff et al., 2007). For example, fundamentals can be capital, whose stock depreciates over time, or advertising, since the number of future customers and thus future profits depend on current decisions on the advertising intensity (Roberts & Samuelson, 1988).

3.2.4.1 Strategic dynamic models

In the strategic case, if a firm deviates from the equilibrium strategy, shaped by the history of the game, and 'cheats' on the other firms, collusive action will break down and firms enter a phase of punishment (Porter, 1983a). In the case, that small changes in the history occur and the reaction of the firms is severe, e.g. regime change from cartel to competitive pricing or 'price-wars', the firms use discontinuous and so-called trigger strategies. However, if firms react adequately to changes in the variables of the history, we consider this as continuous strategies (Perloff et al., 2007). Continuous and discontinuous strategies have been modeled and empirically applied by a series of authors, but in the following we will discuss the applications of Porter (1983b) and Slade (1989), the first being an example for the trigger strategies and the second one for continuous strategies.

In his analysis of the Joint Executive Committee, an U.S. railroad oligopolistic cartel that existed from 1880 to 1886, Porter (1983b) assumes that firms observe only their output level and the industry price and thus collusion breaks down, firms apply trigger strategies, and the industry enters a punishment phase when the actual price falls below a certain threshold. The model is based on the theoretic work of Green and Porter (1984), who also argue that 'price wars' can not only be a result of 'cheating', a firm producing more than agreed, but also of unexpected low demand due to exogenous shocks. The model starts by deriving the total quantity demanded similar to (2.1) in log linear functional form. The industry supply function is derived analogously to Appelbaum (1982). Rearranging (2.3) the industry's supply function and taking the natural logarithm gives,

$$\ln P = \beta_0 + \beta_1 \ln Q + \underbrace{\beta_2}_{-\ln\left(1+\frac{\Theta}{\varepsilon}\right)} I \tag{2.17}$$

where I is a so-called indicator variable that equals one when the industry is acting collusive with the probability ζ and 0 when it is in a revisionary period with the probability 1-ζ. Applying switching regression technique to the system of two equations (2.1) and (2.17), the probability ζ and parameter estimates are obtained. With knowledge on ζ the sample can be split in collusive and revisionary periods. With estimates for β_2 and ε, the value of θ can be approximated and compared to infer on the type of collusive arrangement, pending between, the values H (Herfindahl index $H = \sum_i s_i^2$ for the Cournot outcome or 1 for the monopoly outcome of an effective cartel. In Porter's (1983b) the study of the U.S. railroad cartel a value for Θ of 0.336 was calculated during collusive periods, which is close to the Cournot outcome. This resulted in 66% higher price and 33% lower quantity during cooperative periods compared to competitive ones, benefiting the cartel overall with 11% higher profits (Porter, 1983b).

While, the theoretic model of Green and Porter (1984) and the empirical application (Porter, 1983b) are based on trigger strategies, discontinuous strategies that switch between periods of collusion and competition, Slade (1989) developed a model of the Vancouver gasoline market using continuous strategies in form of reaction functions. Even though, agreements between firms on the quantity produced or price charged are illegal in most countries, Slade (1989) argues that when a game, interaction between firms, is repeated frequently a tacit collusive outcome can arise. In an N firm differentiated product market the quantity sold at time t by firm i is a function of its own price and the prices of the competition j,

$$q_{it} = D(p_{it}, p_{jt}) \tag{2.18}$$

whose parameter vary with time due to occasional structural shifts in demand. Furthermore, it is assumed that marginal costs are equal across firms and since firms interact repeatedly they maximize their discounted-profit stream Π_i rather than single period profits. Given these assumptions, (2.16) can be reformulated to yield the discounted-profit stream of the i^{th} firm,

$$\Pi_i = \sum_{t=0}^{\infty} \delta[(p_{it} - MC_t)q_{it}] \tag{2.19}$$

for whose maximization firm i uses a strategy, depending on the history of the game. By limiting the history of the game to the prices of the preceding period and thus assuming the game to be Markovian, Slade (1989) formulates the strategy of the i^{th} firm to be,

$$p_{it} = P_t^* + \zeta_t \sum_{j \neq i}(p_{jt} - P_t^*) \tag{2.20}$$

where $P_t^*$is a stationary price that all firms charge in the tacit collusive equilibrium at time t and only depends on the structural parameters of (2.18), and the slope of the reaction function ζ_t, which vary due to strategy revision caused by changes in the exogenous parameters. When the parameters instead are constant, a stationary-equilibrium price P^* can be obtained[1]. If firms do not react, $\zeta = 0$, the Bertrand-Bash price is the outcome of the one-shot game. However, if the discount factor and ζ equal one, the price is on perfectly collusive level. Consequently, ζ lies like Θ in the range of zero to one, perfect competition to perfect collusion (Slade, 1989).

By applying the Kalman-Filter (Kalman, 1960), which uses measurement equations on observational data, here prices and quantities, and transition equations to approximate the unobservable, here changes in the parameters, it is possible to allow for time-variation in the estimates. In the empirical application of Slade (1989) the state-space model consist of a system of $N + N$ measurement equations comprising N Equations of the firm i's demand (2.18), and N equations of a differenced version of firm i's strategy or reaction function, as well as N^2 transition equations, allowing the reaction functions to depend on lagged values, lagged prices, and a dummy variable that takes the value one, if rivaling firms increased the price and zero otherwise (for more details see Slade (1989)). The model is applied to a unique dataset from a price-war period in the Vancouver gasoline retail market consisting of weekly data of the summer 1983 on prices, variable costs, and sales volumes of individual gasoline service-stations.

1 with $q_{it} = a + bp_{it} + d\sum_{j \neq i} p_{jt}$ and $p_{it} = p_{jt} = P^*$, $P^* = \frac{a + bMC - (n-1)\delta\zeta dMC}{2b - (n-1)d(1+\delta\zeta)}$ (Slade, 1989).

Slade (1989) reports that the service-stations were successful in tacit collusion and the equilibrium price was above the Bertrand-Nash level (Slade, 1989).

Some downsides to the strategic dynamic concept exist. For trigger strategies to be applicable, no other costs of adjustment and unlimited capacities are necessary conditions. Furthermore, in monopolistic or competitive market settings trigger strategies simply cannot exist, and if in addition no fundamental dynamics occur, these settings can be modeled as a sequence of static problems (Perloff et al., 2007).

3.2.4.2 Fundamental dynamic models

In contrast to the strategic dynamic model, fundamental dynamics always prevail in any kind of market structure as long as quasi-fixed inputs are necessary to the production process. Inputs are titled quasi-fixed if they cannot be instantaneously varied due to adjustment costs (Perloff et al., 2007).

The first ones to apply a model of oligopoly based on fundamental dynamics empirically following the theoretic works of Fershtman and Kamien (1987) and Reynolds (1987) were Roberts and Samuelson (1988) and Karp and Perloff (1989). While the model of the first focuses on the stock of advertising good will as the state variable and the approach of the latter, in their study on the rice export market, owes its dynamics due to costs when adjusting the level of output. Later on Karp and Perloff (1993b) also applied the framework to the coffee export market and generalized their model theoretically (Karp & Perloff, 1993a).

A general model of fundamental dynamics in homogenous product market incorporating adjustment costs like the one of Karp and Perloff (1993a), starts out by assuming a linear inverse demand equation ($P = D(Q)$) and quadratic costs of production. Furthermore, often no firm-specific differences in the marginal cost are supposed to exist ($MC = \alpha\, q_{it}/2$). Furthermore, firm i faces quadratic cost when adjusting its output level from the previous period n ($u_{it} = q_{it} - q_{it\text{-}n}$), which can be formulated as,

$$\left(\gamma_{0i} + \gamma \frac{u_{it}}{2}\right) u_{it} \tag{2.21}$$

where u_{it} is the rate of output level change and since again no firm-specific differences in the adjustment cost are assumed, the constant γ_{0i} is dropped from (2.21) and adjustment cost are zero if no change in output level occurs. Having made these assumptions and given a common discount factor δ the firm i's aim is to maximize its discounted-profits stream Π_i,

$$\Pi_i = \sum_{t=1}^{\infty} \delta^{(t-1)} \left[(P_t - \alpha q_{it}) q_{it} - \gamma \frac{{u_{it}}^2}{2} \right] \tag{2.22}$$

assuming that firms use Markov strategies, firm i forms its decision on changes in its output rate as a function of the state variables, its own and other j firms' lagged output levels, the function $J_{it}(q_t,\nu)$ can be defined as the value function,

$$J_{it-1}(q_{t-1}, \nu) = \max(P_t - \alpha q_{it}) q_{it} - \gamma \frac{{u_{it}}^2}{2} - \delta^{(t-1)} J_{it}(q_t, \nu) \tag{2.23}$$

where $\nu = \partial q_{jt} \,/\, \partial q_{it}$ is defined as the market power conduct parameter, which in the static models would represent the conjectural variation. The response of rival j to an output change of firm i, is an index of market power and can range from negative one (perfect competition) over zero (Cournot) to one (monopoly) (Katchova et al., 2005). Taking the first-order condition that maximizes firms i's present discounted value function with respect to the decision on its own output level and rearranging gives:

$$\underbrace{P_t = \alpha + (1+\nu) \frac{\partial P(\bullet)}{\partial q_{it}} q_{it}}_{Static\ model} + \underbrace{\gamma u_{it} - \delta^{(t-1)} \left[\frac{\partial J_{it}(q_t,\nu)}{\partial q_i} + \frac{\partial J_{it}(q_t,\nu)}{\partial q_j} \nu \right]}_{Dyanmics} \tag{2.24}$$

Katchova et al. (2005) create a link between the market power conduct parameter ν of Karp and Perloff (1993a) and the conjectural elasticity Θ of static models by deriving the equality $\theta_i = (1+\nu) q_i / Q$. Consequently, (2.24) equals the static model plus a dynamic component, which disappears when γ and $\delta(^{t-1})$ equal zero (Katchova et al., 2005). To be able to derive estimates for ν first the control function ($q_t = g(t) + \Lambda \cdot q_{t-1}$) is estimated with a matrix Λ, restricted to be symmetric across all firms, and thus implying that firms have the same conjectures, that fulfils a similar purpose to ζ in the reaction function of the strategic approach of Slade (1989).

Furthermore assumptions have to be made on whether firms adapt their strategies to unpredicted changes, use feedback strategies, or not, or use open-loop strategies. In the latter case, firms form a set of optimal response strategies from an initial state but do not revise their strategy in the incidence of unpredicted shocks. Since firms do not react to unpredicted shocks, their strategy is not subgame perfect. Consequently, the open-loop model is similar to the single period static game. However, when firms use feedback strategies they adapt their strategies to unexpected changes. Thus, a model with coherent feedback strategies is subgame perfect. Nevertheless, if the market structure is a competitive or a monopolistic one, the open-loop and feedback equilibria as well as adjustment paths coincide (Karp & Perloff, 1993b; Katchova et al., 2005).

The choice of equilibrium concept defines the equations from which ν and γ can be inferred (for details see Katchova et al. (2005)). In the case of the feedback model further assumptions, apart from the symmetry of Λ, implying also symmetry of ν across firms, and limiting the time horizon, have to be drawn, because otherwise no unique equilibrium will result due to the existence of more unknown parameters than equations that determine the steady-state. By defining the control rule to be linear and the value function to be linear-quadratic a closed-loop equilibrium solution can be obtained (Perloff et al., 2007).

As mentioned before, Karp and Perloff (1989; 1993b) applied their model to the rice and coffee export markets, which are both characterized by oligopolies formed by a small number of large exporting countries. The results are similar for both studies. Brazil and Colombia in the coffee export market as well as China, Thailand, and Pakistan in the rice export market behaved close to the price-taking level (Karp & Perloff, 1989; 1993b).

3.2.4.3 Criticism

Dynamic models solve the issue of the static estimation of a dynamic concept. However, this accomplishment does not come without any essential drawbacks. First, dynamic models are highly complex, thus small changes in the assumptions of the model can change the outcome completely. Slade (1995) states that already slight alterations in the timing of events or information can lead the game to drastically different results. In addition, often firm-level data is required, which is frequently not available (Sheldon & Sperling, 2003). Furthermore, restrictive assumptions on quadratic-linear games have to be made to identify a unique equilibrium, thus the solution is a result of a certain family of equilibria and results in limited explanatory power of the model (Karp & Perloff, 1989; Perloff et al., 2007).

Furthermore, dynamic models are only appropriate if the source of dynamics is actually significant for the equilibrium solution. Consequently, in the case of fundamental dynamics, adjustment costs have to be substantially large to result in dynamics (Karp & Perloff, 1993a). Perloff et al. (2007) further criticize that even if current prices are observed and some sort of MC measure is obtained, a measure of market power can not necessarily be inferred, since they might depend on unobservable opportunity costs.

While it is desirable to apply a dynamic model, due to the issues arising from complexity of the dynamic models and data requirements, some authors have argued that the static conjectural variations is a good approximation of a non-modeled dynamic game in reduced form (Cabral, 1995). While Cabral (1995) restricts his model to the linear oligopoly, Dockner (1992) is able to circumvent this issue by assuming a differential game with adjustment costs. By solving this for the subgame perfect equilibrium he is able to show that the conjectural variation solution is the same as the dynamic one (Dockner, 1992).

3.3 Price transmission analysis

Apart from the NEIO approach, the price transmission analysis has been a dominant framework for the investigation of market power since the 1970s. The general idea is that markets are in almost all cases at least either vertically, e.g. through the transformation process along a supply chain, or horizontally, e.g. via foreign trade, integrated. Considering vertically integrated markets, in the case where changes of prices are transmitted symmetrically in this system of markets then an price increase or decrease on one of the integrated market should be passed on instantaneously and in relative magnitude to the upstream or downstream markets (see Figure 5). Assuming that the downstream price depends on the upstream price in a system of vertically integrated markets, and a linear functional form, the relationship between the prices takes the form,

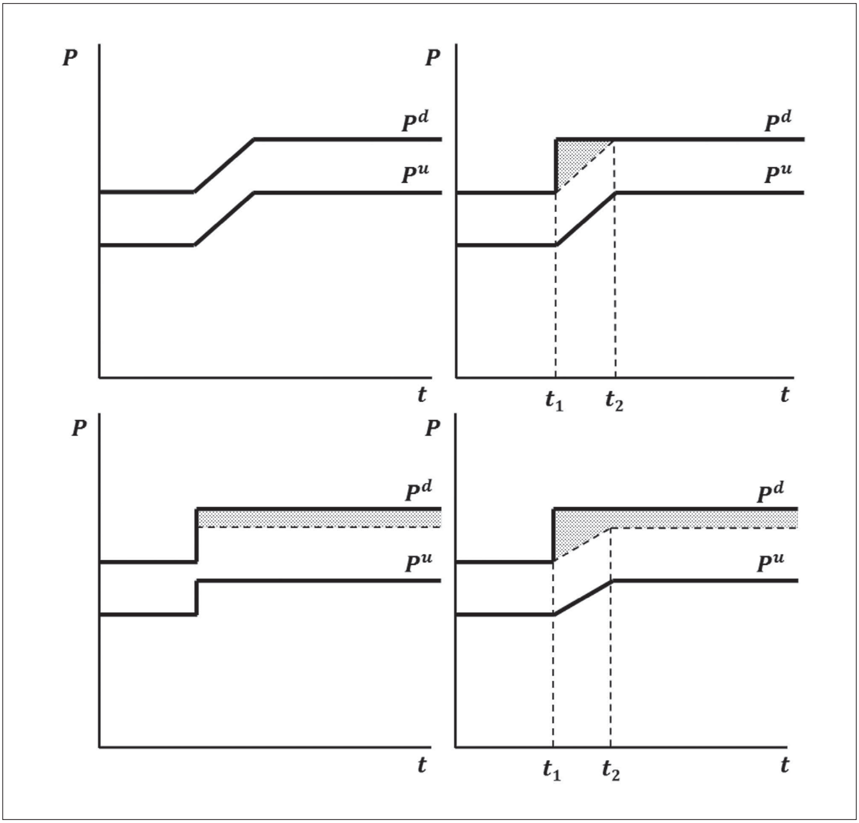
$$P_t^d = \beta_0 + \beta_1 P_t^u + \varepsilon_t \tag{2.25}$$

where ${P^d}_t$ is the downstream price and ${P^u}_t$ is the upstream price at time t. If prices are in natural logarithms, β_1 represents the price transmission elasticity τ, which given perfect price transmission equals one. Since its beginnings in the 1970s two quite different strands of price transmission methodology have evolved in the literature, which focus on market power in their analysis. The asymmetric price transmission framework (APT) tries to detect divergence from perfect price transmission by testing whether a dependent price series reacts symmetrically or asymmetrically to changes in an independent price. The equilibrium displacement model (EDM) instead models market power similar to conjectural variation in the NEIO methodology and then derives a measure of the price transmission elasticity including the effect of market power. In the following sections, both methodological approaches will be presented and their appropriateness for the identification of market power discussed.

3.3.1 Asymmetric price transmission (APT)

In the case of imperfect price transmission, the price transmission elasticity is unequal to one and welfare is transferred to the stage benefiting from this imperfection. The cause can be so-called asymmetries. Asymmetric price transmission and the accompanying welfare transfer can be temporary, e.g. if a delay in the price transmission exists, but the magnitude is transmitted equally (in Figure 5 over the period t_1 to t_2). However, if the magnitude does not symmetrically adjust, the asymmetry and welfare transfer is of permanent nature (Meyer & von Cramon-Taubadel, 2004).

Figure 5: Illustrations of cases of symmetry (upper left), asymmetry in speed (upper right), asymmetry in magnitude (lower left), and asymmetry in speed and magnitude (lower right) in the price transmission of P^d (downstream price) and P^u (upstream price), assuming that a shock in P^d is transmitted to P^u.

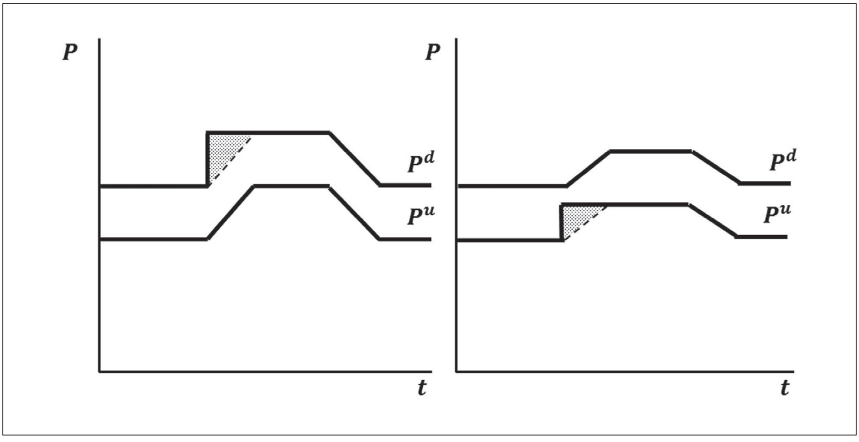


Source: own illustration.

Peltzman (2000) furthermore distinguishes between positive and negative APT (see Figure 5). In the occurrence of positive APT, price changes that could lower the margin between upstream P^u and downstream price P^d, increases in the upstream price and decreases in the downstream price, are faster and more fully transmitted, than respectively price decreases in the upstream and increases in the downstream price. APT is defined as negative, when price changes that could increase the price margin are faster and more fully transmitted. While the downstream market agents profit from the positive asymmetry in price transmission, upstream agents benefit in the case of negative APT (Peltzman, 2000; Meyer & von Cramon-Taubadel, 2004).

The source of APT is normally not clearly identified. One strain of APT literature argues that the cause of APT lies in the abuse of market power by one stage (e.g. Ward, 1982; Kinnucan & Forker, 1987; Borenstein et al., 1997; Peltzman, 2000; Miller & Hayenga, 2001). The actors of the upstream or downstream stage use their bargaining power to delay or absolutely restrain from transmitting price changes to the other stage resulting in a transfer of welfare. Depending on which level of the price transmission system uses market power, either positive or negative APT can arise. While an oligopoly or/and oligopsony at the downstream level will likely try to act in a way which increases the price-margin, an oligopoly at the upstream market will lower the price-margin.

Figure 6: Illustration of positive APT (left plot) and negative APT (right plot).



Source: own illustration.

However, some authors have argued that the picture is not as clear as it seems at first glance. For example, Ward (1982) in his study of the farm-to-retail price transmission has argued that downstream agents acting as an oligopoly might be unwilling to increase downstream prices symmetrically to upstream price increases to avoid the risk of declining market shares or fear the spoilage of perishable products resulting in negative APT rather than positive (Ward, 1982). Borenstein et al. (1997), on the other hand, in their study of the price transmission from crude oil to gasoline prices, state that in imperfect information settings crude oil price increases are transmitted faster than decreases. The original oligopoly price of gasoline in case of a crude oil decrease appears to be a natural point of orientation in uncertainty of the price adjustment behavior of the other firms, while an increase noticeably decreases the price-margin and is adjusted more quickly.

Another often stated source of APT are adjustment costs, also called menu costs. Adjustment costs in the price transmission framework arise if the cost of adjusting the price to a price change on the other level instantaneously would cause greater economic losses than benefits. For example, Bailey and Brorsen (1989) showed that meat packers face large fixed cost of capital and lower margins due to increases in the upstream price for beef in the short-run to enable constant full utilization of the capital. Furthermore, as mentioned before, the risk of food spoilage might be a reason for retailers to be reluctant in increasing their prices (Ward, 1982). Reagan and Weitzman (1982) further argued that firms during phases of low demand would rather build up inventories then decrease their prices and in phases of high demand more quickly increase their prices. Since adjustment costs are a result of adjusting the prices to a change in another price, the welfare transfer is only temporary, while in the case of stable exercise of market power it could be permanent (Meyer & von Cramon-Taubadel, 2004).

Apart from market power and adjustment costs, a series of other causes have been mentioned less frequently in the literature for APT. In the case of food products, Hall et al. (1981) stated that one cause of asymmetries can be the lethargy of the food marketing process, which includes storage, transport, and processing of the goods. Also lethargy or differences regarding price increases and decreases in the price reporting system can cause asymmetries (Bailey & Brorsen, 1989). Moreover, government interventions can cause APT. Kinnucan and Forker (1987) state that policy interventions like intervention prices cause APT, since firms can assume that in the presence of a floor price for a certain product price decreases are only temporary, while increases can be permanent.

With the beginning of the 1970s several studies were conducted to detect APT and indirectly market power as a possible source of these APT. In the following decades, theoretical considerations and methodological advancements have altered the methods applied for this purpose. In the following sections an overview over the methodological approaches that have been established to determine APT will be presented.

3.3.1.1 APT methodology

The idea of irreversibility was first discussed by Marshall (1936) and Haavelmo (1944). Farrell (1952) in his study of irreversible demand describes irreversibility using an example of a smoker that will adjust his smoking consumption differently, i.e. asymmetrically, depending on whether the price of tobacco increases or decreases. Tweeten and Quance (1969) use dummy variables to estimate an irreversible aggregate supply function, with the purpose to answer the question whether farmers adjust their output less to price decreases than increases. In their approach the total farm output is a function of the stock of productive assets, a productivity index, and a price ratio of prices received for their output and the lagged prices paid for inputs by farmers. Using a different notation to make the following approaches comparable, their linear supply function would take the form,

$$Q_t = \beta_0 + \beta_1 P_t D_t + \beta_2 P_t (1 - D_t) + \beta_3 Z_t + \varepsilon_t \tag{2.26}$$

where Q_t is the total output, P_t the price ratio, and Z_t a vector of the other included variables at time t. The dummy variable D_t takes a value of one if $P_t \geq P_{t-1}$ or zero otherwise. Tweeten and Quance (1969) using (2.26) argued that if $\beta_1 \neq \beta_2$ farmers' behavior would be asymmetrical.

The first to create a method to detect irreversibility of prices was Wolffram (1971). He based his approach on the framework of Tweeten and Quance (1969), but altered the price splitting methodology. The reason for this is that he criticized that the approach of Tweeten and Quance (1969) would result in biased estimates for β_1 and β_2 due to a probable non-constancy of the constant β_0 (Meyer & von Cramon-Taubadel, 2004). His model can be formulated as,

$$P_t^d = \beta_0 + \beta_1 (P_0^u + \textstyle\sum_{t=1}^{T} D_t \Delta\, P_t^u) + \beta_2 (P_0^u - \textstyle\sum_{t=1}^{T} (1 - D_t) \Delta\, P_t^u) + \varepsilon_t \tag{2.27}$$

where D_t has the same meaning as in (2.26), Δ is the first difference operator, and the upstream price variable is split by either adding or subtracting the first differences of the upstream price to its original value depending on price increases or decreases compared to the previous period at time t. As in Tweeten and Quance (1969) symmetry of price transmission is tested by testing the hypothesis $\beta_1 = \beta_2$ (Wolfram, 1971).

By dropping the initial values of the prices from (2.27) Houck (1977) was able to give a clearer representation of the method of Wolfram (1971). Houck (1977) elaborated that when the effect of differenced prices is to be determined the initial values are obsolete for the estimation. Thus, (2.27) can be rearranged into,

$$P_t^d = \beta_0 + \beta_1(P_0^u + \sum_{t=1}^{T} D_t \Delta P_t^u) + \beta_2(P_0^u - \sum_{t=1}^{T}(1 - D_t)\Delta P_t^u) + \varepsilon_t \quad (2.28)$$

where the initial value of the downstream price is subtracted from its value at time t and the resulting dependent variable only depends on the cumulative price changes. He further simplifies the model by giving a representation of (2.28), which only includes the first differences without the requirement of estimating the cumulative effect,

$$\Delta P_t^d = \beta_0 + \beta_1 D_t \Delta P_t^u + \beta_2(1 - D_t)\Delta P_t^u + \gamma_t \quad (2.29)$$

where, as in all specifications so far, the symmetry in price transmission is determined by testing the hypothesis that $\beta_1 = \beta_2$. Ward (1982) altered the approach of Houck (1977) by adding additional lags to the first differences of the upstream price and allowing them to differ in their number for the increasing and decreasing phases. The hypothesis of symmetry would have to be accepted if the sum of these lagged parameter polynomials $\sum\beta_1 = \sum\beta_2$ are equal (Ward, 1982).

3.3.1.2 Cointegration and threshold APT

Granger and Newbold (1974) proved that using standard regression techniques for the estimation of a relationship between non-stationary variables would create spurious results that appear to prove the relationship between variables, which truly does not exist. This is of utter importance to APT, since bundles of price time series, in particular or vertically and horizontally integrated markets, are often non-stationary, but rather have a stochastic trend in common (Hendry & Doornik, 2001; Juselius, 2006). Von Cramon-Taubadel (1998) stated that many previous applications in the field of APT suffered first-order autocorrelation, a sign of spurious regression. In addition, it was shown that if the price time-series are cointegrated the approach of Wolffram (1971) and Houck (1977) should reject asymmetry. Time series of variables are labelled as 'cointegrated' when one or more combinations of these exist that are stationary in the long-run

(Juselius, 2006). Consequently, a solution to the issue of spurious regression is to test whether the variables are cointegrated and if so apply a cointegration framework (von Cramon-Taubadel, 1998).

The first to apply cointegration techniques to APT were von Cramon-Taubadel and Fahlbusch (1994). Their approach was based on the 2-step error correction model (ECM) developed by Engle and Granger (1987) and the idea of non-symmetric ECM by Granger and Lee (1989). The procedure is the following. After testing for the existences of unit roots, non-stationarity, as well as for cointegration among the time series, (2.25) represents the long-run equilibrium relationship of the downstream and upstream price. The lagged residuals ε_{t-1} are deviations from this long-run equilibrium, the so-called error correction term (ECT). Consequently, these deviations can be interpreted as adjustments to the price transmission. After splitting the ECT in positive (ECT^{+}) and negative (ECT^{-}) deviations, a non-symmetric error correction representation can be formulated as,

$$\Delta P_t^d = \alpha_0 + \alpha_1 ECT_{t-1}^{+} + \alpha_2 ECT_{t-1}^{-} + \alpha_3 \Delta P_t^u + \alpha_4(L)\Delta P_{t-1}^d$$

$$+ \alpha_5(L)\Delta P_{t-1}^u + \varepsilon_t \qquad (2.30)$$

where $\alpha_4(L)$ and $\alpha_5(L)$ are lag polynomials of the order L. Equation (2.30) allows to determine whether APT is present by testing if the equality of the corresponding ECTs parameters $\alpha_1 = \alpha_2$ holds (von Cramon-Taubadel & Fahlbusch, 1994; von Cramon-Taubadel, 1998). In an extension, von Cramon-Taubadel and Loy (1996) also suggest to split the first difference of the upstream price ΔP^u in positive and negative deviations to test for additional asymmetries in price transmission.

