Price transmission and cost pass-through on the German dairy value chain

Abstract. The formation of value chains is among the central issues in the development of the global trade. This study sheds light on the various price relationships and extends the existing literature on vertical and horizontal price transmission by investigating the causal structures on international dairy markets and their relationships with national wholesale and retail prices in Germany. Methodologically, the study is based on the law of one price, which states that identical goods should have identical prices. Price dynamics are modelled with modern panel and time series models that cope with non-stationary variables. The analysis employs store-level retail scanner data and prices for major international skim milk powder and butter markets. The results suggest that world market prices lead German wholesale prices, which pass on to farmers and retailers. Private label retail prices closely follow the price developments of standard milk products on the world markets. Manufacturer brands product prices deviate from world market trends. At the producer level, raw milk is an almost homogeneous product. The price of raw milk strongly correlates with international skim milk powder and butter markets. Processing creates a multitude of different products. At the retail level, we observe thousands of different products and brands; thus, the complexity of price relationships vastly increases towards the end of the value chain, which enables firms to pass on idiosyncratic costs or to generate extra profits.

Keywords: market development; price transmission; cost pass-through; international dairy market; food retail; EU; Germany.

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Introduction

Since the repeal of the milk quota system in the EU, a great public debate started on the functioning of the various stages of the dairy value chain. Producers often complain about low raw milk prices blaming a highly concentrated retailing sector and price sensitive consumers for putting prices under pressure. The issue is also of interest to
the German Antitrust Commission, which has published two reports on competition in retailing and in the dairy processing industry.\(^1\)

We add information on this topic by estimating price relationships in international and national markets and within the German dairy market. In value chains, upward prices are downward input costs; thus, we can estimate cost-pass through rates by the vertical transmission of prices between different stages of the value chain, e.g. between processing and retailing. Cost pass-through rates measure the proportion of a change in input costs that is passed on to the price \([\text{Kim, Cotterill, 2008}]\). Cost pass-through can provide information on the level of competition in markets and the division between producer and consumer surplus.

The dairy chain consists of producers, processors, retailers and consumers. We observe producer, wholesale and retail (consumer) prices on the German market; for international markets, we collect wholesale prices for commonly traded dairy products, such as skim milk powder and butter.

The relationships between all these prices build the basis of the paper. While at the producer level we observe almost homogeneous goods (raw milk) which are distinguished only by the natural fat content or the process of production, e.g. organic or pasture milk, processing makes a variety of different products. In retailing, we observe thousands of different products and brands; thus, the complexity of price relationships is vastly increasing towards the end of the value chain.

Several studies relate to our paper. First, Loy, Glauben and Weiss [2016] apply a threshold error-correction-model for butter and milk for the vertical relationship between wholesale and retail prices for Germany to estimate the short-run price adjustment between wholesale and retail prices. The results prove the appearance of the rockets and feathers phenomenon for the German dairy market. The economic impact of the phenomenon, however, is small and it shows no positive correlation with brands’ markups (market power)\(^2\). Newton [2016] investigates the price relationships between milk products on the world markets and finds that Oceania is a leading market. Oceania affects the EU and the US markets; feedback only appears in some cases.

While all studies focus on the short-run price dynamics, we estimate the long-run cost pass-through equilibrium, which directly relates to the existing theories in this field. We complement our study by several factors accounting for variations in the cost pass-through such as the fat content, the brand, and other quality characteristics. In a similar study Kim and Cotterill [2008] estimate a demand system for cheese products in the US and simulate cost pass-through rates. They also estimate simple cost-price-relationships.

\(^1\) Bundeskartellamt. (2014). Sektoruntersuchung Lebensmitteleinzelhandel, Bonn. P. 10; Bundeskartellamt. (2012). Sektoruntersuchung Milch, Bonn. P. 407.

\(^2\) Several papers find asymmetries in the dairy chain and stick to the traditional interpretation that market power causes the asymmetry [Rostami, Hosseini, Moghaddasi, 2018; Bor, Ismihan, Bayaner, 2014; Reziti, 2014].
The focus in this paper is on the long-term cost pass-through and its variation for different products at different stages of the dairy chain. We start with a brief overview on the theory. Following, we discuss methods and empirical data. Next, we present the key empirical finds for the long-term and short-term cost pass-through. Finally, we summarize and draw some conclusions on opportunities presented by the variation in the cost pass-through of the German dairy value chain.