The cointegration test elaborated by Engle and Granger (1987) requires the long-run equilibrium to be constant over time. Gregory and Hansen (1996) extended the testing procedure by permitting to test the cointegration relationships of time series with the presence of structural breaks, i.e. level shifts (with and without trend) and regime switches. Furthermore Enders and Granger (1998) modified the test for cointegration to allow for asymmetric adjustment of the deviations to the long-run equilibrium in their work. As a result of the methodic advances, cointegration analysis, as mentioned above, could now be conducted with time series that failed the cointegration test in the first place due to structural breaks. Thus, it is also possible to observe asymmetric price transmission in magnitude and not just in speed as under the original framework of von Cramon-Taubadel and Fahlbusch (1994) (Abdulai, 2000; Meyer & von Cramon-Taubadel; 2004).

One modification that allows for non-linear adjustment in the ECM is the threshold ECM. Instead of splitting the ECT in positive and negative deviations, it is also possible to search the data series for n thresholds that define $n+1$ regimes and split the ECT time series accordingly in regime respective time series. Therefore, the estimated parameters of (2.30) vary with regime (Goodwin & Holt, 1999; Goodwin & Harper, 2000; Goodwin & Piggott, 2001). The number of thresholds is not restricted. For illustration, Goodwin and Harper (2000) in their study of the farm-to-retail price transmission in the U.S. pork sector define two thresholds, a lower and upper threshold, which allows extreme deviations from the long-equilibrium to affect price changes differently than in the 'neutral' interval. The representation of the corresponding threshold cointegration model with two thresholds l_1 and l_2 is given by,

$$\Delta P_t^d = \begin{cases} ECT_{t-1} < l_1: \\ \alpha_{0,1} + \alpha_{1,1} ECT_{t-1} + \alpha_{2,1} \Delta P_t^u + \alpha_5(L) \Delta P_{t-1}^u + \alpha_{3,1}(L) \Delta P_{t-1}^d + \varepsilon_t \\ l_1 \leq ECT_{t-1} \leq l_2: \\ \alpha_{0,2} + \alpha_{1,2} ECT_{t-1} + \alpha_{2,2} \Delta P_t^u + \alpha_5(L) \Delta P_{t-1}^u + \alpha_{3,2}(L) \Delta P_{t-1}^d + \varepsilon_t \\ ECT_{t-1} > l_2 \\ \alpha_{0,3} + \alpha_{1,3} ECT_{t-1} + \alpha_{2,3} \Delta P_t^u + \alpha_5(L) \Delta P_{t-1}^u + \alpha_{3,3}(L) \Delta P_{t-1}^d + \varepsilon_t \end{cases} \quad (2.31)$$

where the estimated parameters change depending on the regime. Consequently, if thresholds are statistically determined, the speed of adjustment parameter could differ between the regimes and inequalities of these estimates indicate asymmetry in price transmission. This allows interpreting the results in a new way in the APT framework. Thresholds can be seen as a measure of adjustment costs, since the ECT has to reach a certain level before price adjustment will take place (Goodwin & Harper, 2000; Meyer & von Cramon-Taubadel, 2004). Apart from threshold cointegration, also Markov-switching (MS) techniques have been applied to the ECM to allow regime shifts. In contrast to applying grid search procedures that find a threshold that maximizes the likelihood function (Tsay, 1989) or minimizes the sum of squared errors (Balke & Fomby, 1997), it is assumed that a state variable, defining the regimes, is driven by a Markov-chain. Like in the case of applications to the dynamic CPM, the state variable depends only on the previous period and not on the whole history of the regime (Hamilton, 1989; Krolzig, 1997). Furthermore, not all parameters have to differ with the regime, but they can be selected, what allows the researcher to model the price transmission more flexible (Djuric & Götz, 2016).

3.3.2 Equilibrium displacement model (EDM)

The equilibrium displacement model (EDM) was introduced by the seminal work of Gardner (1975). It is assumed that n firms produce a homogenous output good using two inputs, a material one and non-material one and sell it at price P. Like Gardner (1975), most EDM works that followed analyzed the farm-to-retail price spread, and assumed the two inputs to be farm and marketing service input. However, to continue the denomination used in the NEIO section, the inputs will be labelled material and non-material respectively (Gardner, 1975; McCorriston et al., 1998; 2001; Weldegebriel, 2004; 2012).

The EDM model consists of supply and demand functions for the output product, production function of the i^{th} firm and an inverse of the demand function of (2.1), for the inputs, inverse supply function, depending on quantities produced and exogenous shift variables, and derived demand through applications of inverse of Shepard's lemma or the price of the inputs equaling VMP with the assumption of profit-maximizing behavior. Each supply and demand equation of this system is differentiated with respect to a change in one of the exogenous variables at either the output or each of the input levels. The new derived equations are solved for the explicit solutions of the endogenous variables, the prices and quantities of the output and inputs, which provide the equilibrium equations where the endogenous variables solely depend on the exogenous variables (Gardner, 1975; McCorriston et al., 2001).

Using the equilibrium solutions for the changes in output and the material input, it is possible to derive the price transmission elasticity τ. Assuming the shock was caused by the exogenous variable of the material supply function, the price transmission elasticity in Gardner (1975) is given by,

$$\tau = \frac{d\ln P / d\ln Z}{d\ln W^M / d\ln Z} = \frac{s^M\left(1+\frac{\sigma}{\eta^Z}\right)}{1+s^M\frac{\sigma}{\eta^Z}-s^Z\frac{\varepsilon}{\eta^Z}} \tag{2.32}$$

where s^M and s^Z are the cost shares of the material input and the non-material input respectively, η^Z is the price elasticity of the non-material input supply, ε is the price elasticity for the output demand, and σ is the elasticity of substitution between the material and non-material input. Gardner (1975) derived further price transmission elasticities with respect to changes due to exogenous shocks at the non-material and output level. Nevertheless, like subsequent works we will focus on the price transmission elasticity derived from a shock at the material input level. From (2.32) it can be deduced that the smaller the elasticity of substitution between the inputs, the more volatile the farm-to-retail price ratio reacts to supply shocks. Furthermore, Gardner (1975) found that the effect on the farm-to-retail spread of retail demand shocks is larger than the effect of farm supply shocks. If the elasticity of substitution is relatively low and supply for material inputs relatively elastic, τ will approximate the value of s^M (Gardner, 1975; Weldegebriel et al., 2012).

Nevertheless, the EDM of Gardner (1975) has little use in the investigation of market power, since competitive markets are assumed. McCorriston et al. (1998) modeled an oligopolistic setting on the output market by deriving a supply relation similar to the static CPM model of Bresnahan (1982) (2.2). The price transmission elasticity is then derived according to the EDM of Gardner (1975) by differentiating the system of equations with respect to a material input supply shock,

$$\tau = \frac{s^M\left(1+\frac{\sigma}{\eta^Z}\right)}{\left(1+s^M\frac{\sigma}{\eta^Z}\right)(1+\mu^\Theta)-s^Z\frac{\varepsilon}{\eta^Z}} \tag{2.33}$$

where μ^Θ = $(\partial(\Theta/\varepsilon)/\partial\varepsilon)(\partial\varepsilon/\partial P)$ is the change in the industry mark-up. If Θ equals zero, also μ^Θ equals zero, (2.33) collapse to the competitive version (2.32). Comparing the price transmission elasticity τ^c in a competitive setting to the noncompetitive level τ lets McCorriston et al. (1998) conclude that in the case of linear demand and supply functions oligopoly power at the downstream market will result in growing imperfect price transmission. Furthermore, using measures for the elasticities of previous studies (Wohlgenant, 1989; Azzam & Pagoulatos, 1990; Schroeter & Azzam, 1990) on the U.S. beef and pork sector, McCorriston et al. (1998) reported that the price transmission would greatly differ depending on whether markets were assumed to be competitive and variable proportions technology or imperfect competitive markets with fixed proportion assumption (1998) (McCorriston et al., 1998).

Like Gardner (1975), the framework of McCorriston et al. (1998) assumes constant returns to scale (CRS). However, this has been questioned by empirical findings, e.g. of Morrison Paul and Siegel (1999) who found short- and long-run increasing returns-to-scale in the U.S. manufacturing sector. Consequently, McCorriston et al. (2001) extended the framework to account for non-constant returns to scale. The main result was that the scale parameter truly influences the effect of market power on the price transmission elasticity. It can be greater or less depending on the returns to scale measure. In case of increasing returns to scale, the influence of market power is 'offset' (McCorriston et al., 2001).

Weldegebriel (2004) extends the work of McCorriston et al. (2001) to account for oligopsony power in the material input market. Instead of using equation

(2.20) for the industry's material input demand, a modification of Schroeter's (1988) derived demand equation (2.8) enters the system of equations to deduce the equilibrium equations. Also accounting for non-constant returns-to-scale by incorporating the scale measure ρ the price transmission elasticity in the event of an exogenously induced supply shock takes the form,

$$\tau = \frac{\rho\psi^M(1+\mu^\Xi)\left(1+\frac{\sigma}{\eta^Z}\right)}{\left(\rho+\psi^M\frac{\sigma}{\eta^Z}\right)[(1+\mu^\Theta)\rho+\varepsilon(\rho-1)]-\psi^Z\frac{\varepsilon}{\eta^Z}} \tag{2.34}$$

where $\psi^M = s^M(1+\Xi/\eta^M)/(1+\Theta/\varepsilon)$ and $\psi^Z = s^Z/(1+\Theta/\varepsilon)$ are the value shares of the material and non-material input respectively, η^M the supply elasticity of the material input, and $\mu^\Xi = (\partial(\Xi/\eta^M)/\partial\eta^M)(\partial\eta^M/\partial W^M)$ is equivalent of μ^Θ on the material input market, the change in the mark-down. Applying comparative static and simulations, Weldegebriel (2004) reported that no clear conclusion on the effect of oligopoly and oligopsony power can be drawn without knowledge of the functional forms. Under the assumptions of certain values for the required elasticities and the presence of market power on the upstream and downstream market the price transmission could even exceed the competitive level (Weldegebriel, 2004).

Based on the EDM approach, but not solving for the price transmission elasticity is the model of Lloyd et al. (2009). Like in the previous EDM models, n firms produce a homogenous output by using two inputs in fixed proportions and with CRS. Furthermore it is assumed that buyer exercise market power on the material input market. The first-order condition of the profit function of the i^{th} firm with respect to the material input level, aggregating across all firms, and assuming linear demand and supply functions yields,

$$P = M + W^M + \Xi\frac{\partial W^M(\bullet)}{\partial X^M}Q \tag{2.35}$$

where $M = \alpha_0 + \alpha_1 W^Z$ represents a composite variable of all other marketing cost, a linear function of the constant α_0 and the cost of the non-material input is given by $\alpha_1 W^Z$. Using (2.35) as the derived demand for material input in a system with output supply and demand as well as material input inverse supply functions, explicit solutions for the endogenous variable P, Q, and W^M can be derived. Deducing from this explicit solutions, the margin (P - W^M) equals in the absence of oligopsony power M. Consequently, a simple test for the presence of oligopsony power is to estimate an unrestricted linear representation of the margin equation, for example formulated as,

$$P = \beta_0 + \beta_1 W^M + \beta_2 M + \beta_3 Y + \beta_3 Z \tag{2.36}$$

and test the hypothesis of perfect competition (here: $\beta_3 = \beta_4 = 0$), since in the absence of market power exogenous supply and demand shocks should not affect the price margin, but in the presence of oligopsony power the shifts should be significant. Lloyd et al. (2009) applied their 'first-pass' test for oligopsony power to the UK food retailing sector and nine basic food product groups. The margin equation (2.36) is embedded in a vector error correction model (VECM) to account for cointegration between the variables. In seven out of nine cases, the hypothesis of perfect competition can be rejected (Lloyd et al., 2009).

3.3.3 Criticism

Apart from the estimation issues of pre-cointegration period price transmission analysis the price transmission framework has been criticized due to a series of critic points that heavily undermine its appropriateness to the analysis of market power.

One certainly big issue is the choice of time series of price transmission studies is already biased. Meyer and von Cramon-Taubadel (2004) as well as Peltzman (2000) surveyed several hundreds of APT studies, 205 and 242 respectively, and found that 48% and around 2/3 of these studies rejected the hypothesis of symmetric price transmission. Consequently, asymmetry and thus market power abuse seem to be the rule. Nevertheless, in reality anti-trust agency cases are rather the exception (Acharya et al., 2011).

Furthermore, the choice of time horizon as well as frequency plays a major role to determine the validity of the study. Meyer and von Cramon-Taubadel (2004) argued that known changes in the market power conduct must have occurred in the investigated time period, otherwise it would not be valid to compare price transmission in the competitive scenario to settings with different levels of market power due to the lack of variation in the 'treatment variable'(Meyer & von Cramon-Taubadel, 2004). Moreover, the frequency of the data has to fit the frequency of the adjustment process. If the price transmission occurs over a couple of days, monthly data will not enable the researcher to detect any asymmetries (Boyd & Brorsen, 1988).

The price transmission framework has experienced large popularity, as shown by the surveys of Peltzman (2000) and Meyer and von Cramon-Taubadel (2004), among economists, since it allows researchers to investigate market power with relatively low data requirements compared to NEIO models. Mostly only easily available data on prices are required. Nevertheless, the major drawback of these studies regarding the investigation of market power is that they hypothesize that the source of the imperfect price transmission is market power but cannot validate their hypothesis with economic theory. As shown by the EDM, less complete price transmission can result from other sources such as non-constant returns-to-scale (Bliss, 1988).

While the EDM approach derive the price transmission elasticity from a theoretic model and thus is able to determine the effect of market power on the price transmission, as shown in the previous section, inference on the effect of market power is heavily dependent on the choice of functional form and diverse technology assumptions lead to completely different outcomes. Consequently, knowledge of the true technology is required to draw valid conclusion. This requires estimation of a system of supply and demand functions similar to NEIO techniques. Apart from losing the appeal of low data requirement, also the same criticism of NEIO model applies then to the EDM framework.

3.4 Summary

In the previous chapter, the three most prominent methodologies to the investigation of market power were presented, the SCPP, NEIO, and price transmission framework. The standard theoretic concepts and the advantages and disadvantages of each approach were presented and discussed.

The SCPP derives from accounting data a measure of industries' performance, e.g. PCM, and tries to explain difference between sectors by market structure measures, such as concentration ratios. Nevertheless, due to endogeneity issues between the chosen variables, accounting data not being truly representative for economic data, and a never ending discussion of which concentration ratio best depicts the market structure the SCPP has submerged into economic oblivion and is hardly ever applied in market power analysis today.

While the SCPP almost completely disappeared from the economic landscape, NEIO and price transmission analysis still enjoy great popularity in empirical applications today. The NEIO concept models firms' behavior and is able to estimate a market power conduct parameter, which nests all forms of market structure from competitive over oligopoly to monopoly, and thus the effect of market power on the market outcome. Furthermore different market settings and how they affect input and output markets, such as oligopoly, oligopsony, or oligopoly and oligopsony, have been theoretically developed and empirically applied. Nevertheless, NEIO models' data requirement are high, the choice of functional form severely affects the estimates, and if modeled dynamically strong assumptions have to be drawn to limit the possible number of equilibria.

In addition, while a measure of the CPM and thus market structure is obtained, the source of the market power is never clearly identified.

In contrast, the price transmission framework only depends on price time series. The price time series are investigated for possible asymmetries and thus imperfect price transmission. One of the sources of this imperfect price transmission is hypothesized to be market power. Consequently, while the simplicity of the framework is desirable, it lacks any theoretic economic link that confirms this hypothesis. The EDM framework creates this link, however if estimated it is very similar to NEIO models, if not the same, and their demanding data requirements. The 'first-pass' test developed by Lloyd et al. (2009), which can somewhat be seen as a hybrid of EDM and NEIO, allows to test for oligopsony power with rather low data requirements. Nevertheless, the extent of market power is not measured and the authors themselves state that it can be seen as a first empirical tool to the investigation of market power (Lloyd et al., 2009).

Overall, this theory review has shown that for the investigation of market power either the data requirements are high and the models highly complex, like in the case of NEIO, but an index of market power can be measured, or the data requirements are rather low and the theoretic models rather simple, like in the case of the price transmission framework, but market power or its extent are not clearly identified. In the next chapter, we will provide an overview of all known empirical applications of the presented concepts to the milk and dairy markets.

4 Empirical applications in the dairy sector

The following section deals with empirical applications of the previously described theoretic models of NEIO and price transmission analysis. Because the dairy agri-food supply chain is the focus of this work, we will limit the overview to applications in this field. For more comprehensive overviews the reader is referred to Bresnahan (1989) and Perekhozhuk et al. (2016) as well as Meyer and von Cramon-Taubadel (2004) and Frey and Manera (2007) for a review of empirical studies in NEIO and APT respectively.

4.1 NEIO

Perekhozhuk et al. (2016) list 38 empirical studies that estimated market power in agri-food and related industries. Eight of these studies examine milk and dairy product markets. Table 10 presents an updated version of the survey of Perekhozhuk et al. (2016) and presents all, to our knowledge, 16 empirical applications of the NEIO approach to the dairy supply chain or one of its submarkets.

Even though these studies are very diverse in their methodological approach, e.g. assuming fixed proportions technology (Gohin & Guyomard, 2000) or accounting for non-constant returns-to-scale (Bhuyan & Lopez, 1998), and scope, raw milk market (Perekhozhuk et al., 2013) to PDO cheese markets (Sckokai et al., 2013), still common grounds can be identified. Each study starts out by either following Bresnahan's (1982) GIM or Appelbaum's (1979; 1982) PTA method and in some cases modify these to either allow for product differentiation (Hovhannisyan & Bozic, 2013) and/or oligopsony market structures (Hockmann & Vőnecki, 2009). The following sections categorize the listed applications in to oligopoly, oligopoly/oligopsony, and oligopsony models and briefly describe notable differences or modifications to the standard methods depicted in theory review chapter.

4.1.1 Oligopoly

Nine of the listed 16 studies assume an oligopolistic structure at either the processor (6) or retail (3) level. Upstream markets are assumed to be competitive. Liu et al. (1995) allow for two different regimes in their application to the U.S. dairy industry, where one of the regimes is defined as 'booming period' and the other as 'government supported'. In the first regime the market price is above the government intervention level and in the second the market price equals the intervention price. Furthermore, they distinguish between dairies that produce fluid milk and other dairy products. Both processor types act to some extent oligopolistic with the dairy products producer abusing their market power more with a CE 0.176 compared to 0.100 for the fluid milk producers' CE.

Bhuyan and Lopez (1998) modified Appelbaum's (1979; 1982) approach to allow for non-constant returns-to-scale and demand price elasticities in the food processing industry. The conjectural variation for the fluid milk sector demonstrates non-competitive market behavior by dairies with a value of 0.182 over the time period from 1972 to 1987.

Hovhannisyan and Gould (2012) as well as Hovhannisyan and Bozic (2013) alter the GIM approach to allow for differentiated products. The products, milk and yogurt respectively, are differentiated into the subgroups national brand, store brand, and other national brands. Furthermore regional markets, U.S. metropolitan city regions, are investigated separately. While Hovhannisyan and Gould (2012) do not find evidence for retailer market power for the store and national milk brands, they report low market distortions with a CV of 0.022 in the other national brand category. Hovhannisyan and Bozic (2013), on the other hand, do not explicitly report the estimates for the CPM, but state that retailers mark-up yogurt depending on the city and brand between 1.4% and up to 12.5% from the competitive price level.

4.1.2 Oligopoly/Oligopsony

Most of the applications that investigate whether one market stage abuses oligopoly power on the output market and oligopsony power on the input market are based on the approach of Schroeter (1988). The firsts to consider that retailers might exercise buyer power were Gohin and Guyomard (2000) in their analysis of the French retail sector regarding three main food product groups over the time period 1977 to 1993. While a CPM close to the competitive level is reported, the Lerner index for dairy products takes a value of 0.20 due to the inelastic demand.

Sckokai et al. (2013) were the first to apply a dynamic CPM model to the dairy sector. In their empirical study of the Italian PDO cheese market, they based their approach on Perloff et al. (2007) with fixed proportion technology, stock of cheese as the state variable, and two outputs, Parmiggiano Reggiano and Grand Padano. While significant levels of oligopoly conduct were identified, CPM of 0.25 for both products, the estimate for oligopsony market behavior was not statistically significant from zero (Sckokai, et al. 2013).

4.1.3 Oligopsony

Most empirical studies that either model an oligopoly or an oligopoly/ oligopsony were conducted in industrialized countries, in particular the USA. Pure oligopsony models, always assuming a non-competitive raw milk and competitive output market, were only applied to former socialist, e.g. Hungary (Perekhozhuk et al., 2013), or emerging countries, e.g. Brazil (Scalco & Braga, 2014). Most of the oligopsony models are based on the work of Muth and Wohlgenant (1999) and use industry aggregated data. One exception is Perekhozhuk et al. (2013), who use plant level data to investigate the Hungarian raw milk market from 1993 to 2006 and reported rather high levels of oligopsony behavior with a CPM value of 0.2219. The other oligopsony studies of Hockmann and Vőnecki (2009) for Hungary, Perekhozhuk et al. (2015) for Ukraine, and Scalco and Braga (2014) for Brazil, found lower levels of market imperfections (see Table 10).

4.2 APT

In this section an overview of APT empirical applications to the dairy supply chain is presented (see Table 11). To our knowledge no empirical applications of the EDM framework to the dairy sector exist. However, most of the studies presented here derive a simplistic measure for the price transmission elasticity by assuming some relationship like in equation (2.25) or the (cumulative) sum of β_1 and β_2 equal τ (e.g. Bolotova & Novakovic, 2015; Dudová & Bečvařová, 2015). By incorporating additional cost variables to the price relationship as in the margin equation similar to Lloyd et al. (2009), where $P - W^M = f(W^M, Q, MC) - W^M$, it is also possible to test for CRS (e.g. Romain et al., 2002).

Evidently, almost all empirical studies find positive asymmetries. Even though APT, as mentioned before, is not able to detect market power directly as the source of asymmetry, most studies explained their results with an oligopoly or oligopoly/oligopsony at the downstream level, which is able to increase the spread between upstream and downstream price (e.g. Rumánková, 2012). Three exceptions exist. While Dudová and Bečvařová (2015) in their analysis of the farm-to-processor and processor-to-retail price transmission for milk and butter in the Czech Republic from 2000 to 2013 found evidence for APT in three out of these four relationships, they could not statistically prove that the processor-to-retail relationship in regards to butter is characterized by APT. Romain et al. (2002), on the other hand investigated the U.S. milk supply chain and report positive long-run price asymmetries for the period before 1991, but full transmission from 1991 to 1997. In contrast, Bakucs et al. (2012) find no evidence for asymmetry in price transmission between the Hungarian raw milk and retail prices for the entire investigated time period from 1995 to 2007.

Surprisingly, even though ECM techniques were already applied to price transmission analysis by von Cramon-Taubadel and Fahlbusch (1994), nine of the listed studies appeared after this paper and still used some form of the Houck representation. Authors either reported that the cointegration test was rejected (e.g. Lass, 2005) or did not consider it at all (e.g. Bolotova & Novakovic, 2015; Romain et al., 2002). Capps and Sherwell (2007) in their study of the milk price transmission for several large U.S. cities made the effort to compare both methods. They concluded that both methods yielded almost identical statistical results (Capps & Sherwell, 2007).

Furthermore, most of the APT studies use monthly data. As mentioned before, in the criticism of price transmission analysis, the choice of frequency of the data is of utter importance to the analysis, since data with a lower frequency than the adjustment process will not be able to reveal asymmetries in the price transmission process (Boyd & Brorsen, 1988). Serra and Goodwin (2003) in their analysis of the price transmission along the Spanish dairy supply chain examine whether the choice of weekly or monthly data will affect the result. When only data with a weekly frequency was used, asymmetries were stronger and only revealed for dairy products with long-shelf life, like cheese. However, lowering the data frequency to be monthly, also revealed APT for perishable dairy products, like fresh milk, and lowered the asymmetry. The author explained that farm prices in Spain appear to be adjusted on a monthly basis instead of a weekly one and retail and farm prices for lower value-added milk products, mostly perishable ones, are tighter connected due to scarcity of raw milk, less market power in the 'white line' due to the absence of product differentiation and cost-minimizing strategies, and thus the price transmission more symmetric (Serra & Goodwin, 2003).

4.3 'First-pass' test

In contrast to the NEIO and APT methodology the rather young 'first-pass' test by Lloyd et al. (2009) has to our knowledge been only applied empirically to the dairy sector three times. Lloyd et al. (2009) applied their developed test to the UK retail sector for main food products from January 1990 to October 2001. Even though oligopsony power was found for the procurement of meat products, dairy products were no subject of market power exertion according to the study. In contrast to this, Fałkowski (2010) and Madau et al. (2016) in their empirical applications of the 'first-pass' test, found oligopsony power in the Polish, from January 1996 to December 2006, and Italian, from January 2000 to December 2013, milk supply chain respectively.

4.4 Summary

In general, the dairy supply chain has experienced great popularity as a sector worth studying in NEIO and price transmission analysis. Main country of focus has been the U.S. dairy sector, but recently the European dairy sector has been studied more and more frequently, in particular Eastern European countries. A reason for this might be that the dairy supply chains of these countries have undergone dramatic restructuring since the abolishment of socialism and thus are an interesting case for the empirical studies (Bakucs & Fertő, 2005).

Empirical applications of both strains of methodology in general report market power abuse in the corresponding dairy supply chain. Nevertheless, all APT studies only assume that market power could be the source of the found asymmetries in price transmission and cannot empirically prove the validity of their assumption. Furthermore, it can be criticized, in the fashion of Peltzmann (2000), since all APT studies except for one, the study on the Hungarian milk market and its farm-to-retail price transmission by Bakucs et al. (2012), find some sort of asymmetry in the respective dairy supply chain, that asymmetries are rather the rule than the exception and thus market power should be omnipresent.

NEIO studies on the dairy supply chain, on the other hand, derive via the structural modelling of markets with supply and demand functions an estimate of market power conduct. Even though, almost all of the listed studies find evidence for some level of market power abuse, the estimates for the CPM are rather low and dairy supply chain markets seem to be closer to the competitive than the monopolistic or monopsonistic market structure.

The ‘first-pass’ test, developed of Lloyd et al. (2009) as a synergy of EDM and NEIO, has only been applied empirically in three cases. While this test showed that the Polish and Italian retail sector in the recent past used market power in their procurement of milk, it was not able to identify oligopsony power of the UK retail sector towards the upstream dairy chain actors. Even though, the ‘first-pass’ test allows to test the presence of oligopsony power, no estimate of the level of market power or the mark-down is obtainable.

Furthermore, as described before, although agri-food supply chains are more and more retailer dominated and the threat of buyers power towards dairy farmers is eminent due to the perishableness of raw milk, no study or theoretic model exists that accounts for a subsequent oligopsony at the raw milk and dairy output market. The following theoretic model and empirical application to the German dairy supply chain will try to fill this gap in the literature.

Table 10: NEIO studies in the dairy sector.

year	author	country	product	time	level	aggregation	frequency	method	model	CE/CV
2010	Ahn & Lee	Republic of Korea	infant formula	1975-2009	processor	national	annual	GIM	oligopoly	0.29
1998	Bhuyan & Lopez	USA	milk	1972-1987	processor	national	annual	PTA	oligopoly	0.182
2012	Cakir & Balagtas	USA	dairy products	2000-2007	processor/ retailer	regional	annual	PTA	oligopoly/ oligopoly	≤0.021a/≤0.0023a
2005	Chidmi et al.	USA	milk	1996-2000	retailer	regional	weekly	GIM	oligopoly	0.1663
1999	De Mello & Brandao	Portugal	milk	1962-1991	processor	national	annual	PTA	oligopoly	0.05403
2000	Gohin & Guyomard	France	dairy products	1977-1993	retailer	national	annual	GIM	oligopoly/ oligopsony	-0.0187
2009	Hockmann & Vőnecki	Hungary	milk	1998-2006	processor	national	monthly	PTA	oligopsony	0.05
2012	Hovhannisyan & Gould	USA	milk	2001-2006	retailer	regional	weekly	GIM	oligopoly	0.022
2013	Hovhannisyan & Bozic	USA	yogurt	2001-2007	retailer	regional	weekly	GIM	oligopoly	NA
1995	Liu et al.	USA	dairy products	1975-1992	processor	national	quarterly	PTA	oligopoly	0.1
			milk	1975-1993	processor					0.176
2009	Mérel	France	Comté cheese	1985-2005	processor	national	quarterly	GIM	oligopoly	0.001
2013	Perekhozhuk et al.	Hungary	milk	1993-2006	processor	firm	annual	PTA	oligopsony	0.2219b
2015	Perekhozhuk et al.	Ukraine	milk	1996-2003	processor	regional	monthly	PTA	oligopsony	0.1475b
2012	Salhofer et al.	Austria	milk	1997-2008	retailers	national	monthly	PTA	oligopoly/ oligopsony	0.011/NA
			cheese							NA/NA
			Butter/others							NA/0.102
2014	Scalco & Braga	Brazil	milk	1997-2011	processor	regional	annual	GIM	oligopsony	0.01b
2013	Sckokai et al.	Italy	PDO cheese	2002-2008	processor	national	monthly	dynamic	oligopoly/ oligopsony	0.25/none
1993	Suzuki et al.	Japan (Hokkaido)	dairy products	1979-1988	processor	regional	annual	GIM	oligopoly	0.12a
		Japan (other regions)	dairy products	1979-1989	processor	regional	annual	GIM	oligopoly	0.23a

Source: own illustration, based on Perekhozhuk et al. (2016). Notes: [a] maximum value in region or over time reported; [b] average value reported.

Table 11: APT studies in the dairy sector.

year	author	country	product	time	relationship	frequency	model	asymmetries
2014	Acosta & Valdés	Panama	milk	1991-2011	farm-wholesale	monthly	ECM	positive
2002	Aguiar & Santana	Brazil	milk	1987-1998	farm-retail	monthly	Houck	positive
2009	Awokuse & Wang	USA	cheese	1987-2006	farm-retail	monthly	ECM (regime)	positive
2012	Bakucs et al.	Hungary	milk	1995-2007	farm-retail	monthly	ECM	none
		Poland	milk	1995-2007	farm-retail	monthly	ECM	positive
2012	Bolotova & Novakovic	USA	milk	1982-2008	farm-retail	monthly	Houck	positive
2015	Bolotova & Novakovic	USA	cheese	2000-2014	farm-wholesale	monthly	Houck	positive
2007	Capps & Sherwell	USA	milk	1994-2002	regional	monthly	Houck & ECM	positive
2005	Carman & Sexton	USA	milk	1999-2003	farm-retail	monthly	Houck	positive
2004	Chavas & Mehta	USA	butter	1980-2001	wholesale-retail	monthly	ECM (regime)	positive
2015	Dudová & Bečvařová	Czech Republic	milk	2000-2013	farm-processor	monthly	Houck	positive
					processor-retail			positive
			butter		farm-processor			positive
					processor-retail			none
2010	Fałkowski	Poland	milk	1995-2006	farm-retail	monthly	ECM	positive
2016	Hahn et al.	USA	cheese	2000-2012	farm-retail	monthly	ECM/STAR1 (regime)	positive
2015	Kharin	Russia	milk	2002-2014	farm-retail	monthly	ECM	positive
1987	Kinnucan & Forker	USA	dairy products	1971-1981	farm-retail	monthly	Houck	positive
2015	Lajdová & Bielik	Slovakia	milk	2004-2011	farm-processor	monthly	ECM	positive
					processor-retail			positive
2001	Lass et al.	USA	milk	1982-1996	farm-retail	monthly	Houck	positive
2005	Lass	USA	milk	1982-2001	farm-retail	monthly	Houck	positive
2015	Loy et al.	Germany	milk & butter	2005-2008	wholesale-retailer	weekly	ECM (regime)	positive
2016	Loy et al.	Germany	milk	2005-2008	wholesale-retailer	weekly	ECM (regime)	positive
2015	Popovics	Hungary	dairy products	1995-2003	processor-retail	monthly	Houck	positive
					farm-processor			positive
2011	Rezitis & Reziti	Greece	milk	1989-2009	farm-retail	monthly	ECM (regime)	positive
2002	Romain et al.	USA	milk	1980-1997	farm-retail	monthly	Houck	positive & none
2012	Rumánková	Czech Republic	milk	2007-2011	farm-wholesale	monthly	ECM	positive
2003	Serra & Goodwin	Spain	dairy products	1994-2000	farm-retail	weekly & monthly	threshold	positive
2011	Stewart & Blanely	USA	milk	2000-2010	farm-retail	monthly	ECM (regime)	positive
			cheese					positive

Source: own illustration. Notes: [1] Smooth transition autoregression model (instead of the thresholds to be 'hard' values and sudden regime changes, the STAR allows for gradual, soft regime transition (Hahn et al., 2016)).

5 Theoretical model

The description of the German dairy supply chain's structure as well as the report of the German anti-trust agency's sector study suggest the possibility of oligopsonistic behavior on the raw milk and dairy output market. Since the literature review has shown that no model that accounts for oligopsonistic conduct on subsequent markets, input and output, of a supply chain so far exists, such a theoretical model will be developed in the following section. The model is based on Muth and Wohlgenant's (1999) oligopsony model, described in Subsection 3.2.2, but adds the prospect of oligopsony conduct also to the output market. Furthermore pricing equations with a procedure similar to Lloyd et al. (2009) will be derived in the second part.

To limit the complexity of the model and assure empirical applicability, a series of assumptions has to be drawn first. We start by assuming that raw milk and dairy output are homogenous products. For raw milk this seems plausible, since raw milk is an unprocessed product and the importance of a possible differentiated product, such as organically produced raw milk, remains marginal.

Dairy products, on the other side, is a product category that comprises a vast number of product subgroups, from cheese to milk powder, further distinguished in brand and standard products. Nevertheless, it has been argued that brand and standard dairy products can be seen as perfect substitutes as well as products of other differentiation within one dairy product subgroup, e.g. fat-reduced milk and standard milk, since no real quality difference seems to exist (Bundeskartellamt, 2009; Davis et al., 2009). Since products can be defined as perfect substitutes, at least the product groups can be stated to be homogenous products (Stigler, 1964). Aggregation is consequently achieved by forming a weighted average dairy product price using selected individual dairy product group prices of Emmentaler cheese, butter, and skim milk powder. The procedure is further described in the data description section.

Additionally, export markets are hypothesized to be of less to no significance. Even though, this is a general quite restrictive assumption made in NEIO models to define clear markets and limit the complexity (Sckokai et al., 2013), for the German dairy supply chain this hypothesis can be proven to be a good approximation of reality. While regarding raw milk this is done at ease, since German dairies sourced around 93.8% of raw milk domestically in 2015, for the dairy product market the need for more elaboration exists. Around 49% of milk equivalent was exported in 2015, but only accounted for 28% of total revenue generated from processing raw milk. Furthermore, large shares of the German dairies' exports are actually marketed via German retailers. Unfortunately no data is available, but it has been stated by the German anti-trust agency that regarding milk for consumption exports, two retailers market more than 50% of the quantity (Bundeskartellamt, 2014). Consequently, retailers seem to almost exclusively market dairy product exports or at least have a dominant position in this regard.

Furthermore, it is assumed that at no level of the dairy supply chain any form of stockpiling is conducted. Raw milk and dairy products, in particular the first one, are highly perishable products and have to be refrigerated to be stored over longer durations. Since this a costly form of storage, the effect of storage is assumed to be marginal and consequently not modeled (Loy et al., 2016; Sckokai et al., 2013). With the exclusion of imports and exports as well as storage, the quantity of dairy output cannot exceed the raw milk quantity produced in time period t.

Moreover, it is assumed that no agent involved in the transformation of the product from raw milk to marketed dairy products faces any form of adjustment costs. Consequently, the market power measure of the later derived model is 'static'. As mentioned in the theory review, the static NEIO model has been criticized and led to establishment of dynamic models. However, due to the complexity of dynamic models and the notion that the static outcome in some cases approximates the outcome of dynamic models or even coincides, this assumption was considered feasible, in particular, since this assumption will be further relaxed in the methodology.

In Subsection 3.2.3 it was noted that NEIO models have been heavily criticized for their choice of, mostly linear, functional form and assumptions of the applied technology in the industry such as fixed proportions technology (Schroeter, 1988). To avoid this criticism and any limiting assumptions on the technology, second order-differential quadratic forms are used for any cost, production, or revenue function stated in the following sections (Chambers, 1988). This allows approximating the true technology without a prior knowledge, and does not set any restrictions on "homotheticity, homogeneity or the elasticities of substitution between factors" (Gollop & Roberts, 1979). Furthermore, flexible functional forms also provide the necessary non-linearity to derive the CPM and avoid multicollinearity issues (Bresnahan, 1989; Perloff & Shen, 2012). Explicit forms of all functions used in the subsequent sections are presented in the appendix (see (A1) to (A5)).

5.1 Oligopsony model of two markets

In the following section the structural model of oligopsony power on two subsequent markets of a supply chain is developed. Because we defined both products, the material input and output, as homogenous the competition is in quantities as strategic variables (Sexton, 2000). With the previous stated assumptions in mind, we assume that the processing industry consist of n firms sourcing their material input exclusively on the material input market and selling their output to m retailers on the output market. Given the cost function of farmers and the assumption that farms are price takers on the material input market, due to their low bargaining power, we can derive the inverse supply function of material input, since their marginal costs equal the farm gate price for the material input W^M,

$$W^M = \frac{\partial C(X^M, W_h^F, T^F)}{\partial X^M} = S^{M^{-1}}(X^M, W_h^F, T^F) \tag{5.1}$$

where $W^F{}_h$ is a vector of prices of h non-material inputs involved in the production of the aggregated farm output X^M, and T^F is a trend variable depicting technical change at the farm level. Given this supply relation we can formulate processor i's profit function

$$\pi_i^P = r_i^P(P, x_i^M, x_{ki}^{P^*}, T^P) - W^M x_i^M - W_{ki}^P x_{ki}^{P^*} \tag{5.2}$$

where P demarks the output price, $r^P{}_i(\bullet)$ is the revenue function of the i^{th} processor, $x^P{}_{ki}{}^* = x^P{}_{ki}(x^M{}_i, P, W^P{}_{ki})$ is a vector of k non-material inputs used in the production of the output at their optimal quantity conditional on processor i's choice of material input $x^M{}_i$, $W^P{}_{ki}$ a vector of the corresponding prices of the k non-material inputs, and T^P captures technological change at the processing level. Profit maximization with respect to the choice of $x^M{}_i$ yields the following first-order condition:

$$\frac{\partial \pi_i^p}{\partial x_i^M} = \frac{\partial r_i^P(\bullet)}{\partial x_i^M} + \left(\frac{\partial r_i^P(\bullet)}{\partial x_{ki}^{P^*}} - W_{ki}^P\right)\frac{\partial x_{ki}^{P^*}}{\partial x_i^M} - W^M - \varkappa_i^P \frac{S^{M^{-1}}(\bullet)}{\partial x_i^M} x_i^M = 0 \tag{5.3}$$

where $\varkappa^P{}_i = \partial X^M / \partial x\mathrm{M}_i$ is the i^{th} firm's CV. Under the assumption of procurement of the non-material inputs $x^P{}_{ki}$ in competitive input markets, and aggregating across firms by averaging over all dairies' marginal product (5.3) can be reduced and rearranged to yield:

$$\underbrace{W^M\left(1 + \frac{\Xi^P}{\eta^F}\right)}_{'perceived' MFC} = \underbrace{\frac{\partial R^P(P, X^M, X_k^P(X^M, P, W_k^P), T^P)}{\partial X^M}}_{MRP} \tag{5.4}$$

where the observed material input price plus a relative mark-down Ξ^P/η^F is the 'perceived' MFC, which equals its marginal revenue of product (MRP) and with perfect competitive output market $MRP = VMP$, where $\Xi^P = \sum(\partial X^M/\partial x^M{}_i)(x^M{}_i/X^M)$ and $\eta^F = (\partial S^M(\bullet)/\partial W^M)(W^M/X^M)$ is the elasticity of material input supply. Ξ^P, as discussed in the theory review section, can be either interpreted as the average industry's conjectural elasticity, which measures the response in total industry input quantity to a change in the i^{th} processor's input level, or as one of the elements that define the wedge between the material input price and its MRP. In general, it can be seen as an index which represents the processing industry's ability to mark-down the price of the material input given η^F. The range of the index is zero to one. While zero signals perfect competition, one stands for monopsony. Values in between the extremes represent some level of oligopsony with $1/n$ as the Cournot outcome (Bresnahan, 1989).

The downstream market for the output product is modelled in a similar fashion as the upstream material input market model, but using Morrison Paul's (2001) cost side approach to the oligopsony model. The supply function S^Q of the output Q is derived by differentiating the processing industry's profit function with respect to the output product price P,

$$\frac{\partial \Pi^P(P,W^M,W_k^P,X^M,X_k^P(X^M,P,W_k^P),T^P)}{\partial P} = Q \tag{5.5}$$

where Π^P is the total processing industry's profit. Given the supply of the output product (5.5), the j^{th} retailer's demand can be derived. Profit maximization behavior implies that j^{th} retailer's cost function differentiated with respect to the choice of output product level as a material input as well as keeping the quantities of the l non-material inputs used in the marketing process again at their optimal quantity $q^R{}_{lj}{}^* = q^R{}_{lj}(q_j,P,W^R{}_{lj})$ conditional on the j^{th} retailer's chosen input level of the processing industry's output q_j, yields

$$\underbrace{\frac{\partial c_j^R\left(q_j,P,q_{lj}^R(q_j,P,W_l^R),W_l^R,T^R\right)}{\partial q_j} - \varkappa_i^R\frac{\partial S^{Q^{-1}}}{\partial q_j}q_j}_{'perceived'MFC} = \underbrace{P}_{VMP} \tag{5.6}$$

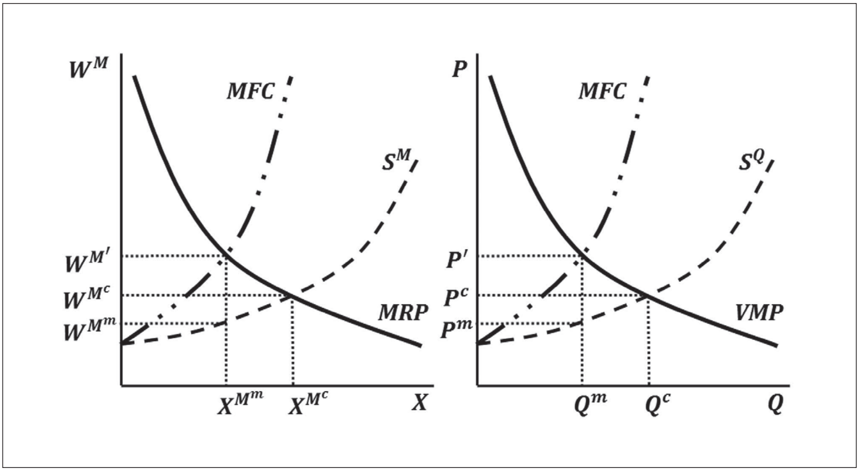
where the 'perceived' MFC of the output product equals the output price. $\varkappa^R{}_i = \partial Q/\partial q_j$ represents retailer j's CV, $W^R{}_{lj}$ is a price vector for l non-material inputs required for marketing, and T^R stands for the technological change at the retail level. Aggregating across all retailers through averaging across all retailers' marginal costs gives us

$$\frac{\partial C^R(Q,P,Q_l^R(Q,P,W_l^R),W_l^R,T^R)}{\partial Q} = P\left(1+\frac{\Xi^R}{\eta^P}\right) \tag{5.7}$$

where the ‘perceived’ MFC equals the output price plus a relative mark-down Ξ^R/η^P. Consequently, as on the material input market, $\Xi^R = \sum(\partial Q/\partial q_j)(q_j/Q)$ is the retailers’ ability to mark-down the price of the processing industry’s output given the supply elasticity of the output $\eta^F = (\partial S^Q(\bullet)/\partial P)(P/Q)$. Interpretation is according to Ξ^P.

The equations (5.1), (5.4), (5.5), and (5.7) are the supply and demand relations respectively for the material input and output market which incorporate the possibility of oligopsonistic behavior and provide the equilibrium outcome on both markets (see Figure 7). The system is very similar to the model of Muth and Wohlgenant (1999), but includes oligopsony power on the output market, and would still require data on material input and output quantity. However, in the following section we derive pricing equations using theoretical considerations used in the EDM framework, which do not incorporate quantity variables anymore.

Figure 7: Monopsony *m* and competitive *c* outcome on the material input (left) and output market (right).



Source: own illustration.

5.2 Pricing equations and determining the level of market power

Due to the assumption that all non-material inputs used along the supply chain to transform the product are procured on competitive markets, the respective prices are exogenous and only the material input and output quantities X^M and Q as well as the respective prices W^M and P remain as endogenous variables.

The equations for material input supply (5.1), processors' demand for material input (5.4), output supply (5.5), and retailers' demand for output (5.7) form a system, which allows determining the simultaneous partial market equilibria and the explicit solutions for the endogenous variables,

$$X^M = f_{X^M}(W_h^F, W_k^P, W_l^R, T^F, T^P, T^R, \Xi^P, \Xi^R) \tag{5.8}$$

$$W^M = f_{W^M}(W_h^F, W_k^P, W_l^R, T^F, T^P, T^R, \Xi^P, \Xi^R) \tag{5.9}$$

$$Q = f_Q(W_h^F, W_k^P, W_l^R, T^F, T^P, T^R, \Xi^P, \Xi^R) \tag{5.10}$$

$$P = f_P(W_h^F, W_k^P, W_l^R, T^F, T^P, T^R, \Xi^P, \Xi^R) \tag{5.11}$$

where the remaining endogenous variables solely depend on exogenous variables, time trends that depict the technology change at each stage, and the measures for oligopsony power on the respective markets Ξ^P and Ξ^R (for explicit forms see in the appendix (A6)).

Solving the explicit solution of P (5.11) once for one of the non-material input prices at the processing level ${W^F}_h$ and once at the retail level ${W^R}_l$ as well as substituting these solutions into the explicit solution for W^M permits to derive two pricing equations, denoted in the rest of the paper as farm-processor equation (FPE), from which all the retail level specific variables ${W^R}_l$ and T^R are excluded, and as processor-retail equation (PRE), from which the farm specific variables ${W^F}_h$ and T^F are omitted (see in the appendix). For reasons that will become obvious in the methodology section, the FPE is rearranged and solved for the price of non-material inputs at the farm level ${W^F}_h$ and the PRE is similarly solved for the prices of non-material inputs at the retail level ${W^R}_l$. To simplify the notation, only one non-material input per stage is represented and the trends depicting technological change at each individual stage are merged to one time trend T. Thus, the FPE (5.12) and the PRE (5.13) take the form,

$$W^F = \underbrace{\left(\omega_0^C + \omega_1^C \Lambda^{\Xi^P}\right)}_{\beta_1^C} + \underbrace{\left(\omega_0^{W^M} + \Lambda^{\Xi^P}\right)}_{\beta_1^{W^M}} W^M$$

$$+ \underbrace{\left(\omega_0^P + \omega_1^P \Lambda^{\Xi^P}\right)}_{\beta_1^P} P + \underbrace{\left(\omega_0^{W^P} + \omega_1^{W^P} \Lambda^{\Xi^P}\right)}_{\beta_1^{W^P}} W^P + \underbrace{\left(\omega_0^T + \omega_1^T \Lambda^{\Xi^P}\right)}_{\beta_1^T} T \tag{5.12}$$

$$W^R = \underbrace{\left(\tau_0^C + \tau_1^C \Lambda^{\Xi^R}\right)}_{\beta_2^C} + \underbrace{\left(\tau_0^{W^M} + \tau_1^{W^M} \Lambda^{\Xi^R}\right)}_{\beta_2^{W^M}} W^{M^*} \Omega^{\Xi^P} + \underbrace{\left(\tau_0^P + \tau_1^P \Lambda^{\Xi^R}\right)}_{\beta_2^P} P +$$

$$\underbrace{\left(\tau_0^{W^P} + \tau_1^{W^P} \Lambda^{\Xi^R}\right)}_{\beta_2^{W^P}} W^P + \underbrace{\left(\tau_0^T + \tau_1^T \Lambda^{\Xi^R}\right)}_{\beta_2^T} T \tag{5.13}$$

where the ωs and τs are parameters consisting of the parameters of the supply and demand relations and Λs and Ω are parameters containing the parameters of the supply and demand relations as well as the oligopsony power measures Ξ^P and Ξ^R (for the detailed forms see in the appendix (A8) and (A9)). W^{M^*} is a transformed variable obtainable after knowledge on the parameter estimates of the FPE[2]. Interestingly, if both markets are competitive, consequently Ξ^P and Ξ^R equal zero, and also the Λs vanish from the FPE and PRE. However, in this case, Ω would not equal zero, only the effect of Ξ^P on Ω would not be present. For this reason, Ω was not denoted with a Λ. The FPE equation has to be rewritten in the form that the dairy output P is the dependent variable, since otherwise identification of Ξ^P is not unique (for details see in the appendix (A8)).

Assuming now that all parameters of the FPE and PRE are known or could be estimated allows determining the values of Ξ^P and Ξ^R:

$$\Xi^P = \frac{\Lambda^{\Xi^P}}{\omega_0^{W^M} - \frac{\omega_0^{W_i^F}}{\omega_1^{W_i^F}}} \tag{5.14}$$

$$\Xi^R = -\Lambda^{\Xi^R} \frac{\tau_1^P}{\tau_0^P - \frac{\tau_0^{W^M} \tau_1^P}{\tau_1^{W^M}}} \tag{5.15}$$

where with information on η^F and η^P (for the formulas see in the appendix (A10)) the Lerner indices, also Buyer Power Index (BPI) (Blair & Harrison, 1993), called BPI^P and BPI^R could be calculated as well,

$$BPI^P = \frac{VMP^M - W^M}{W^M} = \frac{\Xi^P}{\eta^F} \text{ and } BPI^R = \frac{VMP^Q - P}{P} = \frac{\Xi^R}{\eta^P} \tag{5.16}$$

which provide the percentage mark-down due to oligopsony conduct and thus the effect of market power on the prices. Even though the pricing equations al-

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2 $W^{M^*} = W^M - \varphi^{PX} P - \sum_{j=1}^{k} \varphi_j^{XN} W_j^P - \varphi^{XT} T - \varphi^X$

low determining the percentage mark-down without the requirement for any kind of quantity data, it is not possible to derive the welfare loss and the rents at any level without information on quantity data.

5.3 Summary

In this section with the assumptions of homogenous material input and output products, exclusion of exports and storage, no adjustment costs in any variables, and flexible functional forms a theoretical model of oligopsony power on subsequent markets of a supply chain without the requirement of any kind of quantity data is developed.

First, the two markets for the material input and output are modeled as a structural model familiar from the classic static NEIO framework. The system of derived supply and demand equations is then used to obtain explicit solutions of the endogenous variables, the material input and output prices as well as quantities. After rearrangement and substitution, two pricing equations, one depicting the farm-processor relation, and the other depicting the processor-retailer relation, are found which only depend on material input and output prices as well as the non-material input prices, technological change, and the measures for oligopsony power. Consequently, quantity data is obsolete. In the next step, it is shown that if the parameters of these two pricing equations would be known the level of oligopsony power and its effect on prices, in form of Lerner indices, could be determined.

However, estimation of the parameters of the pricing equations is not possible with standard techniques usually applied in NEIO or APT studies, such as iterative least squares or VECM, since they cannot be separately identified. In the following chapter, a methodology is presented that permits to uniquely identify the parameters of the pricing equations from each other without prior knowledge.

6 Methodology

In this chapter the methodology, which allows determining the market power measures of the theoretical model developed in the previous chapter, is presented. As in Lloyd et al. (2009) we embed the derived pricing equations (5.12) and (5.13) in the long-run cointegration relationships of a VECM. Instead of estimating a standard VECM with globally or locally constant parameters, as in the case of threshold or MS-VECM, we use a state-space representation of a transformed VECM to allow for time-varying parameters. The source of the time-variation is assumed to be the changes in the market power indices. Consequently, we allow ${\Xi^P}_t$ and ${\Xi^R}_t$ to vary over time, which is denoted in the rest of the paper with the subscript t. Since ${\Xi^P}_t$ and ${\Xi^R}_t$ are components of the compound parameters of (5.12) and (5.13) their time variation causes these parameters to be non-constant as well, and will be denoted as β_t in the following section.

Gollop and Roberts (1979) argued that conjectural variations, one interpretation of the derived market power indices ${\Xi^P}_t$ and ${\Xi^R}_t$, are not fixed constants, but rather vary with time. The reason is that unlike the parameters of technology, the conjectural variations are directly formed and influenced by the firms' behavior through procedure of adaptive expectations. By allowing the market power indices, i.e. the conduct parameters, to vary over time, the critic of NEIO with its frequent static estimation of a dynamic concept is refuted.

As can be seen in (5.12) and (5.13) the time-varying β_t are further split in constant, the ωs and τs, and non-constant components, the Λ_ts. This is achieved through the application of dynamic factor analysis (DFA), whose results permits to determine ${\Xi^P}_t$ and ${\Xi^R}_t$ with (5.14) and (5.15). The following sections will in detail present the above described methodology.

6.1 VECM

The non-stationarity of price time series, in particular of prices of vertically or horizontally integrated markets, is frequently present due to a common trend. Ignoring the possibility of non-stationarity might result in auto-correlation and biased estimates. As described in the APT theory review section, error correction techniques have been established to avoid spurious regression results (Hendry & Doornik, 2001; Juselius, 2006). Engle and Granger (1987) with their ECM only accounted for one long-rung equilibrium relation. Johansen (1988; 1991) developed the vector error correction model (VECM), which permits estimating a system of n cointegrated time series with n-1 cointegration vectors via maximum likelihood (ML). The VECM representation of Johansen (1988; 1991) is the following,

$$\Delta Y_t = \alpha\beta' Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + u_t \tag{6.1}$$

where Y_t is the data vector of the n variables, Δ is the difference operator, Γ_i (n×n) is a parameter matrices quantifying the short-run response of ΔY_t to past shocks, t is a subscript indicating the time dimension, and p is the number of lags. Furthermore, β is the cointegration matrix (r×n) that quantifies the long-run equilibrium relationship with r, the so-called 'rank', being the number of cointegration relationships among the n time series. The α matrix (n×r) is the so-called loading matrix, which measures the speed by which the system moves back to the equilibrium after deviations, given by $\beta' Y_{t-1} = ECT_{t-1}$, with regard to t. The error term u_t is a (n×n) matrix of normal and identical distributed disturbances with zero mean and non-diagonal covariance matrix (Steen & Salvanes, 1999; Lloyd et al., 2009).

To simplify the estimation of a VECM Lütkepohl and Krätzig (2004) developed the simple two step (S2S) estimation procedure. By applying the Frisch-Waugh-Lovell Theorem (Lovell, 2008) in their procedure, (6.1.) can be reduced to,

$$M\Delta Y_t = \alpha\beta' M Y_{t-1} + u_t \tag{6.2}$$

where $M = I - \Delta Y_{t-1}(\Delta Y_{t-1}^T \Delta Y_{t-1})^{-1} \Delta Y_{t-1}^T$ transforms the variables Y_t and Y_{t-1} so that they incorporate the partial effect of the short-run dynamics. In the next step of the S2S, (6.2.) is estimated via simple OLS, and a parameter matrix $\gamma = \alpha\beta'$ (n×n) is obtained. By normalizing the cointegration vector β, setting the value of the corresponding βs of r variables to one and zero otherwise, permits identification of the α matrix. Furthermore, it is important to note that the choice of normalization does not affect the estimates of a cointegration relationship (Juselius, 2006). With knowledge of the loading matrix α, (6.2.) (for explicit form see in the appendix (A7)) is rearranged to yield,

$$MW_t = \beta' M Y_{t-1}^2 + v_t \tag{6.3}$$

where $W_t = (\alpha^T \sum_u^{-1} \alpha)^{-1} \alpha^T \sum_u^{-1} (\Delta Y_t - \alpha Y^1_{t-1})$ is a r scaled vector, $\sum_u$ being the residual covariance matrix of the error term u_t and $Y_{t-1} = (Y^1_{t-1}, Y^2_{t-1})$ is split into Y^1_{t-1},the r time series whose cointegration parameters were normalized, and Y^2_{t-1}, the remaining data vector (Lütkepohl & Krätzig, 2004). Even though, the S2S approach uses OLS for estimation, its estimator has the asymptotic distribution of a maximum likelihood estimator (Ahn & Reinsel 1990; Reinsel, 1993).

6.2 State-space representation of the transformed VECM

To permit the cointegration parameters β_t to vary with time, instead of using standard OLS techniques, as suggested by Lütkepohl and Krätzig (2004), the Kalman-Filter (Kalman, 1960) is applied to the transformed VECM (6.3). This allows accounting for the firms' behavior of adaptive expectations and updating ${\Xi^P}_t$ and ${\Xi^R}_t$, in each single time period. The state-space representation of (6.3) takes the form,

$$MW_t = \beta_t' MY_{t-1}^2 \ + v_t \tag{6.4}$$

$$\beta_{t+1}' = \beta_t' + {\varsigma_t}' \tag{6.5}$$

where (6.4) represents the observation equation and (6.5) the state equation. The error term ς_t (r×1) is a vector of normally and identically distributed disturbances assumed to be Gaussian. The Kalman-Filter is a recursive procedure in which the estimates of the unknown state, here the parameters β_t as well as the corresponding covariance matrix $\sum_t$, are estimated using last observed values. In each time period, with new observations on the observable data, here W_t, floating in, these estimates are updated (Kalman, 1960). Even if the assumption of Gaussian error terms fails to be true, the ML estimates of β_t are still the best linear unbiased estimates (Wildi, 2013).

The Kalman-Filter requires to be initialized by a set of chosen starting values at time t_0. In this case, we use the OLS estimates, as initially suggested by Lütkepohl and Krätzig (2004) for their S2S method, for β and $\sum$ to initiate the Kalman-Filter. After obtaining the optimized ML values for the initial parameters βt_0 and $\sum t_0$, the procedure is repeated (Wildi, 2013).