**Some theoretical aspects of cost pass-through**

The starting point in modelling cost pass-through (CPT) is the comparison of perfect competition and monopoly, e.g. illustrating the relationship between retailers and consumers. Figure 1 captures the main findings for a linear demand setting and constant marginal costs of production and retailing. The main marginal costs of a retailer are buying-in prices of the purchased products. Retailers negotiate the input prices with the upstream processing industry.

![Fig. 1. Simple cost pass-through model](image)

The main finding for the comparison between perfect competition and monopoly is a reduced pass-through of cost changes. In the linear demand case under constant marginal costs, pass-through decreases by 50% in the monopoly case compared to perfect competition. However, non-linear demand and/or increasing marginal costs can change this outcome considerably (see [Bulow, Pfleiderer, 1983; Weyl, Fabinger, 2013])².

The German Antitrust Commission assesses the monopolistic or oligopolistic retail market power over the consumers as limited, except in some specific regions and competitive settings. It is therefore more likely that the highly concentrated retail sector uses its market power in the process of negotiating purchasing prices with the upstream processing industries. Retailers pass on the gains of these negotiations to compete for the price sensitive consumers. Therefore, the traditional idea of executing market power by

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¹ Source: own representation.

² In our application, changing marginal costs are not relevant as we employ wholesale prices instead of direct costs of the dairy and/or the retailing industry.
cutting volumes to lowering buying-in prices does not mimic the real world picture. If retailers pass on price reductions to the consumer, they cannot cut down volumes unless they limit their sales, which they do not. Instead, retailers negotiate volumes and prices with the processing industry. For the extreme case of perfect unilateral market power on the retailer side, these retailers would capture the entire profit of the upstream processing industry and demand a similar volume as under perfect competition (Figure 2). If retailers pass on their gains, then the market volume might even be higher than under perfect competition. Thus, the model in Figure 2 presents no equilibrium; however, it demonstrates the basic idea.

If we use purchasing prices as cost indicators, the CPT under perfect competition is still one to one as long as the other retailing marginal costs are constant. With market power, the cost pass-through can now be above or below the competitive benchmark depending on the level of market power, the functional forms of demand, and the marginal costs of the processing industry and the retailer(s).

So far, we assumed common marginal costs for retailers and the processing industry and exclusively focused on the impact of common cost shocks on CPT. Retailers and processors, however, may face firm-specific or idiosyncratic costs. CPT of idiosyncratic (firm-specific) cost changes is different to common cost changes. Under perfect or Bertrand competition, the processing industry cannot pass on idiosyncratic cost changes; for perfect market power, however, both costs have the same effect on the CPT. In between, cost pass-through increases from zero (competition) to 0.5 (monopoly) under a linear demand setting and product differentiation [Zimmerman, Carlson, 2010; Bittmann, Loy, Anders, 2020].

Another issue in food retailing is the impact of brands on CPT. A main feature is the difference between private labels (retailer brands) and national brands (manufacturer brands). Private labels make about 50 to 75% of the product volume sold in German food retailing. Private labels are some form of vertical integration, which

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1 Source: own representation.
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may lead to a higher CPT because the impact of double marginalization no longer applies [Walters et al., 2014, p. 160; Durevall, 2018, p. 505]. Further, retailers often use private labels to signalize a low-price image by employing an EDLP (everyday low price) strategy.

Retailers are multiproduct firms, which consider the substitutional and complementary relationships between products in their pricing strategy. Cost changes in one product may have an impact on other products in the category. Price changes of other products to a positive cost shock can even be negative for substitutes [Simon, Fassnacht, 2009, p. 288ff]. In this paper, we focus on common cost changes.

Although most papers estimate the speed of the dynamic cost pass-through processes, there is no theoretical prediction but Borenstein and Shepard [2002]. According to Borenstein and Shepard [2002], the speed of the CPT process decreases with market power.

German food retailers frequently use price promotions to attract customers. Price promotions are per definition independent of cost changes [Hosken, Reifen, 2004a]. However, due to their relevance for the overall movement of prices, they may bias the identification of the CPT processes. To test the impact of sales, we present estimations with and without promotional sales1.