6.3 Dynamic factor analysis

The estimates of the time-varying cointegration parameters β_t can be further separated into a constant and a non-constant component, a so-called common factor. To accomplish this, the time series techniques dynamic factor analysis (DFA) is applied (Stock & Watson, 2005). The general idea is that n univariate time series form a multivariate system of variables, here after referred to as 'response variables'. The system responds to changes in m common factors, where $1 \leq m < n$, instead of trends unique to each individual univariate time series (Zuur et al., 2003). The DFA with one common dynamic factor, here ${\Lambda^r}_t$, based on either ${\Xi^P}_t$ and ${\Xi^R}_t$, for the response variables, here β_ts, can be formulated by,

$$\beta_t^{r\prime} = \mu_0^{r\prime} + \mu_1^{r\prime} \Lambda_t^r + \varepsilon_t \tag{6.6}$$

$$\Lambda_t^r = \kappa^r \Lambda_{t-1}^r + \eta_t^r \tag{6.7}$$

where the μs represent the constant parameters ωs and τs from the pricing equations (5.12) and (5.13), and the κs are weighing the effect of past values of the common trend $\Lambda^r{}_{t-1}$ on current values $\Lambda^r{}_t$. The error terms, here ε_t and η_t, are assumed to be Gaussian normally distributed with zero mean (Zuur et al., 2003).

The state-space representation consisting of (6.6) and (6.7) is estimated with ML. Nevertheless, since the dynamic factors are unknown the log likelihood function cannot be optimized directly. Instead the expectation-maximization (EM) algorithm is applied, an iterative procedure that "successively maximizes the conditional expectation of the complete data likelihood function" (Zuur et al., 2003). Hereby the ML estimates of so-called hyperparameters are obtained. These hyperparameters comprise the variances of the error terms, the parameter μs and κs, and the initial values of the dynamic factors and its variances at t_0. After determining the ML values of the hyperparameters the dynamic factors and their variance is obtained with help of the Kalman-Filter (Shumway & Stoffer, 2000).

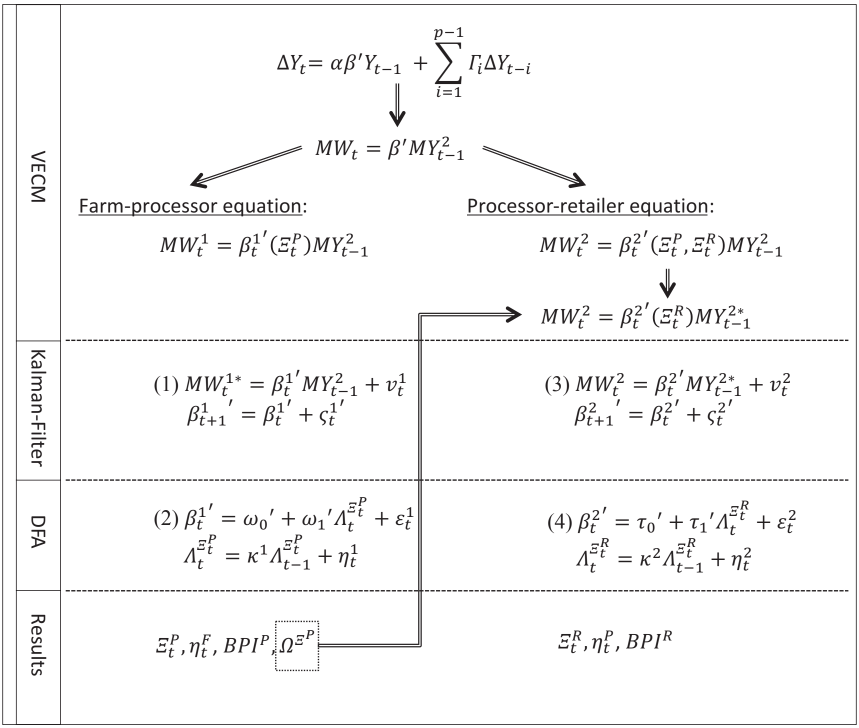
Furthermore, some of the parameters have to be restricted to find a unique solution (Harvey, 1989). In this approach the initial variance of each dynamic factor is chosen to be zero at t_0. However, similar to the estimation of the time-varying parameters in (6.2), an initial ML estimation provides the optimized starting values for the final estimation. The dynamic factor analysis is carried out by using the MARSS package in the software R (Holmes et al., 2012).

As already inclined by incorporating the superscript r into the notation of state-space representation of the dynamic factor model, the time-varying cointegration parameters of the two long-run equilibrium relationships representing the pricing equations (5.12) and (5.13) are pooled (see in the appendix A(11)) and a dynamic factor model for each of the two parameter vectors is estimated separately. The reason is that $\Xi^P{}_t$ enters the PRE through Ω_t and thus must be determined prior to estimating the dynamic factor that extracts the common trend depending solely on $\Xi^R{}_t$.

6.4 Summary

In this chapter the methodology that allows determining the market power measures at the processor and retail level was presented. Figure 8 displays the estimation strategy and all estimation techniques applied to derive the market power indices. Due to the common cointegration of vertically integrated price time series, the pricing equations of the structural model are embedded as cointegration vectors in a VECM. Nevertheless, the standard VECM would not allow identifying the market power indices. Instead, the original VECM is transformed via the simple two step estimation procedure (S2S) developed by Lütkepohl and Krätzig (2004). Assuming two cointegration vectors, this technique permits to estimate the farm-processor equation (FPE) and the processor-retailer equation (PRE) separately. Since the $\beta_t{}'$ parameters of the PRE rely on both market power indices, $\Xi^P{}_t$ and $\Xi^R{}_t$, it is necessary to first derive a measure for $\Xi^P{}_t$, in order to simplify the equation to incorporate only one unknown market power measure.

Figure 8: Estimation strategy.



Source: own illustration.

Due to the assumption of time-variation in the market power indices, the cointegration parameters, the compound parameters of the derived pricing equations, have to change with time if the level of market power changes. Time-varying parameters are derived with the help of the Kalman-Filter, which is applied in step (1) to the FPE.

The obtained time-varying cointegration parameters can now be split in step (2) into constant parameters and a non-constant element via dynamic factor analysis (DFA). This non-constant element is a factor common to all parameters and consists of the corresponding market power index and constant parameters of the derived two market structural model. With the estimates of the DFA for the FPE it is now possible to calculate the market power index of the processing sector, the price elasticity of farm supply, the processors' buyer power index (BPI), and a parameter Ω. The parameter Ω incorporates the effect of the processors' market power on the PRE and thus simplifies the latter to only one unknown market power index instead of two.

In step (3) and (4) the Kalman-Filter and the DFA are applied to the 'simplified' PRE to derive in the same manner the market power index of retailers, the price elasticity of processor supply, and the corresponding retailers' BPI. The following chapter will present descriptive statistics on the data and results of an application of the outlined estimations strategy to the German dairy supply chain.

7 Empirical application

The presented theoretical model and the methodology that allows estimating the market power indices is applied empirically to the German dairy supply chain for the years from 2003 to 2015. At first, the used database is described and the choice of included variables justified. After initial cointegration analysis, the statistically favored VECM specification regarding cointegration, number of differenced lags, and restrictions on the parameter matrices is chosen. The in the methodology chapter explained estimation procedures of the Kalman-Filter and the DFA are then applied to the transformed state-space representation of the selected VECM specification. The results of the estimations of the state-space model and the DFA as well as the calculation of important parameters derived from the theoretical model such as the market power indices, ${\Xi^P}_t$ and ${\Xi^R}_t$, the elasticities of supply, ${\eta^F}_t$ and ${\eta^P}_t$, and the corresponding BPI indices are presented thereafter. Finally, the procedure and findings are summarized.

7.1 Descriptive statistics

In this section the database used in the empirical application is presented and described, variable selection explained, as well as data sources revealed. In addition, necessary data manipulation procedure is elaborated. The time period for the study spans from January 2003 to December 2015 thus covering major policy changes and events including the gradual and actual abolishment of the milk quota, EU enlargements, and intensive structural change at all levels of the supply chain, that have altered irrevocably the business environment and the structure of the German dairy supply chain.

The database includes all publicly available relevant material and non-material input costs for the production and marketing process along the dairy supply chain (see Table 12). The costs of capital, here in form of the money market rate, and transport, here in form of the diesel price, are assumed to be a significant cost variable at all levels. Unfortunately, no data on actual capital costs were available, but it was approximated with the money market rates of the German federal bank. Raw milk is sourced on average by German dairies in a radius of 170 km. Consequently, transport costs play a major role in the procurement of raw milk. Furthermore dairy products are distributed throughout Germany, which again makes the inclusion for transport costs a necessary requirement for the analysis (Tribl & Salhofer, 2013). Apart from capital and transportation costs, it is assumed that the relevant cost in the production of raw milk is dairy cow feed. The procurement of feed summed up to around 41.1% of the intermediate consumption in German agricultural production in 2014 (BMLE, 2016). The dairies main matter of expense is raw milk with a cost share of approximately more than 55% (Bundeskartellamt, 2012). In addition, labor and energy costs are treated as significant at the processing stage with cost shares of 6.8% and 2.1% respectively in 2015 (BMLE, 2016). Aside from the procurement price for dairy products, the main matter of expense for the retail level are wages, e.g. accounting for up to 30% of the retail price in the case of U.S. retailers (Hovhannisyan & Gould, 2012).

Table 12: Descriptive statistics of used dataset.

item	unit	frequency	symbol	min	max	mean	source
raw milk price	€/l	monthly	W^M	0.22	0.41	0.31	BMVEL/BMELV/BMEL
implied dairies' output price[a]	€/l	monthly	P	0.44	0.61	0.48	BMVEL/BMELV/BMEL
skim milk powder[c]	€/kg	monthly		1.39	3.63	2.13	BMVEL/BMELV/BMEL
German brand butter (formed)[c]	€/kg	monthly		2.17	4.44	3.24	BMVEL/BMELV/BMEL
Emmentaler [c]	€/kg	monthly		3.93	5.50	4.32	BMVEL/BMELV/BMEL
milk performance feed	€/kg	monthly	W^F	0.14	0.28	0.19	AMI/ZMP
avg. wage dairy industry[b]	€/h	monthly	$W^P{}_1$	15.25	28.11	21.77	BMVEL/BMELV/BMEL
energy price[d]	€/kWh	monthly	$W^P{}_2$	0.07	0.12	0.09	BMWE/Statistisches Bundesamt
avg. wage retail employee[e]	€/h	quarterly	W^R	9.87	13.13	11.53	Statistisches Bundesamt
money market rate[f]	%	monthly	$W^{F+P+R}{}_1$	-0.20	4.30	1.49	Deutsche Bundesbank
diesel price[d]	€/l	monthly	$W^{F+P+R}{}_2$	0.95	1.52	1.22	BMWE/Statistisches Bundesamt

Source: own elaboration.

Notes: [a] calculated using technical conversion factors and shares on processing; [b] seasonally adjusted using x12arima; [c] after March 2012 continued with index data, since price data has not been published; [d] calculated using index series from Statistisches Bundesamt and avg. price of 2010 for energy procured by industry (0.0971 €/kWh) and diesel (1.23 €/l) provided by BMWE; [e] interpolated to monthly frequency using Eviews Software; [f] EONIA.

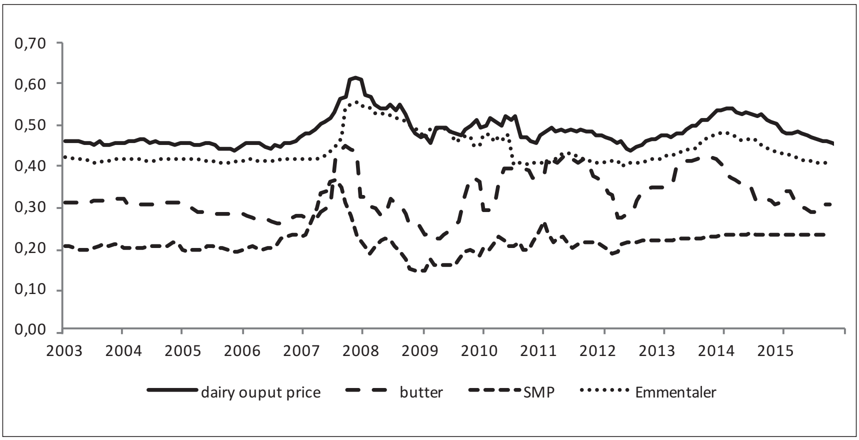
Except for one data series, the frequency of the data was monthly. For the average wage of retail employees only data with quarterly frequency was available. Therefore, this time series was interpolated to a monthly frequency (see Table 12). All price time series were deflated via the Consumer Price Index (CPI) of the German federal statistic service.

While data on the raw milk price is publicly available, the assumption of a homogenous dairy output product implies the construction of a corresponding price time series. As mentioned before this dairy output price P is a share weighted price of major dairy products. It consists of the wholesale prices for Emmentaler, SMP, and German brand butter (formed). The exact formula for calculating the implied dairies' output price is given by,

$$P = \left(\frac{butter\ price}{ME\ butter} + \frac{SMP\ price}{ME\ SMP}\right)\frac{total\ butter\ production * ME\ butter}{total\ milk\ processed} + \frac{Emmentaler\ price}{ME\ Emmentaler}\left(1 - \frac{total\ butter\ production * ME\ butter}{total\ milk\ processed}\right) \quad (7.1)$$

where ME stands for milk equivalent and thus for the conversion rate of raw milk amount required (measured in liter) to produce one kg of the dairy product. The conversion rates for butter, SMP, and Emmentaler are 25 liter/kg, 10 liter/kg, and 7.5 liter/kg respectively. Figure 9 illustrates the price time series for the selected dairy products as well as the derived share weighted dairy output price P.

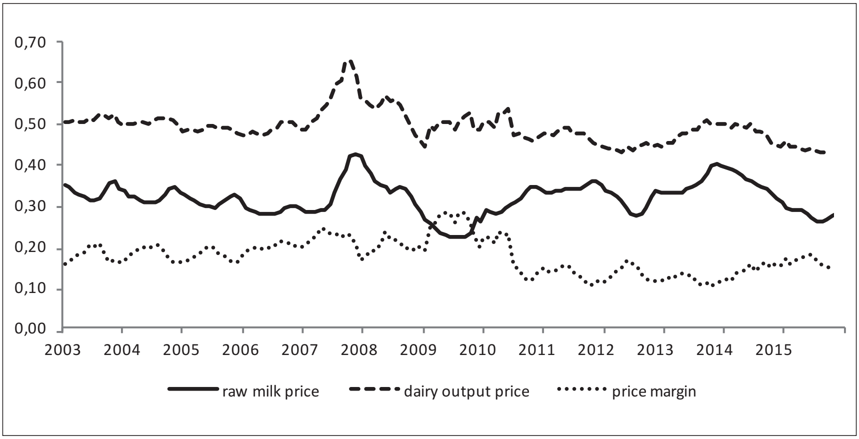
Figure 9: Price for German brand butter (formed), SMP, and Emmentaler in €/100g, and the calculated dairy output price in €/l.



Source: own illustration, based on data from BMVEL/BMELV/BMEL, 2003-2016.

The development of the deflated share weighted dairy output price and the raw milk price are depicted in Figure 10. The raw milk price demonstrates a seasonal pattern up to the year 2007, which is not shared by the share weighted dairy output price. While both price time series evolved slightly downward trending but stable from 2003 to mid-2007, both series drastically rose afterwards. After peaking in the beginning of 2008, raw milk price at 0.42 € and dairy output price at 0.65 € in December and November of 2007 respectively, both prices lost dramatically in value. Interestingly, the raw milk price continued its downward slope, reaching its minimum value over the analyzed period in September 2009 with slightly less than 0.22 €, while the dairy output price stabilized several months earlier. Consequently, the price margin increased during this period to a maximum of almost 0.28 € in October 2009. After 2010 the raw milk price recovered quickly and even reduced the price margin to less than it was before the price peaks, roughly between 0.15 € and 0.20 €, about 0.10 € to 0.11 € until the end of 2010. During almost the entire rest of the analyzed periods both time series evolved parallel, keeping the difference stable. However, since the end of 2014 both prices entered a phase of decline with the raw milk price losing more value, thus increasing the price margin slightly again to around 0.16 €.

Figure 10: Deflated prices for raw milk and dairy output as well as their margin in €/l.



Source: own illustration, based on data from BMVEL/BMELV/BMEL, 2003-2016.

7.2 Initial cointegration analysis

At first we test whether the selected time series are non-stationary, i.e. have a unit root, by applying the Augmented Dickey Fuller Test (ADF) to each data series individually (Dickey & Fuller, 1981). The results of the ADF test for each

Table 13: Augmented Dickey Fuller unit root test results.

symbol	selection criterion	lags	t-statistic
W^M	HQC/SC	2	-0.5893
	AIC/FP	12	-0.5758
P	HQC/SC	1	-0.7668
	AIC/FP	2	-0.6090
W^F	AIC/FP/HQC/SC	1	-0.0758
$W^P{}_1$	SC	2	0.8474
	HQC	5	1.2663
	AIC/FP	8	1.7479
$W^P{}_2$	HQC/SC	0	2.5321
	AIC/FP	12	1.5801
W^R	SC	3	-0.0889
	HQC	4	-0.1083
	AIC/FP	5	-0.0933
$W^{F+P+R}{}_1$	SC	1	-1.3897
	HQC	2	-1.5041
	AIC/FP	6	-1.2216
$W^{F+P+R}{}_2$	HQC/SC	0	-0.2529
	AIC/FP	2	-0.4312

Source: own elaboration, calculated using the JMulti software.

Notes: Akaike Info Criterion (AIC), Final Prediction Error (FP), Hanna-Quinn Criterion (HQC), and Schwarz Criterion (SC). Critical values at the 1%/5%/10%-level: -2.56/-1.94/-1.62.

data series and the choice of lag length suggested by the four selection criterions, Akaike Info Criterion (AIC), Final Prediction Error (FP), Hanna-Quinn Criterion (HQC), and Schwarz Criterion (SC), is provided in Table 13. The presence of a unit root is not rejected in any series or any of their specifications. Consequently, all data series are non-stationary.

Because all series are non-stationary, the next step is to test whether a combination of these exists that is stationary in the long-run and the time series accordingly cointegrated. The Saikkonen & Lütkepohl Test (Lütkepohl et al., 2004) test for cointegration is applied to the system of eight data time series including a time trend and a constant in the possible long-run relationships. The maximum rank, number of cointegration vectors, in this system is seven. Table 14 presents

Table 14: Saikkonen & Lütkepohl cointegration test results for system with seven dimensions including a deterministic constant and trend term.

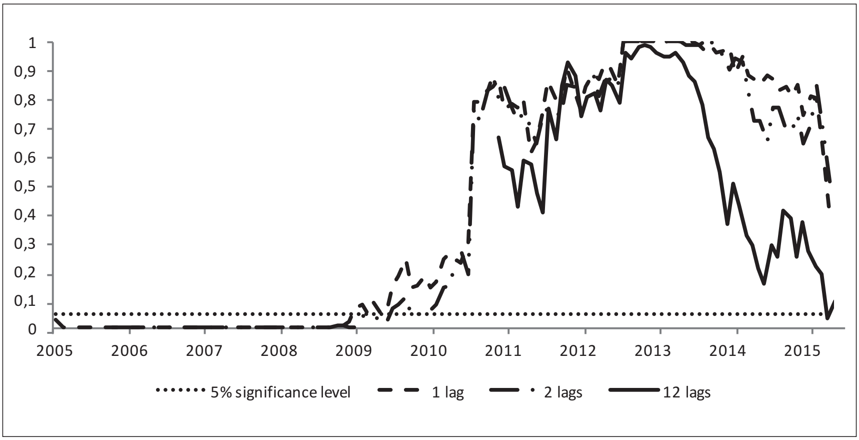
selection criterion	no. of lagged differences	$H_0 : r = r_0$	LR	critical values 1%	5%	10%
Schwarz Criterion	1	$r_0 = 0$	215.69	163.38	152.59	147.04
		$r_0 = 1$	127.63	129.39	119.77	114.84
		$r_0 = 2$	80.12	99.40	90.95	86.64
		$r_0 = 3$	53.15	73.42	66.13	62.45
		$r_0 = 4$	19.51	51.45	45.32	42.25
		$r_0 = 5$	5.66	33.50	28.52	26.07
		$r_0 = 6$	2.70	19.71	15.76	13.88
		$r_0 = 7$	1.31	9.73	6.79	5.47
Final Prediction Error/Hanna-Quinn Criterion	2	$r_0 = 0$	192.25	163.38	152.59	147.04
		$r_0 = 1$	137.98	129.39	119.77	114.84
		$r_0 = 2$	76.20	99.40	90.95	86.64
		$r_0 = 3$	48.15	73/42	66.13	62.45
		$r_0 = 4$	22.34	51.45	45.32	42.25
		$r_0 = 5$	11.47	33.50	28.52	26.07
		$r_0 = 6$	4.11	19.71	15.76	13.88
		$r_0 = 7$	2.08	9.73	6.79	5.47
Akaike Info Criterion	12	$r_0 = 0$	390.19	163.38	152.59	147.04
		$r_0 = 1$	281.33	129.39	119.77	114.84
		$r_0 = 2$	187.66	99.40	90.95	86.64
		$r_0 = 3$	118.68	73/42	66.13	62.45
		$r_0 = 4$	74.64	51.45	45.32	42.25
		$r_0 = 5$	40.66	33.50	28.52	26.07
		$r_0 = 6$	10.23	19.71	15.76	13.88
		$r_0 = 7$	2.23	9.73	6.79	5.47

Source: own elaboration, calculated using the JMulti software.

the results of the cointegration test for all three specifications regarding the included number of lagged differences suggested by AIC, FPE, HQC, and SC. For all three specifications, at least two cointegration vectors can be diagnosed at the 10% significance level. With a lag length of 12, suggested by the AIC, even more than five long-run relationships can be identified. Consequently, the previously described methodology, based on two cointegration vectors, is confirmed by the cointegration test results.

However, since we allow the parameters of the cointegration variables to vary with time, we indirectly model ‘structural breaks’ in the cointegration relationship. Figure 11 displays the p-values of the Chow forecast test results for the VECM with two cointegration vectors and a differing number of included lags. The Chow forecast compares the residual variance of the full sample with those of the first subsample. If these differ, the null hypothesis of constant residual covariance matrix and thus constant parameters has to be rejected (Lütkepohl & Krätzig, 2004). The test confirms our assumption that the parameters are not constant. Until around mid-2009 the hypothesis of constancy is rejected at the 5% level. However, the specification including 12 lags never rejects, except for one month at the end of the analyzed time period, the null hypothesis, which might be caused by the relative small sub period, which only ranges from November 2010 to November 2015, during which all other specifications confirm the stability of the system.

Figure 11: p-values of the Chow forecast test (100 bootstrap replications) for the VECM specification with 1, 2, and 12 lags.



Source: own elaboration, calculated using the JMulti software.

The VECM, in general, regards all variables of the data vector as endogenous. However, as assumed in the model outlaid in the theory section, only the prices and quantities of the material input and the output are assumed to be endogenous. All other prices are treated as being exogenous. Setting linear restrictions on the loading matrix α as well as the parameter matrices that quantifies the short-run response of ΔY_t to shocks in the past, $\Gamma_{i,}$ allows to treat these variables as exogenous to the system. Restrictions are set by setting the corresponding parameters of these matrices to zero. When solely α is restricted, the variables, which are affected by the restriction, are treated as "weakly exogenous for the cointegrating parameters if none of the cointegration relations enter the equation for that variable" (Lütkepohl & Krätzig, 2004). Further restricting the Γ_i as well limits the affected variables to be truly exogenous, not reacting to past developments of the endogenous variables or shocks to the system, and their presence in the VECM to the cointegration relationship. Consequently, these exogenous variables enter the VECM in a similar way as the deterministic components, the trend and the constant term.

Applying these restrictions to the model developed in the theory section, the α matrix will collapse to a (2×2) matrix in the case of weak and complete exogeneity assumption for all variables except for the raw milk and dairy output price. In case of weakly exogenous variables the p Γ matrices remains unrestricted, but with full exogeneity take the same dimension as the restricted α matrix. All three model specifications with either endogenous, weakly exogenous and fully exogenous variables, will be estimated and tested.

The statistical analysis conducted and described in these previous paragraphs leads to a variety of model specifications. The four criteria suggest three different lag lengths for the cointegration analysis. Even though, the explanatory power of any of the criteria could be challenged, e.g. the AIC in many cases overestimates the lag order (Lütkepohl & Krätzig, 2004), all three different cases are treated equally. Consequently, one, two, and 12 differenced lags of the endogenous variables are incorporated in different model specifications. The Saikkonen & Lütkepohl Test for cointegration revealed that in all cases, up to two cointegration vectors are accepted. Even though one specification with 12 lags would also accept up to five cointegration relationships, the forthcoming empirical application is limited to two long-run equilibrium relationships as it is coherent with theory. The two cointegration vectors are normalized respectively on one of the non-material input prices at the farmers and retailers level. With the three different specifications regarding non-material input price variables to be either endogenous, weakly exogenous, or exogenous, in total nine different model specifications were estimated.

7.3 Results

7.3.1 Model selection

The previous section elaborated that nine different models due to different choices of lag length and three different assumptions on the nature of non-material variables were specified. All nine models were transformed as in (6.3.) and the state-space representations of the FPE were estimated. After obtaining the Kalman-Filter estimates and the corresponding standard errors, the p-values of the time-varying parameter were calculated for each t. Graphical depiction of the p-values of the time-variant parameters of all model specification can be found in the appendix (for detail see Figure (A1)-(A9)). To be able to derive ${\Xi^P}_t$ the β_t parameter of W^M and W^F need to be statistically significant. Table 15 lists all model specification and whether the necessary parameters were statistically significant at the 10% significance level and thus a ${\Xi^P}_t$ could be deduced. If the required parameters did not demonstrate any statistical significance and no market power measure could be derived, then these model specifications were dropped from further analysis and consideration.

If the estimates of a specified model yielded theoretically consistent values in the range from zero to one for ${\Xi^P}_t$, also the state-space representation of the PRE equation could be estimated with the obtained knowledge on certain parameter values, in particular Ω, derived from the estimates of the FPE. The time-varying parameters of P and either of the transformed variable W^{M*} or one of the non-material input variables at the processing level are required to be statistically significant at some point in time t to proceed with the DFA and derive a statistically significant measure for ${\Xi^R}_t$. Was this not the case, then the model specification was not estimated via the DFA. An overview of which model specification allowed to derive a theoretically consistent market power index at the retail level is presented again in Table 15.

From these nine specifications the model that best describes the data was chosen for the further analysis. Apart from the pre-requirements of certain parameter significance and the theoretically consistent values for ${\Xi^P}_t$ and ${\Xi^R}_t$, the ΔAICc and, based on the ΔAICc, the weighted AICc were used to identify the best fitting specification. The ΔAICc is the difference between the AICc (Akaike Information Criterion with correction) value of the model and the model with the lowest AICc score. The AICc is calculated in the following way (Hruvich & Tasi, 1989; 1995),

$$AICc = \underbrace{-2\log(\mathcal{L}) + 2K}_{AIC} + \underbrace{\frac{2K(K+1)}{n-K-1}}_{correction\ term} \tag{7.2}$$

where L is the maximum likelihood value, n is the sample size, and K is the number of estimated parameters. The correction term sanctions overfitting models and the tendency of AIC to favor these (Claeskens & Hjort, 2008). The AICc values convey no direct interpretation of the suitability of a model but have to be compared to other specifications. The model with the lowest AICc value is the best fit. Consequently, the difference between the lowest AICc value and the AICc of a model specification allows ordering models according to their suitability. Furthermore the weighted AICc permits to evaluate the probability that one model specification is the best fit for the data in comparison to the other model specifications (Burnham & Anderson, 2004).

Table 15: List of model specifications differing in lag length and the nature of the non-material input variables with their corresponding FPE results for AICc and the weighted AICc values.

no. of differenced lags	non-material input variable	required $\beta_{1t}s$ significant	$0 \leq \Xi^{P}_{t} \leq 1$	required $\beta_{2t}s$ significant	$0 \leq \Xi^{R}_{t} \leq 1$	ΔAICc	weighted AICc
1	endogenous	yes	no	-	-	-	-
2	endogenous	yes	no	-	-	-	-
12	endogenous	yes	yes	yes	yes	2347.3	0%
1	weakly exogenous	no	-	-	-	-	-
2	weakly exogenous	yes	yes	yes	yes	0	100%
12	weakly exogenous	yes	no	-	-	-	-
1	exogenous	no	-	-	-	-	-
2	exogenous	yes	no	-	-	-	-
12	exogenous	no	-	-	-	-	-

Source: own elaboration, AICc values were obtained from the estimations within the MARSS package in R.

The results of the ΔAICc and the weighted AICc for the FPE are listed in Table 15 as well. The DFA results of the PRE are not listed, since, as can be seen in the estimation strategy (see Figure 8), the estimates of the FPE affect the PRE estimation and consequently the models do not share the same data input and are not comparable anymore. Six out of the original nine model specifications revealed the necessary time-varying parameters to be statistically significant at one point in time t at the 10%-significance level. Only two of these specifications allowed deriving theoretically consistent values for $\Xi^{P}{}_{t}$. Furthermore, the further estimation of the PRE for these two specifications revealed that $\Xi^{R}{}_{t}$ lied in the range of zero to one for both model specifications. Based on these results and the AICc values, the best fit for the data is a model specification with two lags of the differenced endogenous variables and weakly exogenous non-material input variables. Furthermore, this specification, according to the weighted AICc measure, compared to the other specifications explains the data with virtual certainty. Due to this high probability and being one of the two specifications that yield theoretically consistent values for $\Xi^{P}{}_{t}$ and $\Xi^{R}{}_{t}$, solely the results of this model specification will be presented and discussed in the following subsections, since it explains the data best.

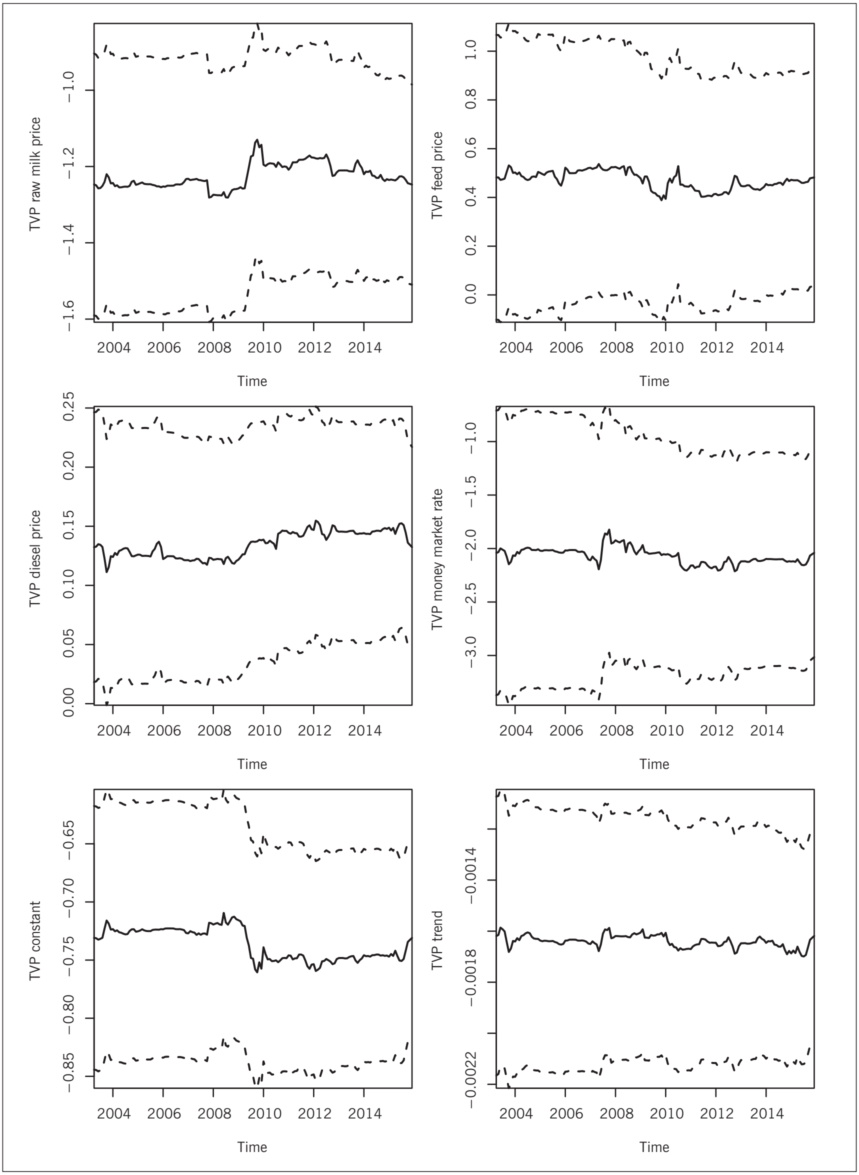
7.3.2 State-space representation

After S2S-VECM transformation the two long-run equilibrium vectors can be separately estimated. By fitting each one individually into a state-space representation and applying the Kalman-Filter, the corresponding β parameters vary over time. The results of the application to the rearranged FPE (see in the appendix (A9)) are depicted in Figure 12 and to the PRE in Figure 13. The corresponding calculated p-values for each point in time of the estimated parameters can be found in the appendix (Figure (A5) and Figure (A11) respectively).

The estimates of the FPE demonstrate that the cointegration parameters indeed change over time (see Figure 12). In general, most parameters evolve stable from the start until the end of the year 2007. Then either a sudden decline or increase in value depending on the parameter sets in. The exceptions are the time-varying parameter for the diesel and feed price. Around the end of 2009 another sudden upwards or downwards bump leads to greater changes in the parameter values, except for the money market rate and trend, but is accompanied by a quick recovery in the opposite direction. The time period afterwards can be generally characterized as period of rather stable parameter evolution.

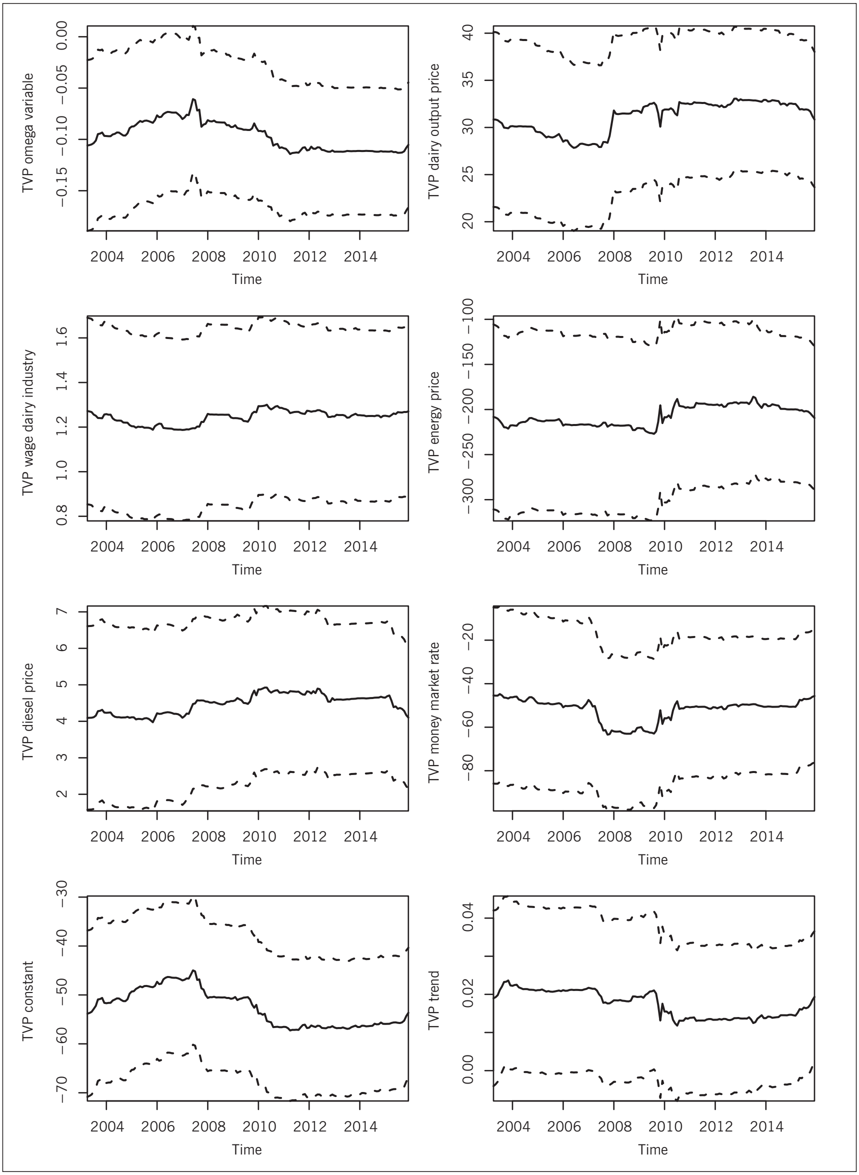
According to the p-values all but one parameter are statistically significant at least at the 5%-level over the entire period (see in the appendix Figure (A5)). Only the time-varying parameter of the feed price drops for brief periods out of the 10%-significance range. However, since the parameter is statistically significant at the 10%-significance level for most of the time, it is included in the further analysis in form of the DFA.

Figure 12: Time-varying parameter (TVP) estimates for the farm-processor cointegration vector including dotted lines for the corresponding 95%-confidence intervals



Source: own elaboration.

Figure 13: Time-varying parameter (TVP) estimates for the processor-retailer cointegration vector including dotted lines for the corresponding 95%-confidence intervals.



Source: own elaboration.

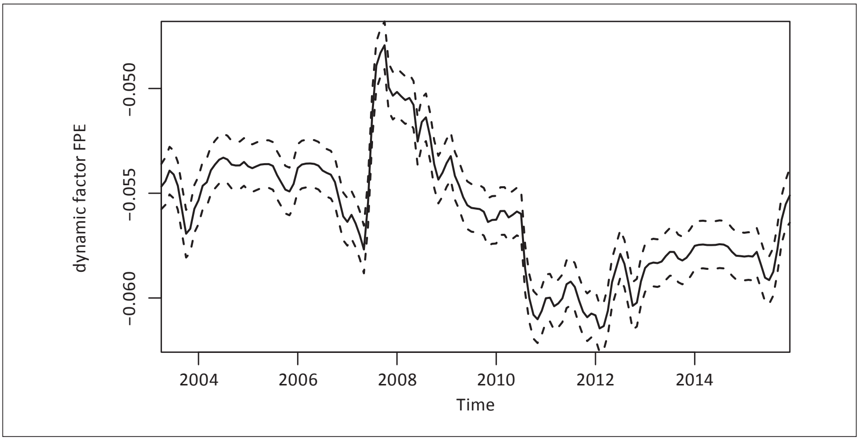
In contrast to the estimates of the state-space representation of the FPE, the results of the PRE show greater absolute movement in the parameter values (see Figure 13), in particular at the start of the period. While until around the beginning of the year 2010 no stable period for any parameter estimate can be observed, some of the parameters, e.g. the time-varying parameter for the constant or the average wage in the dairy industry, start to

stabilize and evolve rather stable until the end of the investigated time horizon. After the start of the year 2011 all parameters evolve rather stable, but most of them on a different level as at the start, e.g. the parameter of the dairy output price.

The p-value graphs for the time-varying parameters of the PRE state-space representation (see Figure (A11)) reveal that all but one parameter are statistically significant at the 10%-significance level over the entire time series. The exception is the parameter of the trend variable, which drops out of this level of statistical significance around the start of the year 2010. Nevertheless, since all estimated time-varying parameters are statistically significant at the 10%-level most of the time, they are treated as dependent variables in the DFA of the PRE.

7.3.3 Dynamic factor analysis

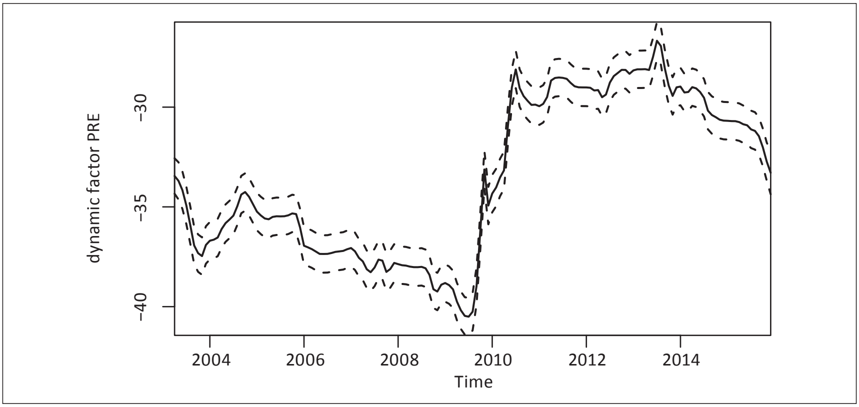
Figure 14: Common factor estimates for the farm-retailer cointegration parameters including dotted lines for the corresponding 95%-confidence interval.



Source: own elaboration.

The results of the Kalman-Filter enter the DFA as dependent variables, whose purpose it is to extract a common factor that explains their variation over time from these. The common factor is a function of the market power indices and parameters of the derived supply and demand functions, and thus allows determining the level of market power abuse on each of the two analyzed markets as described in the theory section.

Figure 15: Common factor estimates for the processor-retailer cointegration parameters including dotted lines for the corresponding 95%-confidence interval.



Source: own elaboration.

Figure 14 and 15 depict the estimated common factor for the FPE and PRE respectively. Both factors are statistically significant at the 1%-significance level (see in the appendix (A12) and (A13)) and show drastic relative values changes over the entire analyzed time period from 2003 to 2015. The dynamic factor depending on the market power of the processors ranges from about -0.06 to -0.05. Around the end of the years 2003, 2006, 2010, and 2012 sudden drops in value can be observed. The sudden decline in value at the end of the year of 2006 is reversed by an even stronger increase in value at the beginning of 2007. Afterwards a continuous decline until around the aforementioned drop at the end of the year 2010 sets in. From 2012 a general positive trend, fragmented by brief periods of quick decline and recovery, evolves and the dynamic factor ends on a level comparable to the pre-2010 drop.

The common factor subject to the retailers' market power varies between a minimum of -40.50 and maximum of -26.67 drastically. The first six years of the analyzed time horizon Λ^{PRE} ranges on a level between approximately -33 to -40. At the end of the year 2009 the dynamic factor raises drastically in value in a few months to reach a local maximum of around -29. Following a slowed growth the absolute maximum is reached in end-2013. The maximum is trailed by a steady decrease in the factor's value. Thus the dynamic factor of the PRE finishes at -33.29 at the end of the analyzed time period. Even though, the values of Λs do not convey any meaning, their evolution represents changes in the level of market power for processors and retailers respectively.

Alongside the dynamic factor also the constant components of which the time-varying parameters consist of are estimated (see Table 16 and 17). Because some of them are necessary for calculating ${\Xi^P}_t$ and ${\Xi^R}_t$ and almost all are required to obtain the price elasticities of supply, their statistical significance plays a crucial role for the reliability of the desired measure. If any parameter estimate did not bear a statistical significance at least at the 10%-significance level it did not enter the calculation of any aforementioned measure. This procedure combined with

Table 16: DFA results for the constant parameters ωs of the FPE with corresponding standard errors and significance level.

variable	symbol	corresponding parameter	value	standard error
raw milk price	W^M	$\omega_0^{W^M}$	-1.1694***	0.0230
milk performance feed	W^F	$\omega_0^{W^F}$	0.9326***	0.1779
		$\omega_1^{W^F}$	8.2354***	1.2335
money market rate	W_1^{F+P+R}	$\omega_0^{W_1^{F+P+R}}$	-0.7486	0.5045
		$\omega_1^{W_1^{F+P+R}}$	23.5763***	3.1322
diesel price	W_2^{F+P+R}	$\omega_0^{W_2^{F+P+R}}$	-0.0271	0.0600
		$\omega_1^{W_2^{F+P+R}}$	-2.8855***	0.6857
trend	T	ω_0^T	-0.0014	0.0014
		ω_1^T	0.0050	0.0297
constant	C	ω_0^C	-0.5403***	0.0811
		ω_1^C	3.4974***	0.7199
state factor loading parameter	κ	κ^{FPE}	1.0000***	0.0014

Source: own elaboration. Notes: ***Significance at the 1 per cent level **Significance at the 5 per cent level *Significance at the 10 per cent level.

the high statistical significance of the two dynamic factors permits to conclude that any measure calculated on basis of these parameters and the common factors will be statistically significant at least at the 10%-significance level as well.

Table 17: DFA results for the constant parameters τs of the PRE with corresponding standard errors and significance level.

variable	symbol	corresponding parameter	value	standard error
(adjusted) raw milk price	W^{M^*}	$\tau_0^{W^{M^*}}$	-0.1961***	0.0069
		$\tau_1^{W_1^P}$	0.0041***	0.0006
dairies' output price	P	τ_0^P	40.1471***	1.4883
		τ_1^P	0.2693***	0.0405
avg. wage dairy industry	W_1^P	$\tau_0^{W_1^P}$	1.3810***	0.0219
		$\tau_1^{W_1^P}$	0.0041***	0.0006
energy price	W_2^P	$\tau_0^{W_2^P}$	-118.0769***	7.5162
		$\tau_1^{W_2^P}$	2.6570***	0.0456
money market rate	W_1^{F+P+R}	$\tau_0^{W_1^{F+P+R}}$	-31.1944***	3.7575
		$\tau_1^{W_1^{F+P+R}}$	0.6187***	0.1169
diesel price	W_2^{F+P+R}	$\tau_0^{W_2^{F+P+R}}$	5.6696***	0.3144
		$\tau_1^{W_2^{F+P+R}}$	0.0355***	0.0075
trend	T	τ_0^T	-0.0069**	0.0028
		τ_1^T	-0.0007***	0.0001
constant	C	τ_0^C	-79.7669***	2.3920
		τ_1^C	-0.8094***	0.0521
state factor loading parameter	κ	κ^{PRE}	1.0000***	0.0015

Source: own elaboration. Notes: ***Significance at the 1 per cent level **Significance at the 5 per cent level *Significance at the 10 per cent level.

7.3.4 Market power indices

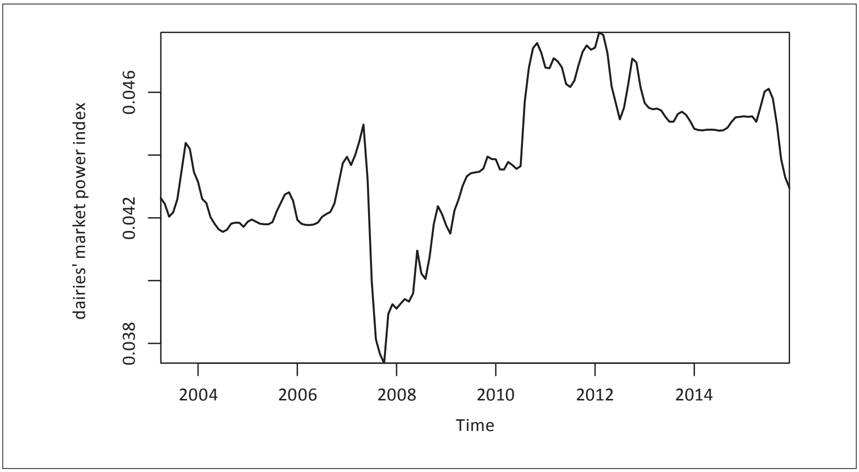
The results of the DFA allow determining the market power indices ${\Xi^P}_t$ and ${\Xi^R}_t$ with (5.14) and (5.15) respectively. As mentioned in the section before, the calculated indices are statistically significant at least at the 10%-level due to the statistical significance of all parameters involved in their calculation.

Figure 16 and 17 display the calculated market power level at the processing and at the retail stage and their evolution over the analyzed time period. Table 15 already revealed that both market power indices lie in the theoretically consistent range from zero, perfect competition, to one, monopsony. Both market power indices show a mirrored development to the dynamic factors which lay at the foundation to their derivation.

The dairies' market power index $\Xi^{P}{}_{t}$ fluctuates from 0.037 to 0.048 between the years 2003 and 2015. Starting with a value of around 0.042, the market power level reaches local maxima of around 0.044 at the end of 2003 and mid-2007. The last local maximum is quickly followed by a sudden drop to the absolute minimum of around 0.037 in the fall of 2007. Until the beginning of 2012 the time series is characterized by a general increasing trend with the maximum value of about 0.048 at the end of this period. The last 36 months are coined with an overall decline in value.

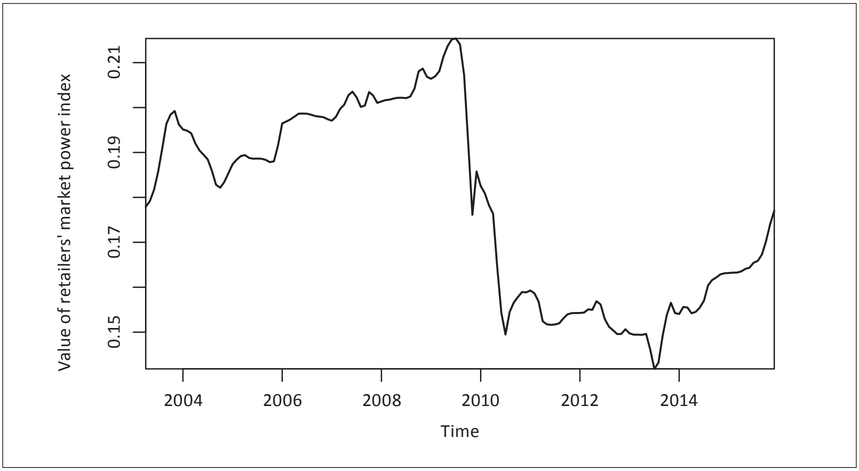
The retailers' market power ranges from 0.14 to 0.22 (see Figure 17). While increasing steadily at the beginning of the analyzed period from around 0.18 to

Figure 16: Calculated market power index $\Xi^{P}{}_{t}$ of dairies.



Source: own elaboration.

Figure 17: Calculated market power index $\Xi^R{}_t$ of retailers.



Source: own elaboration.

its absolute maximum of 0.22 in the fall of the year 2009, $\Xi^R{}_t$ drops drastically in value after the maximum to around 0.15 only a few months later in mid-2010. This drastic change splits the time sample into two distinct time periods. From this date to around mid-2014 the market power index preserves around the value range 0.14 to 0.16. The last one and half years of the analyzed timeframe the index starts to grow in value again and reaches its starting value of 0.18 again.

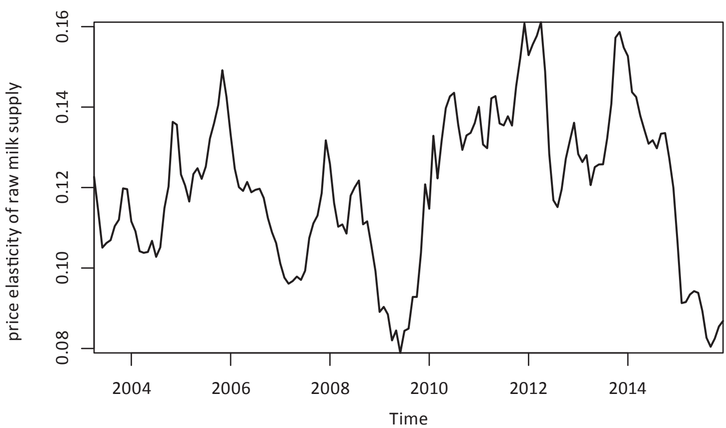
7.3.5 Elasticities of supply

Even though the indices $\Xi^P{}_t$ and $\Xi^R{}_t$ allow to determine the extent of market power, the effect of this market power on the respective price in form of a mark-down can only be evaluated in combination with the corresponding price elasticity of supply. As well as the market power indices, the derived price elasticities of supply $\eta^F{}_t$ and $\eta^P{}_t$ (for details on the calculation see in the appendix (A10)) are statistically significant at least at the 10%-level due to the statistical significance of all parameters involved in their calculation. If a parameter was not significant at least at the 10%-mark it was dropped from the corresponding equation (see Table 16 and 17).

The development of the price elasticity of raw milk supply $\eta^F{}_t$ over the analyzed time period can be split into three dissimilar sub-periods (see Figure 18). From the start of the analysis in 2003 to around end-2009 the elasticity fluctuates in the value range of around 0.09 to 0.16. The second sub-period begins with a sudden shift in the elasticity's value range. The price elasticity of raw milk supply continues to vary, but on a higher level of approximately 0.15 to 0.22 from 2010 to 2014. For the last couple of months of the investigated time horizon ${\eta^F}_t$ drops again abruptly from about 0.18 to 0.11.

The derived price elasticity of dairy output supply is shown in Figure 19. In contrast to ${\eta^F}_t$, ${\eta^P}_t$ oscillates around a value of 0.26 for the first four years. At the start of 2007 the elasticity erupts in a brief period to reach its maximum value of 0.40 at the end of the same year. After reaching its maximum ${\eta^P}_t$ quickly declines to 0.25 in mid-2009, only to stabilize itself around the 0.30-mark for the following two years. From 2011 to the end of the time horizon the elasticity of dairy output supply ranges from its minimum value 0.24 to about 0.30 at the turn of the year 2013/2014. As with the price elasticity of farm supply only parameters entered the calculation of ${\eta^P}_t$ that are statistically significant at the 10% level giving the derived elasticities at least the same statistical significance.

Figure 18: Calculated price elasticity of raw milk supply ${\eta^F}_t$.

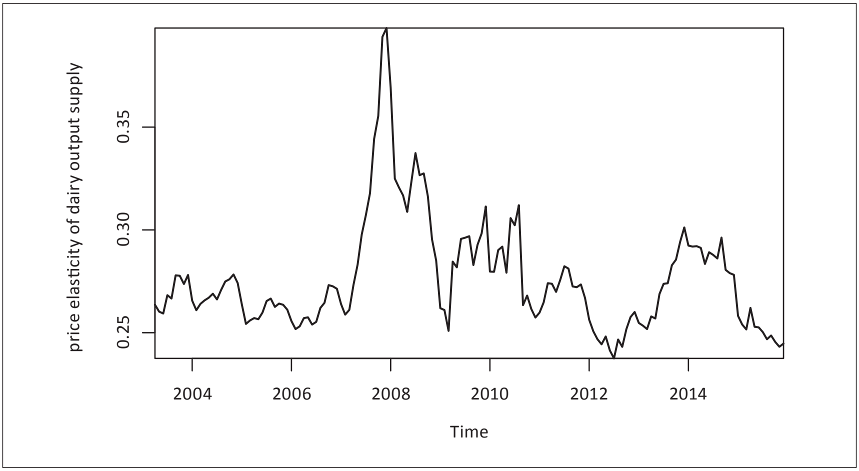


Source: own elaboration.

7.3.6 Buyer power indices

After deriving the market power indices ${\Xi^P}_t$ and ${\Xi^R}_t$ and the price elasticities for raw milk and dairy output supply, ${\eta^F}_t$ and ${\eta^P}_t$, it is now possible to calculate the

Figure 19: Calculated price elasticity of dairy output supply $\eta^P{}_t$.



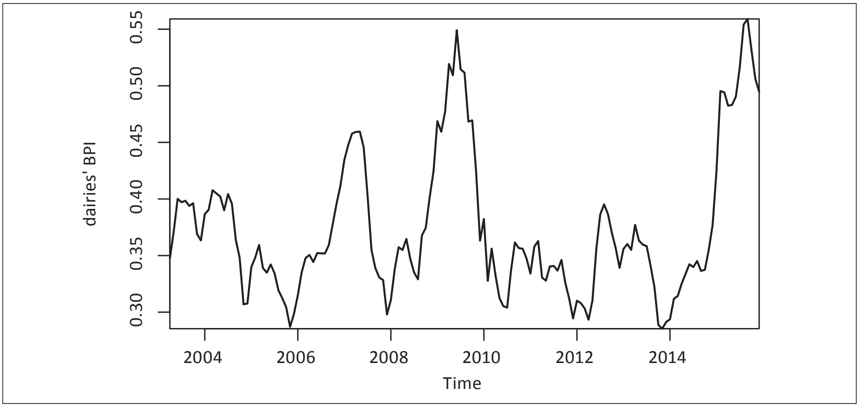
Source: own elaboration.

corresponding buyer power indices (BPI) as in (5.16). These measure the effect of market power on the actual prices. Figure 20 and 21 display the results for the German raw milk and dairy output market respectively.

Even though the market power of German dairies lies close to the perfect competition case with a value between 0.037 and 0.048, the BPI of dairies reaches values up to 0.48 during the analyzed period, which is due to the relatively inelastic supply of raw milk. The German raw milk price was marked-down by around 47.6% in mid-2009. The mark-down ranges from around 0.21 to 0.48 between 2003 and 2015. The evolution is rather erratic with large peaks at the beginning of the analyzed period around summer 2004, mid-2007, mid-2009, and after the fall of 2013. While every peak is followed by a sudden drop in the BPI's value, the period from the beginning of 2010 to the fall of 2013 is characterized by rather low values in the range from 0.21 to 0.30.