The following hypotheses derive from the discussion above:

\( H1 \): Prices are lower and CPT is closer to perfect competition for private labels compared with manufacturer brands.

\( H2 \): Prices and CPT change with the strength of the (manufacturer) brand.

\( H3 \): Prices on world markets determine costs in the German (EU) dairy chain, affecting both farmers and retailers.

Research data

For the analysis, prices along the milk value chain in Germany and international prices for dairy products are collected. We use the average dairies’ sales prices of drinking milk or the wholesale prices for butter and skimmed milk powder (SMP) and data for international market prices for butter and skimmed milk powder. Information on currency exchanges are obtained to convert market prices from US dollar to euro. Finally, we also use detailed retail scanner price data.

The origin of the data can be found in Appendix. Average prices for skimmed milk powder and butter are available for the European Union, Germany and the United States at weekly frequency. Price series for Oceania are observed biweekly. The price series for the Oceania and US markets are converted from dollars per pound to euros per kilogram. German raw milk prices and wholesale prices for drinking milk are available at monthly frequency. German prices for butter raw milk prices and drinking milk are available weekly.

1 For the identification and the relevance of price promotions, see [Holzer, Bittmann, 2019].
The length of the time series varies according to the source of the data. To minimize the number of missing data points, we choose a time window from 2010 to 2018. Table 1 shows the descriptive statistics of price series.

Table 1. Descriptive statistics for international prices of SMP and butter

| Variables | Mean  | St-Dev. | Min   | Max  |
|-----------|-------|---------|-------|------|
| **Butter** |       |         |       |      |
| EU        | 3.710 | 0.853   | 2.497 | 6.551|
| Germany   | 3.823 | 0.959   | 2.260 | 6.990|
| Oceania   | 3.257 | 0.790   | 2.176 | 5.424|
| US        | 3.510 | 0.827   | 2.047 | 6.022|
| **SMP**   |       |         |       |      |
| EU        | 2.190 | 0.510   | 1.313 | 3.311|
| Germany   | 2.209 | 0.530   | 1.270 | 3.335|
| Oceania   | 2.324 | 0.606   | 1.381 | 4.334|
| US        | 2.149 | 0.561   | 1.170 | 3.411|

Source: own representation. Prices for skimmed milk powder and butter are shown in euro per kg.

At the retail level, drinking milk and butter products differ in fat contents. We also use product-specific information such as the brand name, whether the product is organic or conventional, if it is lactose-free or not, and the format of the retail outlet. The sample includes stores from various major key accounts in Germany. For the retail price series, sales and regular prices are identified, so that one price data set with and one without special offers could be created. In general, promotional sales define significant temporary reductions in retail prices, which are unrelated to cost changes. The definition is important as most changes in retail prices are caused by promotional sales, and sales may bias the results of cost pass-through estimates [Hosken, Reiffen, 2004b; Tifaoui, Von Cramon-Taubadel, 2017].

We use two retail data sets, one for drinking milk and the other for butter. The drinking milk price data set comprises 2740 time series (m) with 416 observations each (t = 416, n = m × t = 1,139,840). For butter there are 1823 time series (n = 758,368).

Due to a change in regulation, in 2011, no wholesale prices have been reported since 2012. The number of observations for drinking milk is n = 997,360. In the case of butter, the wholesale quotation of the Süddeutsche Butter- und Käse-Börse e.V. Kempten (SBKB) is used. Table 2 shows the descriptive statistics for the two data sets.

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1. BMEL. (2012). Bundesministerium für Ernährung und Landwirtschaft: Statistische Monatsberichte. Bonn. https://www.bmel-statistik.de/. (in German)
2. SBKB. Süddeutschen Butter- und Käse-Börse e.V. Kempten. https://www.butterkaeseboerse.de/. (in German)
### Table 2. Descriptive statistics for consumer and wholesale prices of drinking milk and butter