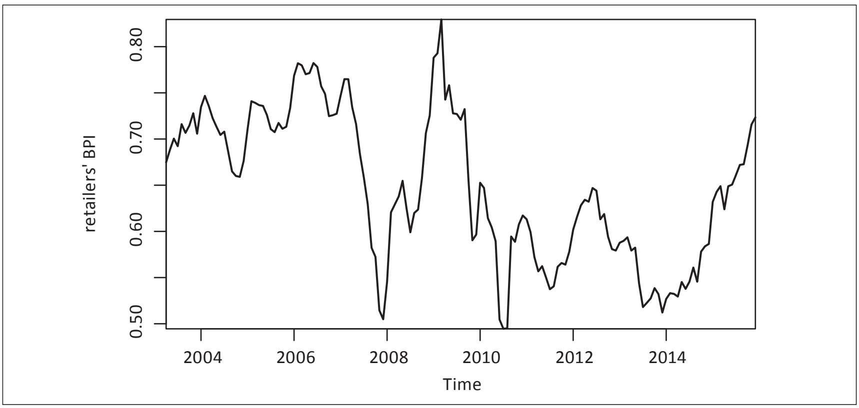
Similar to the dairies' BPI the retailers' BPI's value lies far above the value of the corresponding market power index $\Xi^R{}_t$. However, since the retailers' market power index evolves rather stable in the aforementioned two distinct time periods, and the price elasticity of dairy output supply also evolves rather stable throughout the period, apart from the explosive period between the years 2007 and 2009, the movement of the retailers' BPI is a combination of both patterns. While the two distinct periods of the market power index can be observed with high values around 0.67 to almost 0.78 between the start of the analyzed period and mid-2007, and rather lower values of 0.49 to approximately 0.6 between mid-2010 and mid-2014, also the sudden rise and drop of the elasticity of supply influences the BPI's value strongly between mid-2007 and mid-2009, which can be seen in a mirrored movement in the BPI and its maximum value of 0.82 in the year 2009. As with the market power index, the BPI of retailers starts to grow at the end of the timeframe again to finish with a value of about 0.72.

Figure 20: Calculated buyer power index of dairies.



Source: own elaboration.

Figure 21: Calculated buyer power index of retailers.



Source: own elaboration.

7.4 Summary

The previously derived structural model and the methodology with its estimation strategy were applied to the German dairy supply chain over the time horizon from January 2003 to December 2015 using monthly data. The data consisted of price time series comprising the price for raw milk, a dairy output price derived by share-weighting the prices for skim milk powder, Emmentaler and butter, as well as of other cost variables involved in the product transformation process along the chain.

The initial test for stationarity revealed that all data series possess a unit root. Based on this result, a cointegration test was conducted to test for one or more relationships among the variables that are stationary in the long-run. Depending on the suggested length of lagged differences included in the analysis the number of cointegrated vectors differed. However, all specifications suggested up to two cointegration vectors, which are required to perform the described methodology. Furthermore, the Chow forecast test results support the assumption of time-variant parameters.

With the confirmation of two cointegration vectors and time-varying parameters the previously described estimation strategy was applied to the data using various different model specifications concerning lag length and assumption of the nature of non-material input variables to the system. In the following one model specification was selected for further analysis. From the model specifications that resulted in theoretically consistent values for the derived market power indices, the one best describing the data in accordance to the ΔAICc criterion was selected for further analysis. The model specification with a differenced lag length of two and weakly exogenous non-material input variables revealed to be the best fit.

The first step of the estimation strategy, the application of the Kalman-Filter to the transformed VECM, produced the time-varying parameter estimates. For both long-run equilibrium equations, FPE and PRE, all parameters were statistically significant at the 10%-significance level at least at some point in time over the analyzed period. Furthermore, all parameter estimates vary over time. The time-varying cointegration parameter estimates then entered the dynamic factor analysis as dependent variables.

The DFA produced a for both equations statistically significant time-varying common factor. The other for the calculation of the market power indices required constant parameters were statistically significant as well. The estimates of the common factor cannot be interpreted independently, but their developments over time reveal changes in market power conducts. Consequently, the derived market power indices for dairies, ranging from 0.038 to 0.048, and for retailers, oscillating in the interval 0.14 to 0.22, vary over time as well.

The DFA results do not only allow calculating the market power indices of both markets, but also the price elasticities of raw milk and dairy output supply. While the first evolves rather unstable over time, and shifting to a higher level for the last years of the time horizon, the one of dairy output develops rather stable between 0.24 and 0.30, apart from a peak period with a value of 0.40 in 2009.

With knowledge on the market power indices and the price elasticities of supply it was now possible to derive the buyer power indices (BPI), a percentage measure of the actual mark-down, for both markets. Due to the instability of the raw milk supply price elasticity the development of the BPI of dairies is characterized by this development and ranges from 0.21 to 0.48. On the contrary, the BPI of retailers shows patterns of both variables involved in its calculation. While the two distinct periods of rather high and low market power index values between 2003 and 2009 and mid-2010 to the end of 2015 generate periods of rather high and low BPI values of the range 0.67 to almost 0.78 and 0.49 to about 0.60 respectively, also the sudden peak and drop of the supply elasticity of dairy output supply between mid-2007 and mid-2009 is striking and lifts the BPI to its maximum value of 0.82.

8 Discussion

The previous section was of pure descriptive nature regarding the data, cointegration analysis and the obtained results of the empirical application. This section will provide interpretation of the estimated and calculated indices and elasticities as well as compare the obtained results with previous studies. The last section will discuss theoretical and methodological shortcomings of this approach resulting from drawn assumptions, choice of data and variable selection.

8.1 Market power indices

Several factors would lead to assume that the oligopsony level on the German raw milk market is high. German dairy farmers face a highly concentrated German dairy industry, in some regions more than 50% of the raw milk produced is sold to one firm (Bundeskartellamt, 2009) and almost no outside options exist. In addition, dairy farmers face the issue of a possible hold up through dairies due to the nature of raw milk production with its high asset specificity and the perishable nature of raw milk. The threat of a hold up and possible loss of output due to spoilage puts dairy farmers in a weak bargaining position with dairies (Grau et al., 2015).

Indeed, the market power index for dairies with its value range from 0.037 to 0.048 reveals market imperfections on the German raw milk market due to oligopsonistic conduct, but the level of oligopsony is rather low and close to perfect competition. Other studies on oligopsony conduct on raw milk markets report similar estimates. For example, Hockmann and Vőnecki (2009) report a market power index of 0.05 for the Hungarian raw milk market, and Scalco and Braga (2013) for the Brazilian raw milk market of 0.01. Perekhozhuk et al. (2013) and Perekhozhuk et al. (2015) find higher level of oligopsony conduct on the Hungarian (0.15) and Ukrainian raw milk market, but still far from monopsony level.

A diverse number of reasons can explain the low level of oligopsony conduct on the German raw milk market. Even though the concentration of procurement reaches levels of more than 50% on regional markets, on a national aggregated level these might be local exceptions. Due to the usage of national aggregated price data the oligopsony conduct on regional German markets cannot be evaluated and no statement given. Furthermore, while six dairies summing up a market share of approximately 50% (Loy et al., 2015), around 70% of the German raw milk is processed through cooperatives. Dairy cooperatives are obliged to process all of the raw milk delivered by their members. Consequently, quantity reduction in procurement as a result of oligopsony power is not a feasible option and not in the interest of cooperatives. With cooperatives being dominant on the German raw milk market, the possible higher levels of market power through investor-owned dairies are counterbalanced (Tribl & Salhofer, 2013)

Even without the consideration of cooperative action, an actual hold up that can ruin dairy farmers is not likely to be enforced by dairies, since the benefits of a steady flow of raw milk to fully utilize capacities and therefore achieve cost-minimization production are greater (Schroeter & Azzam, 1991). Apart from the goal of cost-minimization, also dairies' investments in highly specific assets lower the incentive to use market power. The gain from higher profits in the short-run due to the application of market power is offset by lower rates of return on dairies' own investment, since the exertion of market power might force farmers to exit production and shrinks the procurement base and dairies' capability to utilize their capacities fully in the long-run (Crespi et al., 2012).

While the level of oligopsony is rather low throughout the investigated period, drastic relative changes can still be observed (see Figure 16). In particular, in the summer of 2007 the market power index of dairies punctiliously collapsed by about 18%. This might be a result of increased competition for raw milk between dairies due to growing export opportunities and high prices as a result of growth in global demand for dairy products, a production shock in New Zealand that drastically reduced supply on world markets, and low public stocks of dairy products in the EU (Acosta et al., 2014; Bouamra-Mechemache et al., 2008). The growth in the market power index after this period might be a result of mergers and acquisitions boosting concentration at the dairy industry level as well as the growing raw milk supply as a consequence of the gradual abolishment of the quota, in particular since 2010 (see Figure 2). A growing supply base enhances collusive behavior among buyers (Hockmann & Vőnecki, 2009).

On the German dairy output market larger levels of market imperfections compared to the raw milk marked can be observed. The market power index of retailers ranges over the analyzed period from 0.14 to 0.22. Salhofer et al. (2012) find a similar level of market power on the Austrian butter procurement market by retailers with a market power index estimate of around 0.10. Even though, the German retail sector is highly concentrated, as the Austrian is, the level of market power is still far from monopsony or a collusive cartel. Again, the concept of capacity utilization and cost-minimization with the abundance of large storage facilities for dairy products (Loy et al., 2015) might explain the rather low market power index value in the presence of five German retailers accounting for more than 70% of revenues in German food retailing (BEV, 2016).

While the market power index value is far from monopsony level, the presence of significant oligopsony conduct on the dairy output market was still proven by the results. The German retail market, in particular for dairy products where consumers are very sensitive to price changes (Loy et al., 2016), is characterized by intensive horizontal price competition. Consequently, albeit five companies controlling German food retailing, it is unlikely for these to extract oligopoly margins due to intense competition for market shares. The exertion of oligopsony power might be an attempt of retailers to increase profits or market shares on highly competitive markets by offering lower prices secured by significantly marked-down procurement prices (Anders, 2008).

As with the market power index of dairies, drastic relative adjustment in the oligopsony conduct of retailers is apparent (see Figure 17). From 2003 to around mid-2009, the parameter's value increases from around 0.18 to 0.22. The continuing concentration process in form of mergers and acquisition at the retail level, the formation of procurement alliances among larger and smaller retailers, and the growing dairy output supply as a consequence of the gradual quota abolishment as well as cooperatives' commitment to process all their members' raw milk, might have enabled retailers to exert more market power on the dairy output market. However, after this period of growth in the market power index, it suddenly drops in one year, between mid-2009 to mid-2010, from its maximum value to its minimum value of 0.14. In the next three to four years the market power index remains on this level. However, in the summer of 2014 the index starts growing again steadily to finish off with its starting value of 0.18. A possible explanation for the sudden drop in value is that even though the number of retailers might have decreased over the time period, possibly a threshold was passed that made the buyers on the dairy output market procure more competitively (Sexton, 2013). The more recent increase of market power could be a result of the growth in supply as a result of the growth in raw milk production, similar to the previously described situation on the raw milk market.

8.2 Elasticities of supply

The price elasticity of raw milk supply is rather inelastic. Its value ranges from 0.09 to 0.22 over the analyzed period (see Figure 18). Consequently, a 1%-increase in the price of raw milk would lead to an increase of the raw milk quantity of 0.09% to 0.22% depending on time t. The derived value of ${\eta^F}_t$ is coherent with the literature. Bouamra-Mechemache et al. (2008) estimated a supply elasticity of 0.253 for Germany. For the UK Colman et al. (2005) report a value of 0.2 to 0.3. In general, raw milk supply is considered to be inelastic. For example, Perekhozhuk et al. (2013) assume a value of 0.1 for η^F in their study of the Hungarian raw milk market.

Raw milk supply is rather inelastic, since an expansion of production requires high investment in specific assets and cannot be temporary balanced with stocks, which limit a quick adjustment to price changes in the short-run. Consequently, in the long-run raw milk supply reacts more elastic (Bouamra-Mechemache et al., 2008). With the gradual abolishment of the quota, the price elasticity of raw milk supply became more elastic, up to a value of 0.22, since the quota formed a barrier of entry, and supply can freely adjust (Graubner et al., 2011; Bouamra-Mechemache et al., 2008).

The price elasticity of dairy output is also inelastic with a value range of 0.24 to 0.40, but slightly more elastic. In the absence of comparable estimates for Germany, Gohin and Guyomard (2000) with their study on the market power of French retailers provide the only available price elasticity for dairy output with 0.33, which lies in the estimate value range. The inelasticity of dairy output supply is due to similar reasons as at the farm level. With the assumption of dairies trying to fully utilize their existing capacities, a quick response to positive price changes cannot be answered by activating free unused capacities, but rather by high investment cost in processing capacities are necessary to expand production. The possibility to store a number of dairy products to some extent, e.g. SMP and butter, might explain the more stable evolution of ${\eta^P}_t$ compared to the one of ${\eta^F}_t$, as well as the slightly more elastic response of supply.

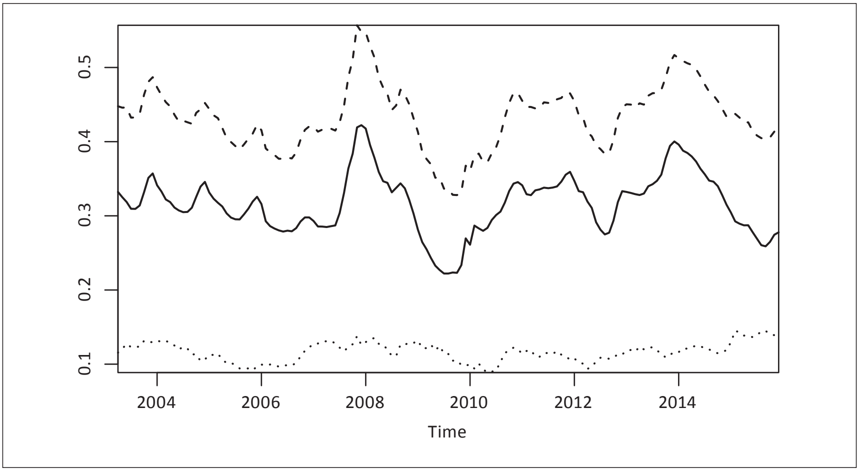
8.3 Buyer power indices

The exertion of market power on agricultural product markets is more dramatic than on other sectors' markets, since the inelastic supply magnifies the market power extend in form of a severe mark-down (Bakucs et al., 2010). The same can be said about the German raw milk and dairy output markets. Even though, the extent of oligopsony on both markets is rather low, in interaction with the corresponding inelastic price elasticity of supply, this leads to considerable mark-downs. The relative mark-down is expressed by the buyer power index (BPI).

On the raw milk market the BPI ranges from 0.21 to 0.48, meaning that the raw milk price was marked-down by oligopsony power in the range of 21% to 48% over the analyzed period (See Figure 20). Unfortunately, no study has calculated a BPI for the raw milk market so far (for more details see Perekhozhuk et al., 2016), but studies on other agricultural products also report relative large relative mark-downs, up to 1.1 for livestock in the USA (Azzam & Pagoulatos, 1990), as a result of low levels of market power but inelastic supply (e.g. Azzam & Pagoulatos, 1990; O'Donnell et al., 2007; etc.).

Interestingly, the BPI of dairies follows a similar development as the margin between raw milk price and dairy output price (see Figure 10). In periods of larger margins, the BPI is high, in particular observable in mid-2009, and low in periods of reduced margins, see the period from 2011 to 2014. Figure 22 displays the absolute mark-down in comparison to the observed raw milk price, as well as the difference between both. The absolute mark-down oscillates around 0.10 € per liter raw milk, with local maxima of approximately 0.12 € in 2004 and 2008, and a minimum of about 0.08 € between 2010 and 2014 due to the growing price elasticity of raw milk supply. Even though, the months around the start of 2008 are characterized by lower values of the BPI, the high prices in this period lead to highest absolute mark-downs.

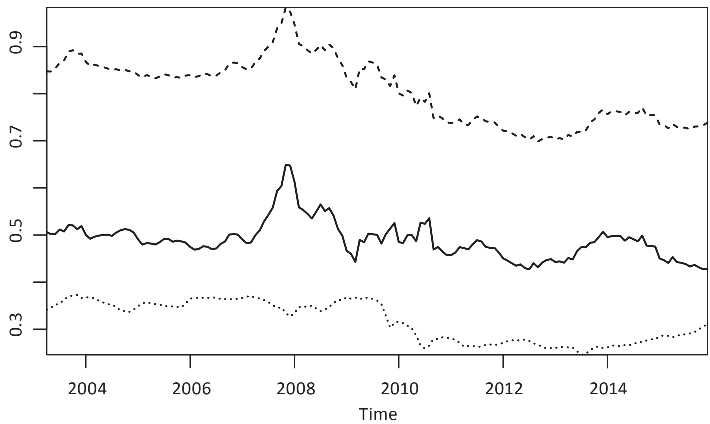
Figure 22: Observed raw milk price (continuous line), observed raw milk price plus absolute mark-down (taunted line), and their difference (dotted line) for the analyzed time period.



Source: own elaboration.

With a larger extent of oligopsony power on the dairy output market in combination with a similar inelastic supply, the BPI of retailers achieves higher values in the range from 0.49 to 0.82 over the analyzed period. While the literature provides at least BPIs for other agricultural markets, the only study that determined

Figure 23: Observed dairy output price (continuous line), observed dairy output price plus absolute mark-down (taunted line), and their difference (dotted line) for the analyzed time period.



Source: own elaboration.

a BPI for the processor output market is Gohin and Guyomard (2000). These authors report a BPI of about 0.20 for dairy products, 0.17 for meat products and 0.12 for other food products. The two distinct time periods in the evolution of the retailers' market power index can also be observed in the BPI as well as the margin between observed prices and prices plus mark-down (see Figure 23). The drop in oligopsony power after 2010 drastically lowers the BPI of retailers to a value of around 0.49 to 0.60. While the pre-2010 margin oscillates between 0.30 € and 0.40 €, the margin reduces to below 0.30 € after 2010.

Overall, while oligopsony levels closer to perfect competition than monopsony were observed, the market imperfections in cooperation with the inelastic supply elasticity lead to drastically marked-down prices for raw milk and dairy output. As a consequence considerable amounts of rents were shifted downstream along the German dairy supply chain. However, if these rents were passed on to consumers in form of low dairy products prices, which some studies (i.e. Loy et al., 2016) state is the daily practice of German retailers, in particular of discounters, institutions like the European Commission do not assess this as anticompetitive. In contrast, the German anti-trust agency holds the opinion that even if consumers benefit in form of low retail prices, it does not justify the use of market power (Bundeskartellamt, 2009). Because in this analysis the consumer market is not included, we have to agree with the view of the German anti-trust agency and characterize the German supply chain as anticompetitive. However, the abolishment of the milk quota boosting the elasticity of raw milk supply (Graubner et al., 2011) as well as the food retail market probably reaching a threshold level of concentration have benefited the competitiveness of the supply chain and lowered the relative as well as the absolute mark-downs at each market.

8.4 Actions against price mark-downs

The two markets of the German dairy supply chain are characterized by different levels of oligopsony behavior. While dairy cooperatives seem to be able to counterbalance the oligopsonistic behavior of investor-owned firms and thus the raw milk market is close to perfect competition, the dairy output market approaches at times Cournot levels. Nevertheless, due to the rather inelastic supply of both products the market power indices lead to rather high mark-downs. In the economic literature a series of suggestions exist that might be feasible for the German dairy supply chain to lower these effects.

Procurement behavior on the German raw milk market is fairly competitive. Actions to further counterbalance the market power of dairies, e.g. diversifying the homogenous product raw milk by switching to organic production, are only niche opportunities and will not greatly affect the entire market (Bundeskartellamt, 2009). Consequently, to lower the mark-downs, supply has to react more elastic to price changes (Hamilton & Sunding, 1997). A first step was already taken by abolishing entry barriers to the market in form of the milk quota, which as a result has likely increased the supply elasticity and lowered mark-downs (Graubner et al., 2011). Furthermore, other actions such as credit availability and technology transfer to dairy farmers as well as innovations at the farm level should be promoted since these allow raw milk production to respond more elastically (Atsbeha et al., 2016).

For the dairy output market, apart from the just mentioned supply elasticity enhancing policies, measures to lower the oligopsony conduct should be discussed. While cooperation among dairies might promote efficiency and the elasticity of supply, the German anti-trust agency is certain that further concentration at the dairy level will not increase their capability to achieve higher prices (Bundeskartellamt, 2009). One possibility to break the level of oligopsony is to increase the number of buyers for dairy products and thus the marketing options for dairies (Rude et al., 2011). One way to achieve this is to promote exports. However, the outcome of this approach might be rather restricted, since the quantities traded globally are growing but compared to the overall production still small.

For example, the main competitor of European dairy products New Zealand only produces a raw milk quantity similar to the magnitude of the German federal state Bavaria (Bundeskartellamt, 2009). Another way is to increase the number of domestic buyers by dissolving procurement alliances between larger retailers and smaller retailers and further lifting regulations that are entry barriers to the German retail market (Perloff et al., 2007). One more possibility to counterbalance an oligopsony is to move from homogenous, generic products to heterogeneous products (Sutton, 1998). This is in particular true for dairy cooperatives which mainly produce standard products under store label brands and thus only achieve low prices for their dairy products (Loy et al., 2016). Though, the creation of higher value-added and more heterogeneous dairy products through the establishment of brands, product innovation, and labelling in form of geographic indications or production method should be promoted (Henson & Reardon, 2005).

In general, actions that promote the price elasticities of supply along the supply chain smother the effects of market power. Nevertheless, due to the nature of raw milk and dairy production with its high asset specific the possibility to do so might be restricted. The oligopsony power of retailers could be offset by increasing the marketing possibilities by dairies, in particular cooperatives, either by increasing the number of possible buyers or promoting the diversification of dairy products through innovations and branding.

8.5 Shortcomings of the approach

The developed theoretical model and the methodology to apply it empirically are capable to determine the level of oligopsony power on two subsequent markets only using price time series. Nevertheless, to model the German dairy supply chain strong assumption had to be drawn. Even though these assumptions seem to be valid and approximate the German dairy supply chain well, these still limit the transfer of the obtained results to the real world. In the following the shortcomings and their implications for the explanatory power of the results will be discussed.

While one of the main criticisms of the NEIO framework, the static estimation of a dynamic concept, is avoided by the estimation strategy, the model is still not completely dynamic. The negligence of any form of adjustment cost due to the complexity of the procedure leaves us with a static market power index, even though it varies with time and considers its history, its nature is not a completely dynamic one. A consequence is that the 'static' estimate of market power might be overestimating the true extent of the oligopsony level, since market participants that consider these dynamics might act more competitively (Perloff et al., 2007). Adding the dynamic component to the here described theoretic model would be an interesting task for future research.

Apart from the negligence of adjustment cost also the *a priori* choice of quantities to be the strategic variable limits the explanatory power of the approach. While the approach permits to evaluate the level of market power and through the supply elasticity its effect on the price, it is not possible to make any statement on the strategic game played by the market participants (Sckokai et al., 2013).

Another criticism is the assumption of homogenous products. While raw milk seems to be a quite homogenous product market, the aggregation across dairy products is at least questionable. Due to the lack of available data, the share weighted dairy output price was calculated using prices determined on the German dairy stock market for generic products. Nevertheless, the German dairy product market also includes a vast majority of heterogonous brand products, which achieve tremendously higher price. While the obtained results might describe the extent of market power for the generic dairy products well, the extent of market power on brand dairy product markets might be lower (Perloff et al., 2007).

The exclusion of exports is a limitation to this study. The exclusion of exports limits dairies in the theoretical model to sell their products to the German retail industry and deprives them of more marketing options. While indeed only small quantities of raw milk are imported and exported, more than half of dairies products produced by German dairies in terms of milk equivalent quantity are actually exported. Thus, excluding exports again might overestimate the market power of retailers. Nevertheless, the exclusion of trade is a necessary requirement in many market power studies due to lack on data of export prices, destinations, and quantities (Sckokai et al., 2013).

Even though, as described before, some drawn assumptions might limit the explanatory power of the obtained results, these were necessary requirements to limit the complexity or due to the availability of data. However, it is desirable to relax some assumptions in future research.

8.6 Summary

The aim of this chapter was to give an interpretation to the results described in the empirical application section. In general, the estimates for the market power indices, price elasticities of supply are in line with the estimates of comparable studies. Furthermore, the large buyer power indices are also no curiosity, but rather common on agricultural markets.

The rather low values of the market power index on the German raw milk market can be explained by the strong presence of German cooperatives, which promote the interests of dairy farmers and seem to erase the issue of a hold up by dairies. The interest of dairies in a constant flow of raw milk as an input to their production to be able to fully utilize capacities and generate the highest return on investment possibly further explains the low level of oligopsony on the German raw milk market.

While the German dairy output market is also closer to perfect competition than monopsony, the value range of 0.14 to 0.22 for the retailers' market power index proves the existence of significant market imperfections. Since five retailers control food retailing in Germany, the obtained value for the market power index is close to the Cournot outcome of 0.2 and consequently not surprising. On the consumer market fierce competition for market shares seems to exist and the exertion of oligopsony power on the procurement market, here for dairy products, is a possibility for retailers to generate larger profits. Nevertheless, the concentration of German retailing seem to have passed a concentration threshold around the year 2010 that actually has boosted competition on the market and lowered the level of oligopsony conduct (Sexton, 2013).

The price elasticity of raw milk supply as well as for dairy output is inelastic. The reason for this is the high asset specificity and thus the need for large investments to increase supply. However, the abolishment of the milk quota has abolished a barrier of entry and consequently made the supply of raw milk gradually more elastic.

Through the interaction of the market power indices and the price elasticities of supply the buyer power indices (BPI) for both markets can be determined. Due to the inelasticity of supply, the BPIs are quite large and range from 0.21 to 0.48 on the German raw milk market and 0.49 to 0.82 on the German dairy output market. In absolute terms, the German raw milk price was marked-down by 0.08 € to 0.12 €, and the share weighted dairy output price between 0.25 € and almost 0.40 €. The level of mark-down was in the latter stages of the time horizon reduced on the German raw milk market due to the growing elasticity of supply, and on the German dairy output market due to the decreasing extent of oligopsony power.

In general, the results prove that the effect of market power on the prices of raw milk and dairy output are large. Even though, the levels of oligopsony power are closer to perfect competition than monopsony, the inelastic supply of raw milk and dairy output lead to large relative and absolute mark-downs, in particular on the German dairy output market. Because the consumer market is not part of the analysis, it is not clear whether retailers have passed the lower prices for dairy products on to consumers. Without knowledge on this, the conclusion can only be that the market behavior along the German dairy supply chain is anticompetitive and has lowered the overall welfare.

The literature provides insights on how to counter the negative effects of oligopsony. In general, actions, e.g. credit availability, knowledge transfer, etc., that promote the price elasticities of supply along the supply chain lower the mark-downs. Nevertheless, due to the nature of raw milk and dairy production with its high asset specific the possibility to do so might be restricted. The oligopsony power of retailers could be offset by increasing the marketing possibilities by dairies, in particular cooperatives, either by increasing the number of possible buyers or promoting the diversification of dairy products through innovations and branding.

Nevertheless, a series of drawn assumption limit the explanatory power of this analysis. The negligence of adjustment costs and the exclusion of exports are likely to lead to an overestimation of the effect of market power. However, these are common and necessary requirements in most market power studies (Sckokai, et al., 2013). The relaxation of these assumptions is a desirable achievement in future approaches.

9 Conclusions

The identification of market power along the German dairy supply chain was the primary objective of this study. The report of the German anti-trust agency as well as a descriptive analysis of the chain's structure acknowledge that on each of the two markets of the supply chain, the raw milk market and the dairy product market, a large number of sellers face a small number of buyers (Bundeskartellamt, 2009). Consequently, the threat of oligopsony power on both markets is a realistic approximation. To address the subsequent threat of oligopsony power in the analysis of market power along the German dairy supply chain a coherent model was required.

Therefore, three approaches, structure-conduct-performance paradigm (SCPP), new empirical industrial organization (NEIO), and asymmetric price transmission (APT), were revised and their suitability for the study on hand discussed. While, the SCPP was quickly dropped from considerations, because of endogeneity issues and the use of accounting data instead of economic data, NEIO and APT have been widely used in the economic literature. Both approaches have their benefits, but also heavy drawbacks. NEIO is based on structural models that allow deriving a measure of market power, but the data requirement is high and the dynamic concept is estimated statically in most applications. If estimation is dynamic, strong assumptions on the behavior of market participants have to be drawn to be able to identify a unique market equilibrium. APT, on the other side, has a low data requirement and applies time series techniques, but is only capable of assuming that market power is the source of revealed price asymmetries rather than proofing it. In addition, the true extent of market power cannot be evaluated. Furthermore, neither NEIO nor APT provide a model that allows identifying oligopsony power on two subsequent markets of a supply chain. From the theory review it was concluded that none of the discussed approaches is suitable in this case.

In the absence of a proper model, the NEIO and APT approach were merged what permitted to derive a model of oligopsony power on two subsequent markets. The two markets were structurally modeled in the spirit of NEIO with demand and supply equations, while accounting for possible oligopsony conduct in form of market power indices. In the next step the equilibrium displacement model (EDM), a sub branch of APT, is applied by using the supply and demand equations as a system of equations. This allows deriving the simultaneous partial equilibria for all endogenous variables, the prices and quantities. From these simultaneous partial equilibria two pricing equations can be deduced, which only incorporate the prices for material input and output, other non-material costs as well as the market power indices for processors and retailers. Consequently, quantities are eliminated and the data requirement significantly lowered in comparison to the classic NEIO framework.

To estimate the two derived pricing equations simultaneously and derive non-static estimates for the market power indices, three time series estimation techniques had to be linked. The vector error correction model (VECM), which accounts for stationarity of long-run relationships among the variables, commonly found between price series of integrated markets, is transformed via the simple two step estimation technique of Lütkepohl and Krätzig (2004). The Kalman-Filter is applied to the transformed VECM and time-varying parameters obtained. The time-variation is assumed to be caused by changes in oligopsony conduct and is extracted in form of dynamic factors through the application of dynamic factor analysis (DFA) from the VECM's parameter. In addition, the DFA also allows separating the dynamic factors from other constant components. The results of the DFA permit to uniquely identify the time-varying market power indices.

The derived theoretical model and the estimation strategy were applied to the German dairy supply chain using monthly data over the time horizon from January 2003 to December 2015. The data consisted of price time series comprising the price for raw milk, a dairy output price derived by share-weighting the prices for skim milk powder, Emmentaler and butter, as well as prices of other cost variables involved in the product transformation process along the chain. The initial statistical analysis revealed nonstationary of the variables and two long-rung cointegration relationships among them, justifying the use of a VECM in the further steps. Furthermore, the Chow forecast test proved parameter instability of the VECM. The estimation strategy was applied to a total of nine different VECM specifications differing in lag length and assumptions on the nature of exogenous cost variables. The specification with a lag length of two and weakly exogenous variables was the best fit for the data.

The empirical application was successful and revealed theoretically consistent and statistically significant market power indices on the German raw milk market and dairy output market for the investigated time horizon. While the raw milk market is close to perfect competition with a market power index value range of 0.038 to 0.048, the dairy output market is subject to larger market imperfections. The market power index of retailers lies in the interval of 0.14 to 0.22 and reaches probably Cournot level at times. Consequently, the five firms in control of German food retailing abused their oligopsony power by splitting the procurement market for dairy products among themselves. However, since

2010 the level of market imperfection significantly dropped on the dairy output market and the firms acted more competitively.

After calculating the respective price elasticities of supply it is possible to calculate buyer power indices that measure the effect of the market power level on the observed prices. The rather inelastic supply due to asset specificity and high investment costs lead in collaboration with the derived market power indices to large mark-downs. While the German raw milk price was marked-down by 21% to 48%, the mark-down of the share-weighted dairy output price ranges between 49% and 82% over the analyzed time period. However, as a consequence of the lower levels of oligopsony power since 2010 on the dairy output market also the corresponding mark-down declined. Overall, large rents were shifted in disadvantage of dairies and in particular of dairy farmers downstream the supply chain and welfare was lost. If the mark-downs resulted in lower consumer prices this might be socially desirable. Nevertheless, consumer markets were excluded from the analysis, and the markets of the German supply chain have to be marked as anticompetitive.

To overcome the market imperfections on each market of the German dairy supply chain different steps can be taken. While cooperative action on the raw milk market seems to be capable to counterbalance a possible oligopsony behavior of investor-owned firms and only low levels of oligopsony conduct are observed, the inelastic response of raw milk supply to price changes causes the rather large mark-downs. Consequently, policies that enhance the responsiveness of supply, e.g. credit availability and technology transfer to dairy farmers, should be implemented (Atsbeha et al., 2016). A first step was already taken by abolishing the entry barrier in form of the milk quota, which has likely increased the supply elasticity and lowered mark-downs (Graubner et al., 2011).

For the dairy output market, apart from the just mentioned supply elasticity enhancing policies, measures to lower the oligopsony conduct should be discussed. One possibility is to increase the number of buyers of dairy products and thus the marketing options for dairies (Rude et al., 2011). This could be done in the case of the German dairy supply chain by promoting exports or dissolving procurement alliances between larger and smaller retailers. Another possibility to counterbalance an oligopsony is to move from homogenous, generic products to heterogeneous products through the creation of brands (Henson & Reardon, 2005; Sutton, 1998; Weatherell et al., 2003).

Several innovations make the presented approach a novelty in the field of market power studies. To our knowledge no attempts to model oligopsony power on two vertically integrated markets exist so far in the economic literature. Furthermore, even though, the use of quadratic-flexible functional forms increases the complexity of the model, it also allows approximating the true technologies closer than any linear functional forms that have been widely used as the foundation for determining simultaneous partial equilibria (e.g. Lloyd et al., 2009). While the markets are model in the fashion of NEIO, the derivation of partial equilibrium equations and the final pricing equations significantly lower the data requirement and the necessary number of equations for estimation. Moreover, by assuming time-variation in the oligopsony conduct and applying the developed estimation strategy, the market power indices are adaptive rather than 'static'.

Nevertheless, a series of assumption that ultimately limit the explanatory power of this analysis had to be drawn in order to ensure the approach's empirical applicability. The negligence of adjustment costs and the exclusion of exports are likely to lead to an overestimation of the market power indices. However, these are common and necessary requirements in most market power studies (Sckokai, et al., 2013). Consequently, the values of the market power indices should be interpreted with care. The relaxation of these assumptions should be the focus of future research.

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Appendix

(A1) Derived inverse supply function of material input:

$$W^M = \rho^X + \sum_{i=1}^{h} \rho_i^{NX} W_i^F + \rho^{TX} T^F + \rho^{XX} X^M$$

(A2) Aggregated revenue function of the processing industry:

$$\begin{aligned} R^P = {} & \varphi^0 + \varphi^P P + \varphi^{PP} \frac{P^2}{2} + \varphi^X X^M + \varphi^{XX} \frac{X^{M^2}}{2} + \sum_{j=1}^{k} \varphi_j^N W_j^P + \sum_{j=1}^{k} \varphi_j^{NN} \frac{W_j^{P^2}}{2} + \varphi^T T^P + \varphi^{TT} \frac{T^{P^2}}{2} \\ & + \varphi^{PX} P X^M + \sum_{j=1}^{k} \varphi_j^{PN} W_j^P P + \varphi^{PT} T^P P + \sum_{j=1}^{k} \varphi_j^{XN} W_j^P X^M + \varphi^{XT} X^M T^P \\ & + \sum_{\substack{i=1 \\ i \neq j}}^{k} \sum_{j=1}^{k} \varphi_{ij}^{NN} W_i^P W_j^P + \sum_{j=1}^{k} \varphi_j^{NT} W_j^P T^P \end{aligned}$$

(A3) Derived demand function for material input:

$$W^M + \rho^{XX} X^M \Xi_t^P = \varphi^X + \varphi^{PX} P + \varphi^{XX} X^M + \sum_{j=1}^{k} \varphi_j^{XN} W_j^P + \varphi^{XT} T^P$$

(A4) Derived inverse supply function of output:

$$P = -\frac{-Q + \varphi^P + \varphi^{PX} X^M + \sum_{j=1}^{k} \varphi_j^{PN} W_j^P + \varphi^{PT} T^P}{\varphi^{PP}}$$

(A5) Derived demand function for output:

$$P + \frac{Q \Xi_t^R}{\varphi^{PP}} = \vartheta^Q + \vartheta^{QQ} Q + \sum_{k=1}^{m} \vartheta_k^{NQ} W_k^R + \vartheta^{TQ} \; T^R$$

(A6) Explicit solutions for the endogenous variables X^M, W^M, Q, and P:

$$X^M = -\frac{1}{\varphi^{PX}}\left(B - \frac{\varphi^{PP}E}{\Xi_t^R - \varphi^{PP}\vartheta^{QQ}} + \frac{(-1 - \Xi_t^R + \varphi^{PP}\vartheta^{QQ})\left((A+BZ)\left(-\frac{\Xi_t^R}{\varphi^{PP}} + \vartheta^{QQ}\right) + EZ\right)}{(\Xi_t^R - \varphi^{PP}\vartheta^{QQ})D}\right)$$

$$W^M = \sum_{i=1}^{h}\rho_i^{NX}W_i^F + \rho^{TX}T^F + \sum_{j=1}^{k}\varphi_j^{PN}W_j^P - \frac{\rho^{XX}}{\varphi^{PX}}\left(B - \frac{\varphi^{PP}E}{\Xi_t^R - \varphi^{PP}\vartheta^{QQ}} + \frac{(-1 - \Xi_t^R + \varphi^{PP}\vartheta^{QQ})\left((A+BZ)\left(-\frac{\Xi_t^R}{\varphi^{PP}} + \vartheta^{QQ}\right) + EZ\right)}{(\Xi_t^R - \varphi^{PP}\vartheta^{QQ})D}\right)$$

$$Q = -\frac{A + BZ + \left(Z\varphi^{PP} + \varphi^{PX^2}\right)E}{\varphi^{PP}D}$$

$$P = -\frac{(A+BZ)\left(-\frac{\Xi_t^R}{\varphi^{PP}} + \vartheta^{QQ}\right) + EZ}{\varphi^{PP}D}$$

where $A = \varphi^{PX}\left(-\sum_{i=1}^{h}\rho_i^{NX}W_i^F - \rho^{TX}T^F + \varphi^X + \sum_{j=1}^{k}\varphi_j^{XN}\left(W_j^P - 1\right) + \varphi^{XT}T^P\right)$,
$B = \varphi^P + \sum_{j=1}^{k}\varphi_j^{PN}W_j^P + \varphi^{PT}T^P$,
$E = \vartheta^Q + \sum_{k=1}^{m}\vartheta_k^{NQ}W_k^R + \vartheta^{TQ}T^R$,
$D = \frac{-Z}{\varphi^{PP}} + \left(Z + \frac{\varphi^{PX^2}}{\varphi^{PP}}\right)\left(-\frac{\Xi_t^R}{\varphi^{PP}} + \vartheta^{QQ}\right)$, and
$Z = (1 + \Xi_t^P)\rho^{XX} - \varphi^{XX}$.

(A7) Transformation of dependent variable after first step of S2S procedure:

$$\begin{pmatrix} W_t^1 \\ W_t^2 \end{pmatrix} = (\alpha^T\Sigma_u^{-1}\alpha)\alpha^T\Sigma_u^{-1}\left(\Delta Y_t - \begin{pmatrix}\alpha_{W^F} \\ \alpha_{W^R}\end{pmatrix}\begin{pmatrix} W_1^F + \sum_{i=2}^{h}\underbrace{\frac{\rho_i^{NX}}{\rho_1^{NX}}}_{\beta_1^{W_i^F}}W_i^F & W_1^R + \sum_{k=2}^{m}\underbrace{\frac{\vartheta_k^{NQ}}{\vartheta_1^{NQ}}}_{\beta_2^{W_m^R}}W_k^R \end{pmatrix}\right)$$

(A8) Farm-processor pricing equation (FPE):

$$W_t^{1^*}M = \underbrace{\left(\overbrace{\left(\frac{1}{\varphi^{PX}} - \frac{\varphi^{XX}}{\varphi^{PX}\rho^{XX}}\right)}^{\omega_0^{W^M}} + \Lambda_t^{\Xi^P}\right)}_{\beta_{1t}^{W^M}} W^M M + \sum_{i=1}^{h} \underbrace{\left(\overbrace{\left(\frac{\rho_i^{NX}\varphi^{XX}}{\varphi^{PX}\rho^{XX}}\right)}^{\omega_0^{W_i^F}} + \overbrace{\left(-\rho_i^{NX}\right)}^{\omega_1^{W_i^F}} \Lambda_t^{\Xi^P}\right)}_{\beta_{1t}^{W_j^P}} W_i^F M + \underbrace{\left(\overbrace{\left(\frac{\rho^{TX}\varphi^{XX}}{\varphi^{PX}\rho^{XX}} - \frac{\varphi^{XT}}{\varphi^{PX}}\right)}^{\omega_0^T} + \overbrace{\left(-\rho^{TX}\right)}^{\omega_1^T} \Lambda_t^{\Xi^P}\right)}_{\beta_{1t}^T} TM + \underbrace{\left(\overbrace{\left(\frac{\rho^X\varphi^{XX}}{\varphi^{PX}\rho^{XX}} - \frac{\varphi^X}{\varphi^{PX}}\right)}^{\omega_0^C} + \overbrace{\left(-\rho^X\right)}^{\omega_1^C} \Lambda_t^{\Xi^P}\right)}_{\beta_{1t}^C} M$$

$$+ \, v_{1t}$$

where $\Lambda_t^{\Xi^P} = \frac{\Xi_t^P}{\varphi^{PX}}$ and $W_t^{1^*}M = \frac{W_t^1 + W_1^F + \sum_{i=2}^{h} \underbrace{\frac{\rho_i^{NX}}{\rho_1^{NX}}}_{\beta_1^{W_i^F}} W_i^F - \beta_{1t}^P P - \sum_{j=1}^{k} \underbrace{\frac{-\varphi_j^{XN}}{\varphi^{PX}}}_{\beta_{1t}^{W_j^P}} W_j^P}{\beta_{1t}^P} M.$

(A9) Processor-retailer pricing equation (PRE):

$$W_t^2 M = \underbrace{\left(\overbrace{\left(\frac{\vartheta^{QQ}}{\vartheta_1^{NQ}\rho^{XX}}\right)}^{\tau_0^{W^M}} + \overbrace{\frac{1}{\rho^{XX}}}^{\tau_1^{W^M}} \Lambda_t^{\Xi^R}\right)}_{\beta_{2t}^{W^M}} \left[\Omega_t^{\Xi^P}\left(W^M - \overbrace{\varphi^{PX}}^{\tau_2^P} P - \sum_{j=1}^{k} \overbrace{\varphi_j^{XN}}^{\tau_2^{W_j^P}} W_j^P - \overbrace{\varphi^{XT}}^{\tau_2^T} T - \overbrace{\varphi^{X}}^{\tau_2^C}\right)\right] - M + \underbrace{\left(\overbrace{\left(\frac{1-\varphi^{PP}\vartheta^{QQ}}{\vartheta_1^{NQ}}\right)}^{\tau_0^P} + \overbrace{\left(-\varphi^{PP}\right)}^{\tau_1^P} \Lambda_t^{\Xi^R}\right)}_{\beta_2^P} PM$$

$$+ \sum_{j=1}^{k} \underbrace{\left(\overbrace{\left(\frac{-\varphi_j^{PN}\vartheta^{QQ}}{\vartheta_1^{NQ}}\right)}^{\tau_0^{W_j^P}} + \overbrace{\left(-\varphi_j^{PN}\right)}^{\tau_1^{W_j^P}} \Lambda_t^{\Xi^R}\right)}_{\beta_{2t}^{z_j^P}} W_j^P M + \underbrace{\left(\overbrace{\left(\frac{-\varphi^{PT}\vartheta^{QQ}-\vartheta^{TQ}}{\vartheta_1^{NQ}}\right)}^{\tau_0^T} + \overbrace{\left(-\varphi^{PT}\right)}^{\tau_1^T} \Lambda_t^{\Xi^R}\right)}_{\beta_{2t}^{t}} TM + \underbrace{\left(\overbrace{\left(\frac{-\varphi^{P}\vartheta^{QQ}-\vartheta^{Q}}{\vartheta_1^{NQ}}\right)}^{\tau_0^C} + \overbrace{\left(-\varphi^{P}\right)}^{\tau_1^C} \Lambda_t^{\Xi^R}\right)}_{\beta_{2t}^{c}} \mathrm{M} + v_{2t}$$

where $\Omega_t^{\Xi^P} = \frac{\varphi^{PX}}{\left(\Xi_t^P - \frac{\varphi^{XX}}{\rho^{XX}}\right)}$ and $\Lambda_t^{\Xi^R} = \frac{-\Xi_t^R}{\varphi^{PP}\vartheta_1^{NQ}}$.

(A10) Calculation of η^F *and* η^P:

$$\eta^F = \frac{W^M}{\rho^{XX} X^M} = \frac{W^M}{W^M - \rho^X - \sum_{i=1}^{h} \rho_i^{NX} W_i^F - \rho^{TX} T^F}$$

$$\eta^P = \frac{\varphi^{PP} P}{Q} = \frac{\varphi^{PP} P}{\varphi^{PP} P + \varphi^P + \frac{\varphi^{PX}}{\rho^{XX}}\left(W^M - \rho^X - \sum_{i=1}^{h} \rho_i^{NX} W_i^F - \rho^{TX} T^F\right) + \sum_{j=1}^{k} \varphi_j^{PN} W_j^P + \varphi^{PT} T^P}$$

where $\rho^X = -\omega_1^C$,

$\rho^{TX} = -\omega_1^T$,

$\rho_i^{NX} = -\omega_1^{W_i^F}$,

$\varphi^{PX} = \frac{1}{\omega_0^{W^M} - \frac{\omega_0^{W_i^F}}{\omega_1^{W_i^F}}} - \omega_1^P$,

$\frac{\varphi^{XX}}{\rho^{XX}} = -\varphi^{PX} \omega_0^{W^M} + 1$,

$\rho^{XX} = \frac{1}{\tau_1^{W^M}}$,

$\varphi^{PP} = -\tau_1^P$,

$\vartheta_1^{NQ} = \frac{1}{-\frac{\tau_0^{W^M} \tau_1^P}{\tau_1^{W^M}} - \tau_0^P}$,

$\vartheta_k^{NQ} = \beta_2^{W_m^R} \vartheta_1^{NQ}$,

$\vartheta^{QQ} = \frac{\vartheta_1^{NQ}(\tau_0^P - 1)}{\tau_0^P}$,

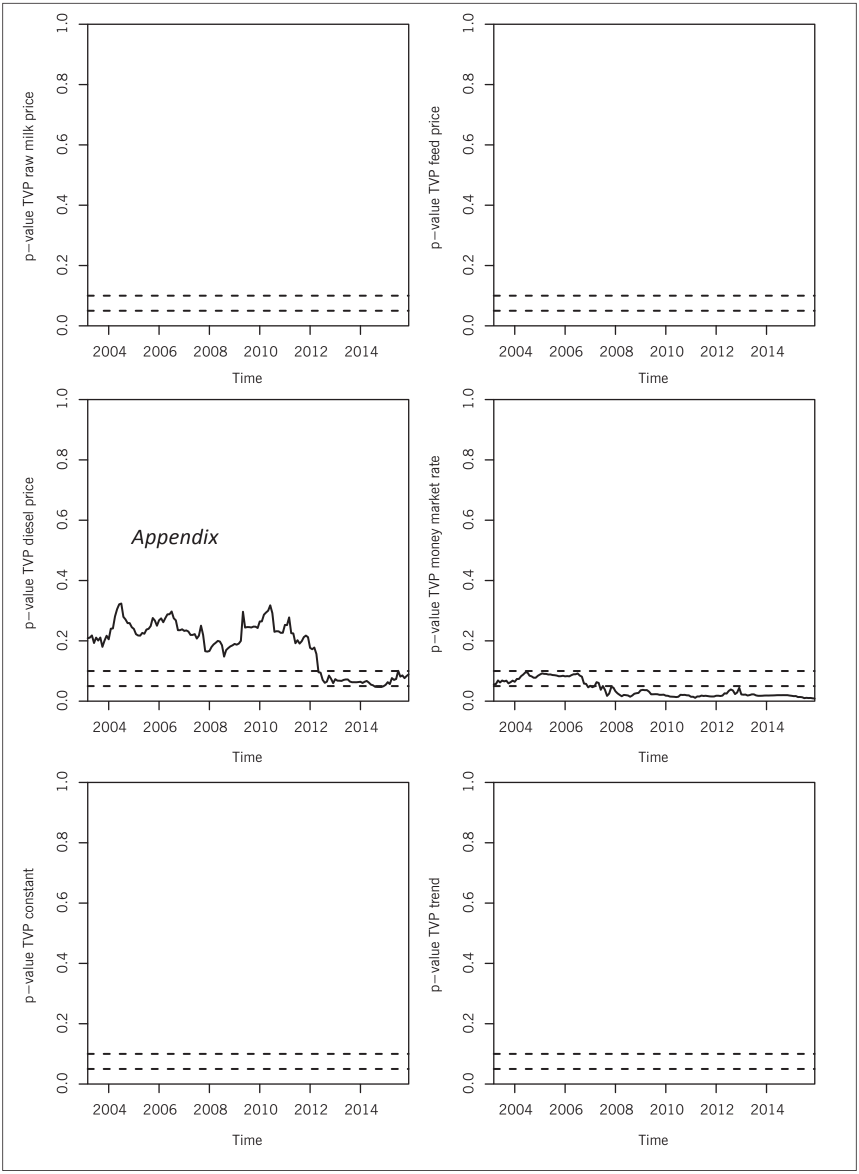
$\vartheta^Q = -\tau_0^C \vartheta_1^{NQ} + \tau_1^C \vartheta^{QQ}$,

and $\vartheta^{TQ} = -\tau_0^T \vartheta_1^{NQ} + \tau_1^T \vartheta^{QQ}$.

(A11) The ECTs of the ECM with two cointegration relationships:

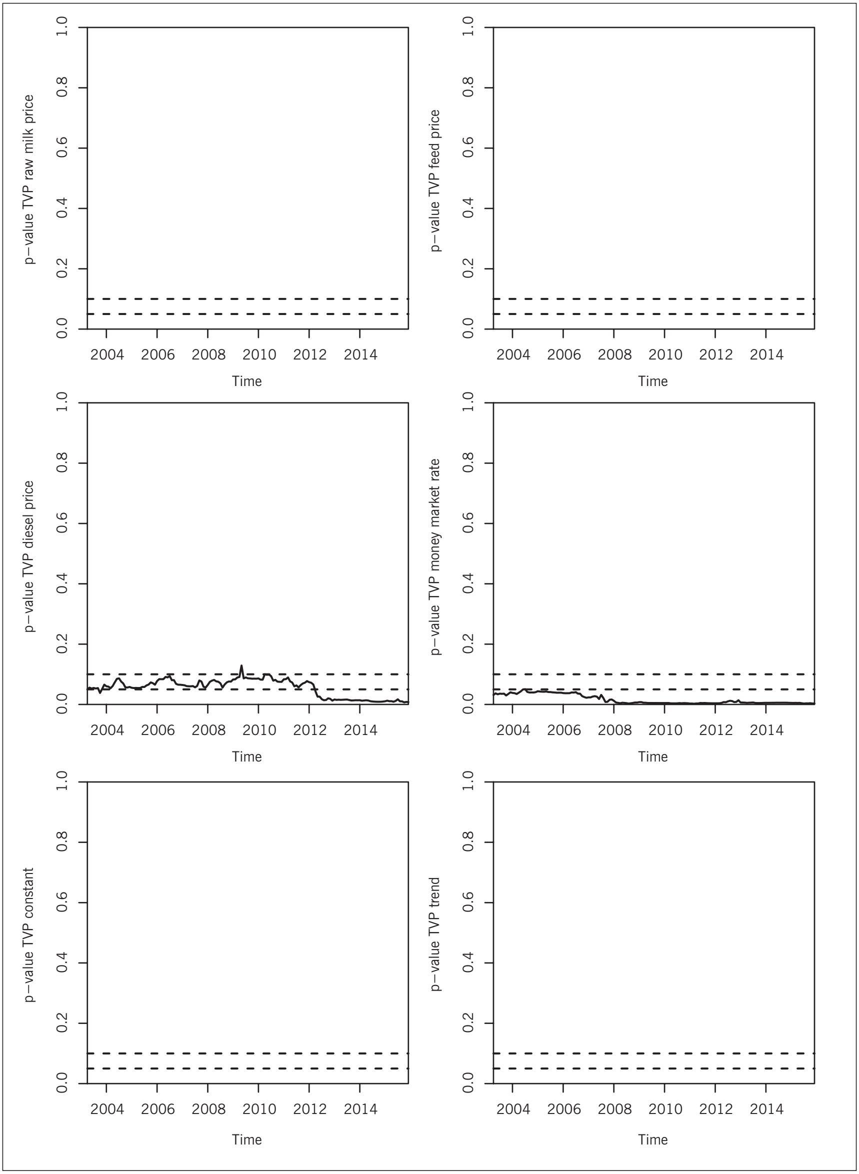
$$\begin{pmatrix} ECT_{FPE} \\ ECT_{PRE} \end{pmatrix} = \begin{pmatrix} 1 & 0 & \beta_{1t}^{W^M} & \beta_{1t}^{P} & \sum_{i=1}^{h} \beta_{1}^{W_i^F} & \sum_{j=1}^{k} \beta_{1t}^{W_j^P} & 0 & \beta_{1t}^{T} & \beta_{1t}^{C} \\ 0 & 1 & \beta_{2t}^{W^M} & \beta_{2t}^{P} & 0 & \sum_{j=1}^{k} \beta_{2t}^{W_j^P} & \sum_{k=1}^{m} \beta_{2}^{W_m^R} & \beta_{2t}^{T} & \beta_{2t}^{C} \end{pmatrix}' \times (W_1^F \quad W_1^R \quad W^M \quad P \quad W_h^F \quad W_k^P \quad W_m^R \quad T \quad 1)$$

Figure (A1): P-values of time-varying parameters of FPE coint. vector of model with 1 lag and endogenous non-material input variables (dotted: p-value of 0.05 and 0.1).



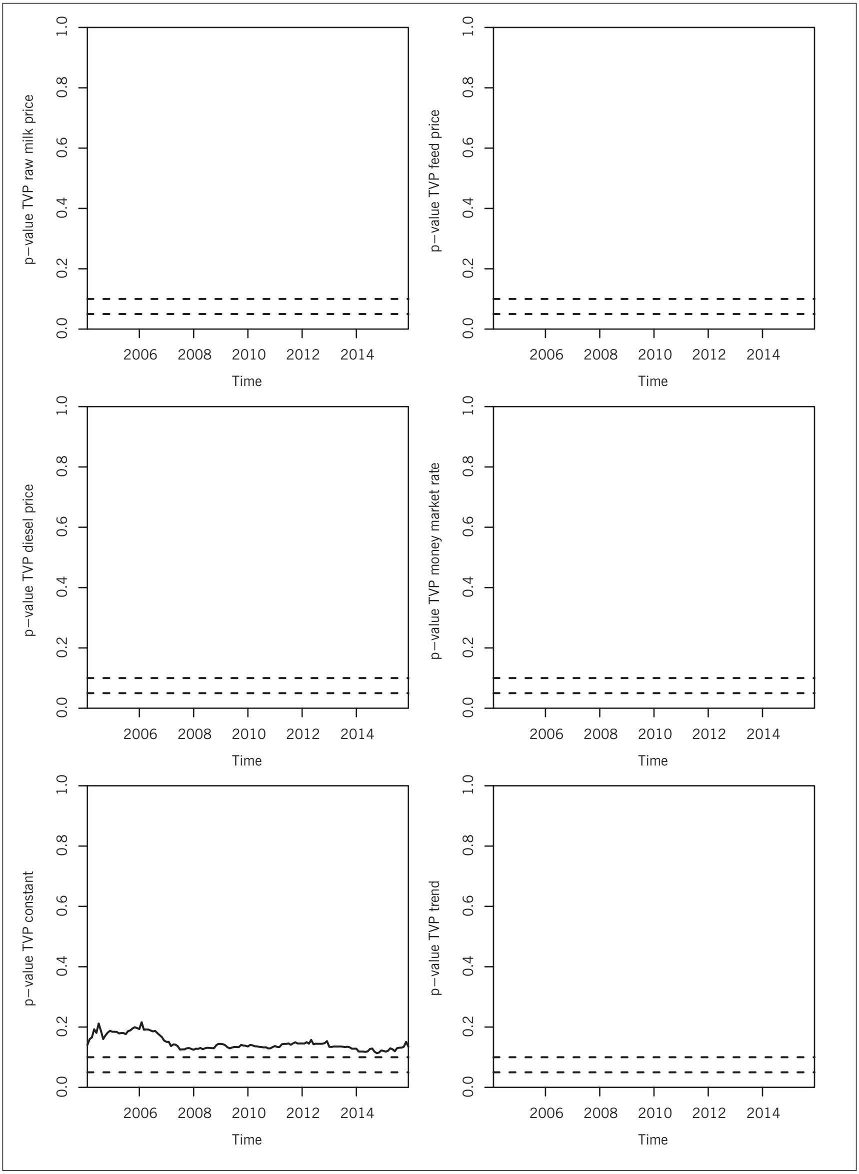
Source: own elaboration.

Figure (A2): P-values of time-varying parameters of FPE coint. vector of model with 2 lags and endogenous non-material input variables (dotted: p-value of 0.05 and 0.1).