| Variable                      | n      | Mean | St-Dev. | Min   | Max   |
|-------------------------------|--------|------|---------|-------|-------|
| **Milk**                      |        |      |         |       |       |
| RPrice (all)                  | 896,532| 0.794| 0.333   | 0.131 | 8.084 |
| RPrice w. Sale (all)          | 896,532| 0.798| 0.333   | 0.131 | 8.084 |
| RPrice (Bio)                  | 70,980 | 1.327| 0.529   | 0.346 | 2.757 |
| RPrice (PL without Bio)       | 320,684| 0.510| 0.077   | 0.131 | 8.084 |
| RPrice (NB without Bio)       | 234,416| 1.001| 0.256   | 0.140 | 5.972 |
| RPrice (Coop. without Bio)    | 270,452| 0.812| 0.154   | 0.234 | 1.579 |
| WPrice                        | 896,532| 0.507| 0.051   | 0.442 | 0.600 |
| **Butter**                    |        |      |         |       |       |
| RPrice (all)                  | 758,368| 1.199| 0.276   | 0.075 | 2.514 |
| RPrice w. Sale (all)          | 758,368| 1.216| 0.273   | 0.075 | 2.514 |
| RPrice (Bio)                  | 3,744  | 1.890| 0.318   | 1.206 | 2.514 |
| RPrice (PL without Bio)       | 37,024 | 0.820| 0.156   | 0.336 | 1.393 |
| RPrice (NB without Bio)       | 304,512| 1.247| 0.221   | 0.112 | 2.327 |
| RPrice (Coop. without Bio)    | 193,440| 1.263| 0.248   | 0.075 | 2.047 |
| WPrice                        | 758,368| 0.798| 0.152   | 0.561 | 1.133 |

Note: WPrice: Dairy retail price; NB: Private dairy; PL: Private label; Bio: Organic product. RPreis: consumer price or retail price. RPreis w. Sale: Consumer price excluding special offer prices.

Source: own calculations with Stata Version 15 based on data obtained from SIG. (2012). SymphonyIRI Group. Retail Scanner Data. Duesseldorf: SymphonyIRI Group GmbH. (in German); BMEL. (various years). Bundesministerium für Ernährung und Landwirtschaft: Statistische Monatsberichte. Bonn. https://www.bmel-statistik.de/. (in German)

The average price for drinking milk across all brands and qualities (fat, organic etc.) is 80 ct per litre\(^1\). The difference between the prices with and without special offers is comparatively low due to the large number of private labels, which rarely show price promotions. One third of the observations are private labels.

Private label milk, which is not organic, yields the lowest average price of 51 ct per litre. This is only 3 ct per litre higher than the average wholesale prices. Compared to private label, national brands are on average about 50 ct per litre more expensive. National brands are for the most part located in Southern Germany. The price of the cooperative brands is in between, with an average retail price of 81 ct per litre, which is roughly 20 % cheaper than the national brands. However, some national brands belong to cooperative dairies due to acquisition (e.g. Landliebe and Bärenmarke approx. 8 % of the observations). Organic brands add a price premium of 33 ct per litre on average.

\(^1\) For butter and milk, some extreme values in the data set seem implausible. Since we work with a large number of observations, these outliers have no influence on the overall results. Robustness checks without these extreme values give very similar results.
For butter, we find fewer organic products and brands. The price structure is similar to that of drinking milk. Private brands are the cheapest, 20 ct per 250 g above the wholesale price, followed by cooperative brands and national brands. However, we find little price difference between cooperatives and private dairies. Again, there are some national brands that have been acquired by cooperative dairies. If we look at national brands adopted by cooperative dairies, the price difference is reversed, i.e. manufacturer brands are then on average 2 ct per 250 g more expensive than cooperative brands.

**Model specifications and estimation procedures**

Granger causality tests are used to determine the relationships between world market prices and the effects of these prices on the German value chain [Granger, 1969]. Granger causality can be tested by estimating a vector autoregressive (VAR) model. To account for non-stationarity of the price series, we use a test proposed by Toda and Yamamoto [1995] (see also [Toda, Phillips, 1994; Dolado, Lütkepohl, 1996; Zapata, Rambaldi, 1997]). Toda and Yamamoto [1995] propose to determine the order of integration of the time series first. The time series in the following analysis are stationary after the first differentiation, i.e. they are integrated of order one (I(1)). A well specified VAR model is then estimated. The optimal lag length is determined by using standard information criteria. Serial autocorrelation of residuals is also tested. In case of misspecifications, the lag length is increased. Because time series are integrated of order one, one additional lag is added to each equation of the VAR. These additional lags are not considered in the Wald test for Granger causality, but rather serve as asymptotic correction of the test. To formalize the testing procedure, we consider a Vector Autoregression with L lags,

\[ P_t = a_0 + A_1 P_{t-1} + \ldots + A_L P_{t-L} + u_t. \]  