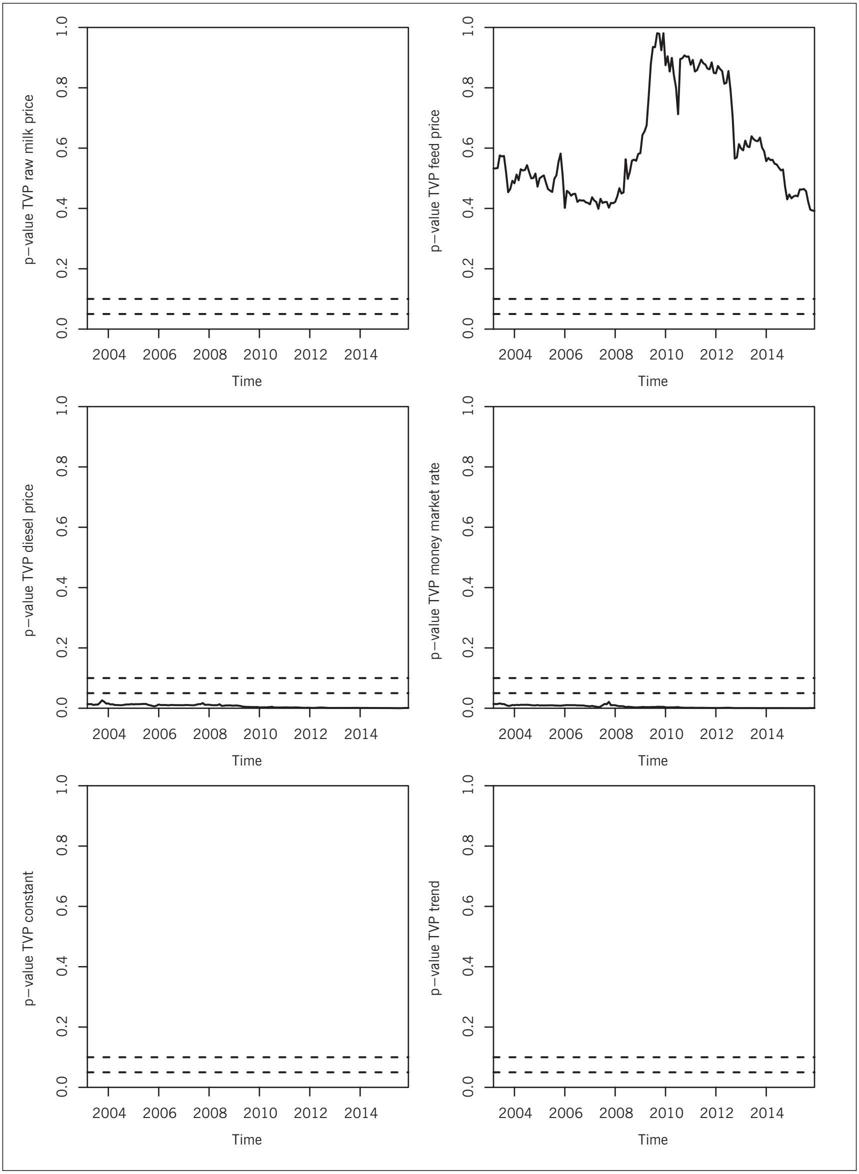
Source: own elaboration.

Figure (A3): P-values of time-varying parameters of FPE coint. vector of model with 12 lags and endogenous non-material input variables (dotted: p-value of 0.05 and 0.1).



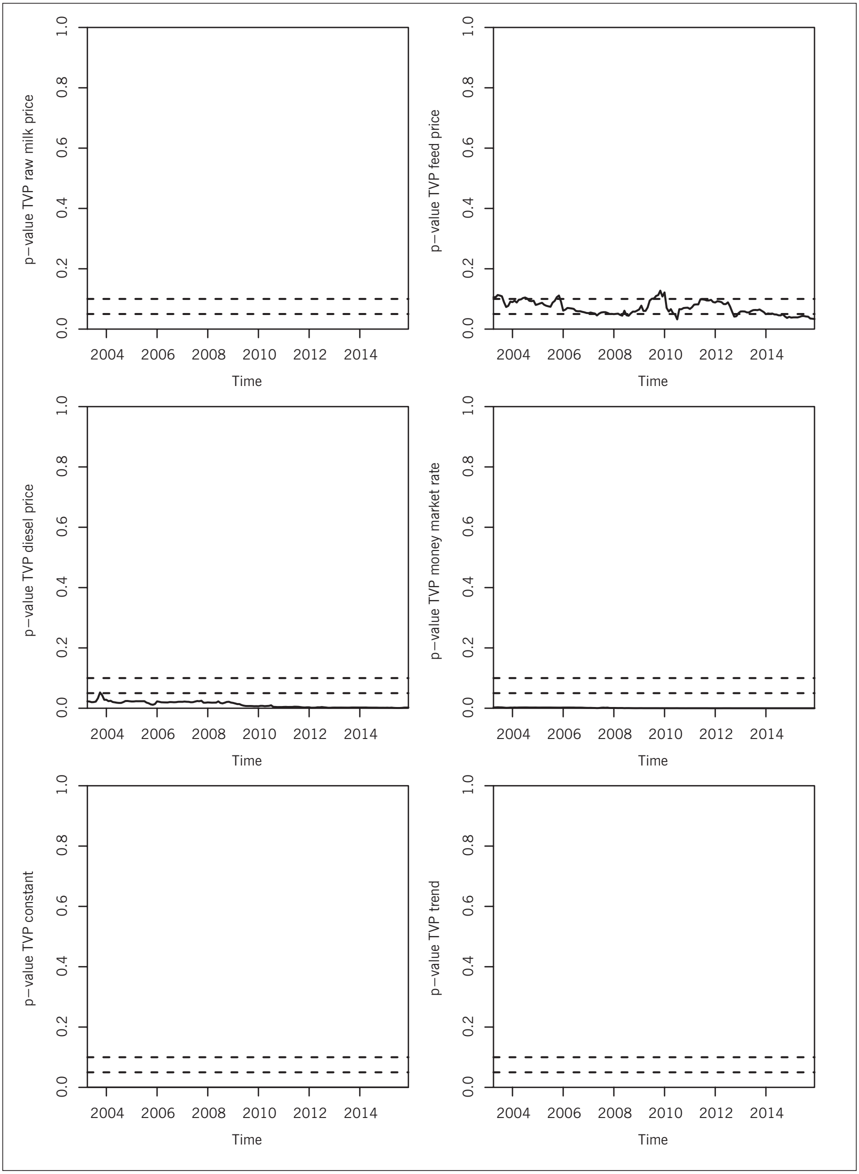
Source: own elaboration.

Figure (A4): P-values of time-varying parameters of FPE coint. vector of model with 1 lag and weakly exogenous non-material input variables (dotted: p-value of 0.05 and 0.1).



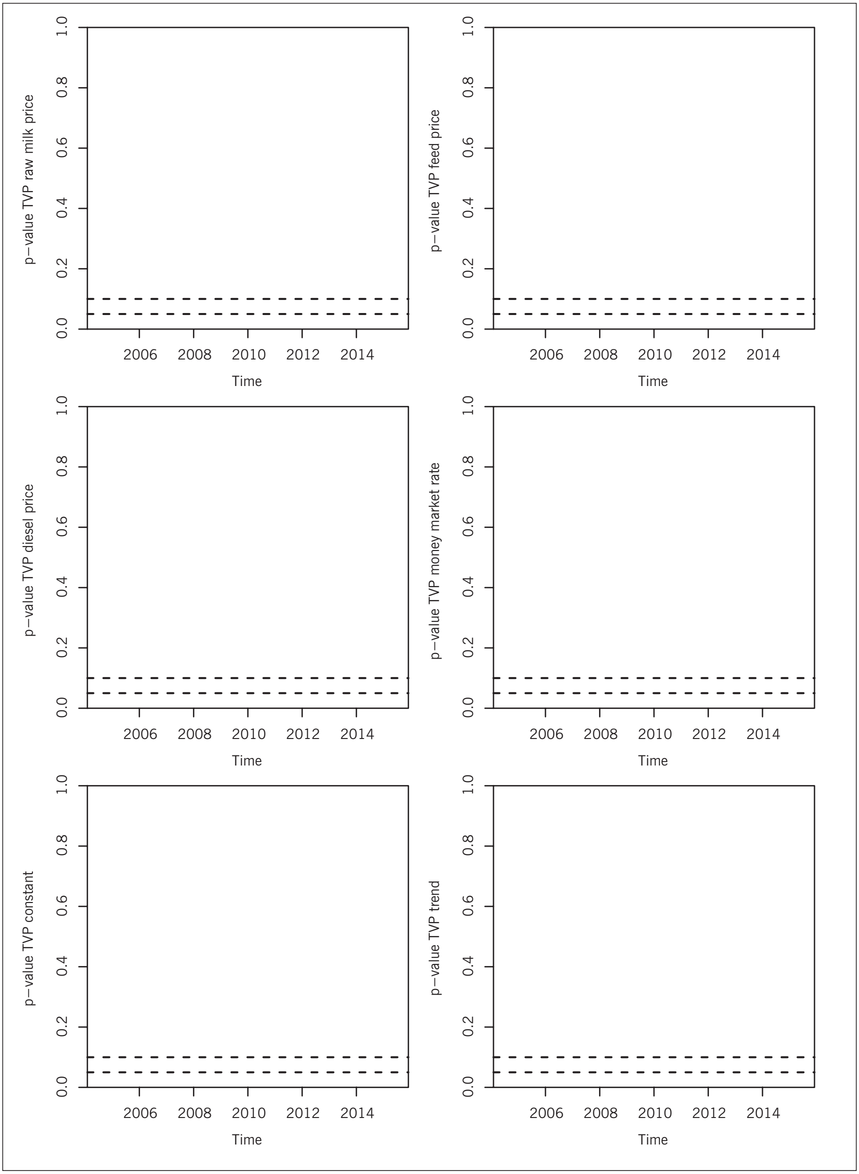
Source: own elaboration.

Figure (A5): P-values of time-varying parameters of FPE coint. vector of model with 2 lags and weakly exogenous non-material input variables (dotted: p-value of 0.05 and 0.1).



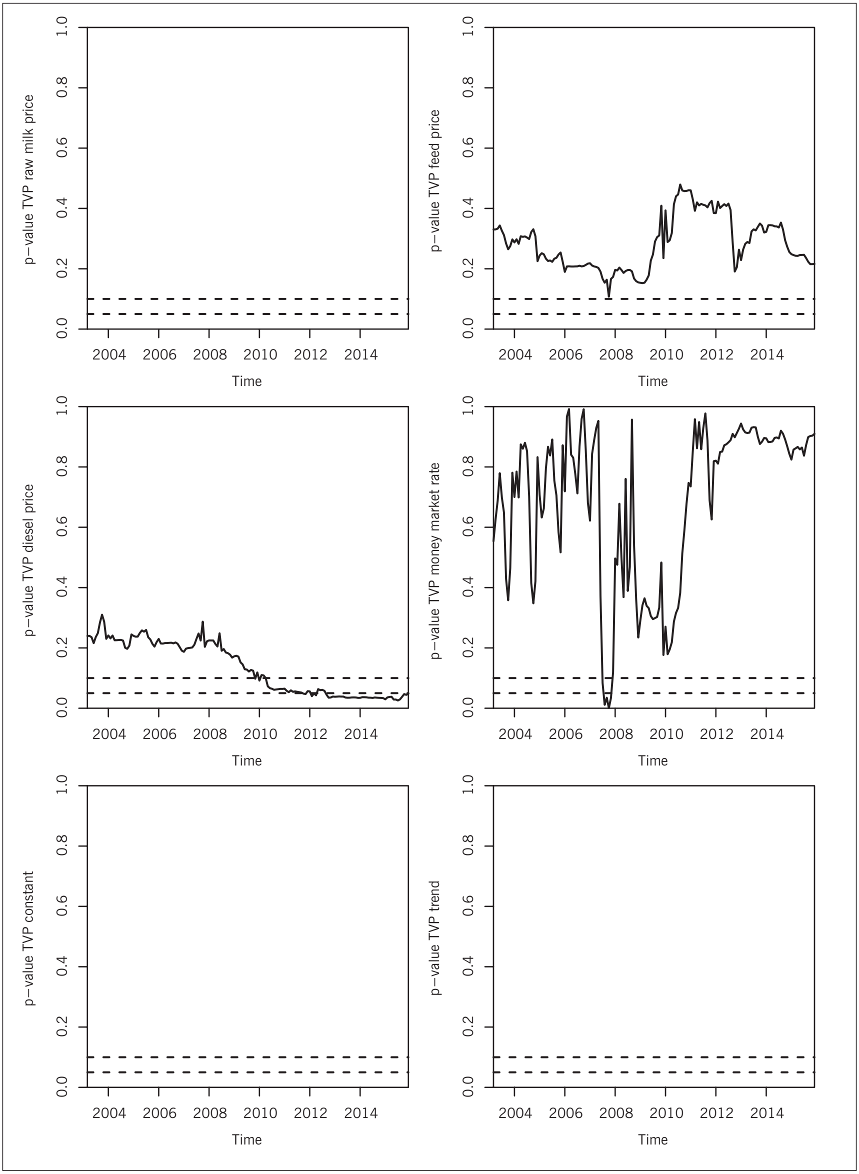
Source: own elaboration.

Figure (A6): P-values of time-varying parameters of FPE coint. vector of model with 12 lags and weakly exogenous non-material input variables (dotted: p-value of 0.05 and 0.1).



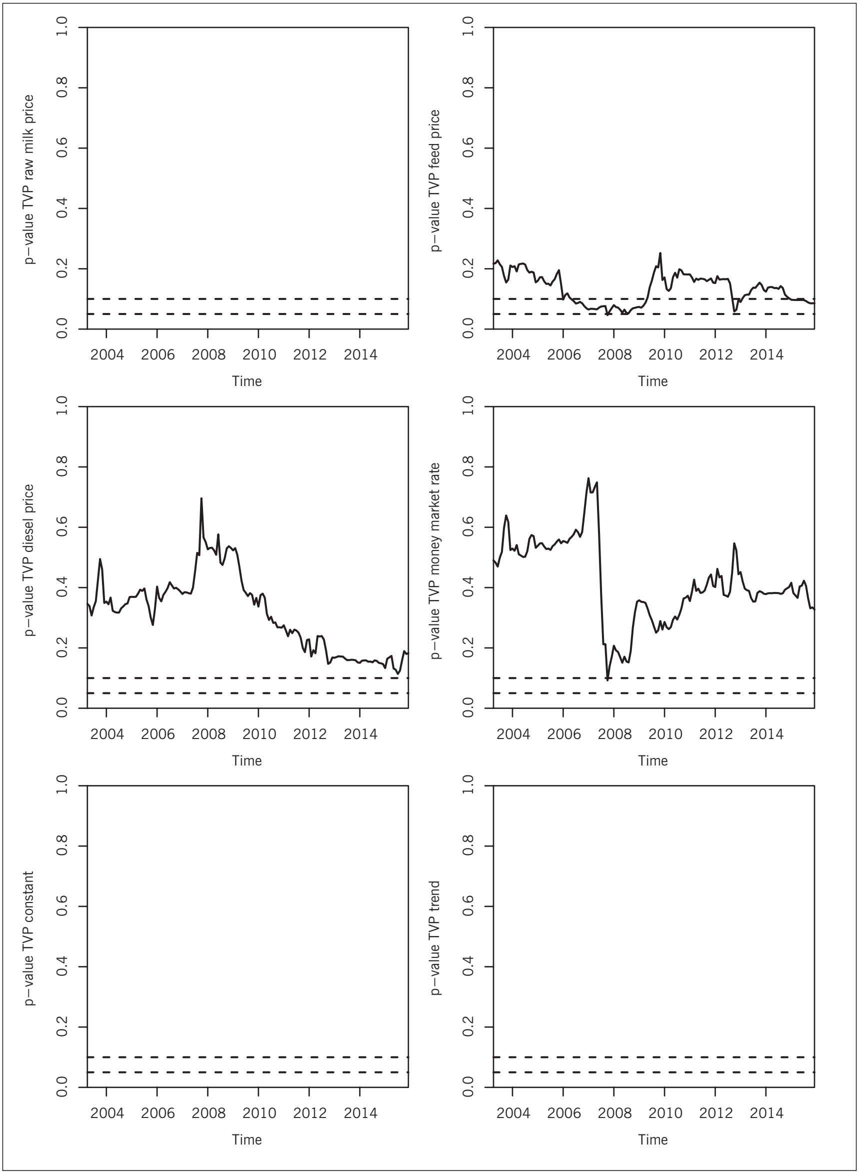
Source: own elaboration.

Figure (A7): P-values of time-varying parameters of FPE coint. vector of model with 1 lag and exogenous non-material input variables (dotted: p-value of 0.05 and 0.1).



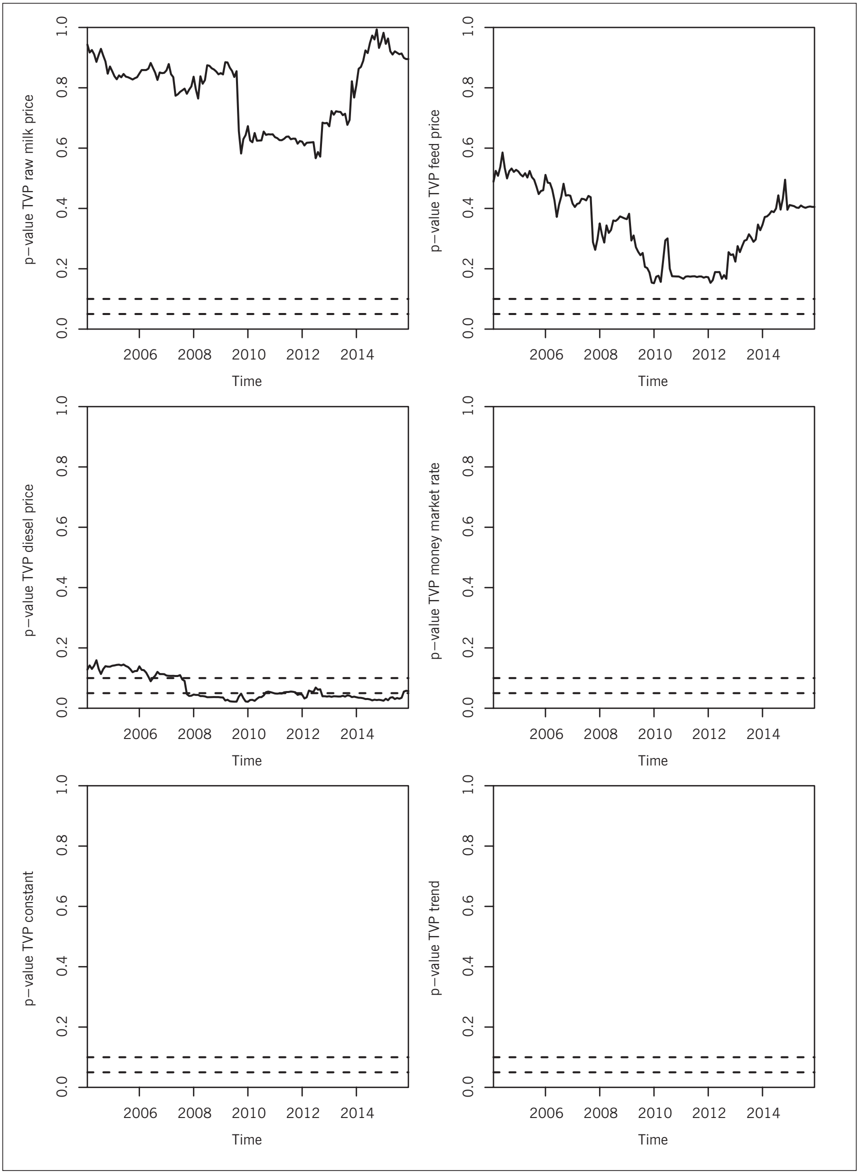
Source: own elaboration.

Figure (A8): P-values of time-varying parameters of FPE coint. vector of model with 2 lags and exogenous non-material input variables (dotted: p-value of 0.05 and 0.1).



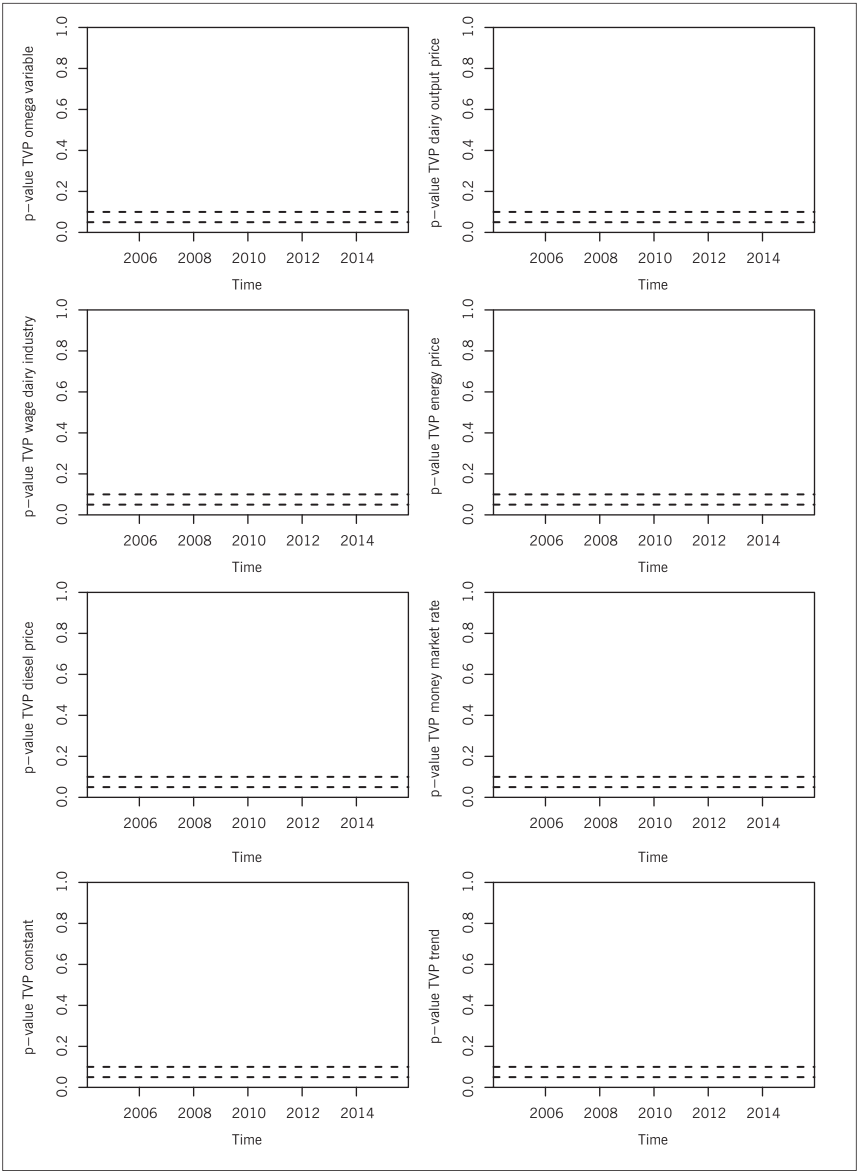
Source: own elaboration.

Figure (A9): P-values of time-varying parameters of FPE coint. vector of model with 12 lags and exogenous non-material input variables (dotted: p-value of 0.05 and 0.1).



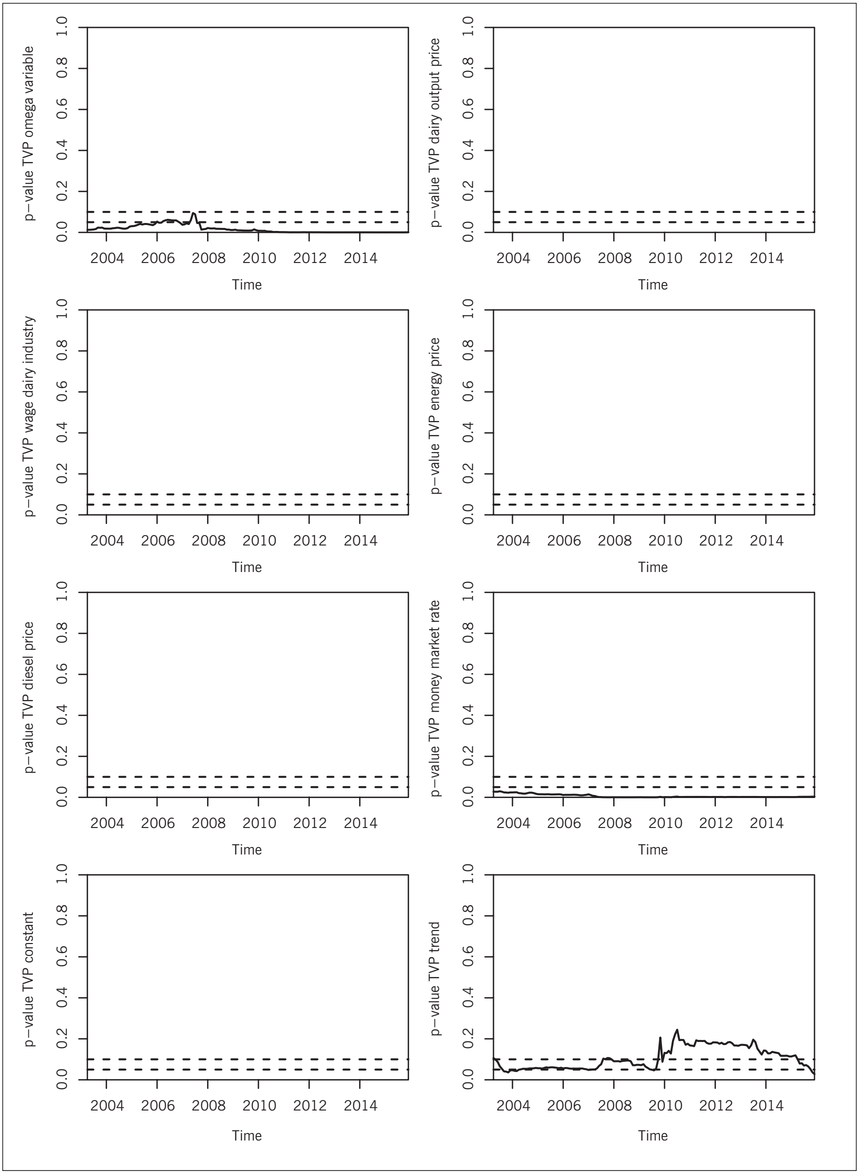
Source: own elaboration.

Figure (A10): P-values of time-varying parameters of PRE coint. vector of model with 12 lags and exogenous non-material input variables (dotted: p-value of 0.05 and 0.1).



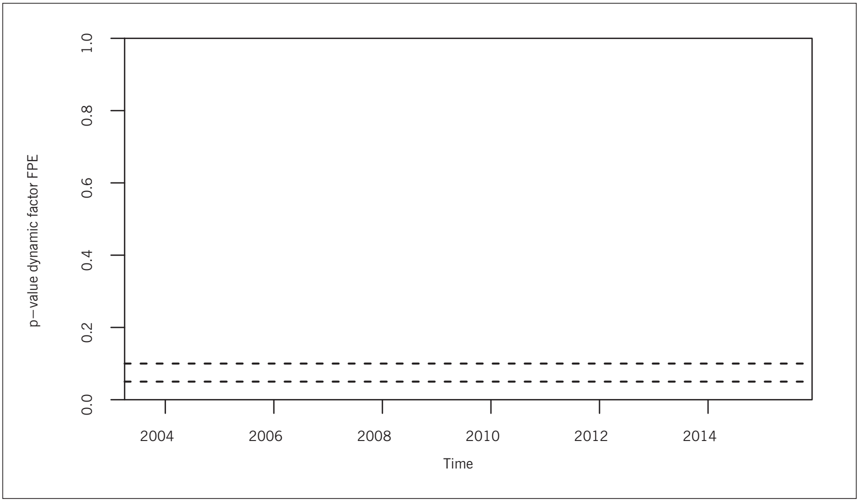
Source: own elaboration.

Figure (A11): P-values of time-varying parameter of PRE coint. vector of model with 2 lags and weakly exogenous non-material input variables (dotted: p-value of 0.05 and 0.1).



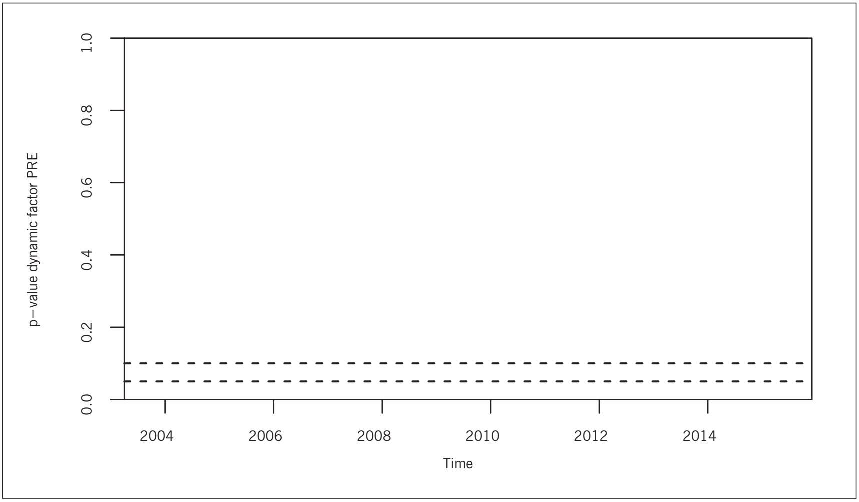
Source: own elaboration.

Figure (A12): P-value of dynamic factor of FPE with 5%- and 10%-significance bands.



Source: own elaboration.

Figure (A13): P-value of dynamic factor of PRE with 5%- and 10%-significance bands.



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