Let \( P_t = \begin{bmatrix} p_{t1} \\ p_{t2} \end{bmatrix} \) denote a 2×1 vector of price variables, \( u_t = \begin{bmatrix} e_{t1} \\ e_{t2} \end{bmatrix} \) denotes a 2×1 vector of errors, \( a_0 \) is a vector of ones, and \( A_1 \) is a matrix of dimension 2 × 2. \( A_L \) denotes the matrix corresponding to the \( L \)th lag of the price pair. \( P_{t-L} \) denotes the additional surplus lag, which is added to (A1):

\[ P_t = a_0 + A_1 P_{t-1} + \ldots + A_L P_{t-L} + A_{L+1} P_{t-L-1} + u_t. \]  

We write the matrices with typical elements,

\[ \begin{bmatrix} p_{t1} \\ p_{t2} \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} p_{t-1} \\ p_{t-2} \end{bmatrix} + \ldots + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} p_{t-L} \\ p_{t-L-1} \end{bmatrix} + \begin{bmatrix} a_{11}^{L+1} & a_{12}^{L+1} \\ a_{21}^{L+1} & a_{22}^{L+1} \end{bmatrix} \begin{bmatrix} p_{t-L-1} \\ p_{t-L-2} \end{bmatrix} + u_t, \]  

and multiply matrices accordingly to obtain the system of two equations:

\[ p_{t1} = a_{11} p_{t-1} + a_{12} p_{t-2} + \ldots + a_{11}^{L+1} p_{t-L-1} + a_{12}^{L+1} p_{t-L-2} + u_{t1}, \]

\[ p_{t2} = a_{21} p_{t-1} + a_{22} p_{t-2} + \ldots + a_{21}^{L+1} p_{t-L-1} + a_{22}^{L+1} p_{t-L-2} + u_{t2}. \]
\[ p_t^2 = a_2 + a_{21}p_{t-1}^1 + a_{22}p_{t-1}^2 + \ldots + a_{21}p_{t-L}^1 + a_{22}p_{t-L}^2 + a_{21}^+p_{t-L}^1 + a_{22}^+p_{t-L}^2 + u_t^2. \quad (A1.4) \]

For example, in equation (A1.3) the null hypothesis to be tested is that \( p^1 \) has no predictive power on \( p^1 \). The rejection of the null hypothesis implies Granger causality (\( p^2 \rightarrow p^1 \)). In equation (A1.4), the null hypothesis to be tested is that \( p^1 \) has no predictive power on \( p^2 \). If both hypotheses are rejected, we speak of a feedback relationship. Table 3 summarises the hypotheses to be tested.

**Table 3. Overview of hypotheses of Granger causality tests**

| Hypothesis | Description |
|------------|-------------|
| \( H_0 : a_{11}^1 = 0 \land \ldots \land a_{12}^L = 0 \) | \( p^2 \) does not Granger-cause \( p^1 \) |
| \( H_1 : a_{11}^1 \neq 0 \lor \ldots \lor a_{12}^L \neq 0 \) | \( p^2 \) does Granger-cause \( p^1 \); \( p^2 \rightarrow p^1 \) |
| \( H_0 : a_{21}^1 = 0 \land \ldots \land a_{22}^L = 0 \) | \( p^1 \) does not Granger-cause \( p^2 \) |
| \( H_1 : a_{21}^1 \neq 0 \lor \ldots \lor a_{22}^L \neq 0 \) | \( p^1 \) does Granger-cause \( p^2 \); \( p^1 \rightarrow p^2 \) |
| Reject both \( H_0 \) | \( p^1 \leftrightarrow p^2 \) |

Source: own representation.

As mentioned, the additional surplus lags \((a_{L+1}^1)\) are not considered in the Wald test for Granger causality. The Johanssen procedure is used to test for cointegration [Johansen, 1991]. We rewrite the system in (A1) as a restricted VAR,

\[ dP_t = a_0 + \Pi P_{t-1} + \sum_{j=1}^{L-1} \Gamma_j dP_{t-j} + u_t, \quad (A2) \]

where \( \Pi = A_L - \cdots - A_1 - I \) and \( \Gamma_j = -\sum_{q=j+1}^{L} A_q \). \( I \) denote the identity matrix. \( dP_t \) denotes the first differenced price vector. The standard procedure for testing cointegration is to investigate if there is a level relationship in (A2), either with a trace or with an eigenvalue test. We distinguish the following cases: (1) \( \text{rank} (\Pi) = 0 \) : Both variables are non-stationary and not co-integrated; (2) \( \text{rank} (\Pi) = 1 \) : Both variables are non-stationary and co-integrated; (3) \( \text{rank} (\Pi) = 2 \) : Both variables are stationary.

In case 2, \( p^1 \) and \( p^2 \) are co-integrated and the VAR can be represented as a vector error correction model [Engle, Granger, 1987]:

\[ dP_t = a_0 + \alpha \beta' P_{t-1} + \sum_{j=1}^{L-1} \Gamma_j dP_{t-j} + u_t. \quad (A3) \]

We define \( ECT_{t-1} = \beta' P_{t-1} \) as deviation from long-run equilibrium, \( \alpha = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} \) as the vector of speed of adjustment and \( \beta = \begin{bmatrix} 1 \\ -\beta_1 \end{bmatrix} \) as the cointegration vector. Substituting \( ECT_{t-1} \) into (A3) gives

\[ dP_t = a_0 + \alpha ECT_{t-1} + \sum_{j=1}^{L-1} \Gamma_j dP_{t-j} + u_t. \quad (A4) \]

The Vector Error Correction Model (VECM) can be used to test whether deviations from long-run equilibrium are corrected by both or only one of the price processes. If two time series are cointegrated, then Granger causality also exists at least in one direction. This validates the Granger causality tests. Table 4 summarizes the hypotheses to be tested.
Table 4. **Overview of hypotheses of weak exogeneity**

| Hypothesis | Description |
|------------|-------------|
| $\alpha_1 = 0 \land \alpha_2 = 0$ | There is no error correction |
| $\alpha_1 = 0 \land \alpha_2 \neq 0$ | $p^1$ is weakly exogeneous; $p^1 \rightarrow p^2$ |
| $\alpha_1 \neq 0 \land \alpha_2 = 0$ | $p^2$ is weakly exogeneous; $p^2 \rightarrow p^1$ |
| $\alpha_1 \neq 0 \land \alpha_2 \neq 0$ | $p^1 \leftrightarrow p^2$ |

Source: own representation.

For example, if a disequilibrium is only corrected by $p^1$ and not by $p^2$, then $p^2$ is weakly exogenous with respect to $p^1$. Both Granger causality and the test for weak exogeneity can thus be used to uncover causal structures across markets.

Reduced time series econometric models are commonly used to estimate the relationships between prices at the different stages of the value chain [Richards, Gómez, Lee, 2014; Loy, Glauben, Weiss, 2016]. Since a large number of observations are available for the same brands or products in the different shops (retail panel), panel-based models and methods are employed. In a first step, the long-term relationships between the price series are estimated. We rewrite the cointegrating vector ECT and add control variables to the model to consider the price level differences in the panel time series. In the following, the random effects model for drinking milk is explained in detail:

$$p_{it}^R = \beta_0 + \beta_1 p_{t}^W + \beta_2 Bio_i + \beta_3 Bio_i p_{t}^W + \cdots + v_i + ECT_{it}. \quad (B1)$$

The consumer price is the dependent variable ($p_{it}^R$), which does not only vary over time, but also over the cross section. The same product time series may appear multiple times in the dataset, because it is sold at different locations in varying store formats. The central variable on the right-hand side of the equation is the wholesale price ($p_{t}^W$), which is used as a cost indicator (wholesale price of the retailers). Since there is only one wholesale price, this represents the common cost component. Note that this assumption is also justified by the strong correlation of this variable with world market prices. The estimator of this variable indicates how much of a cost change is passed on to consumer prices on average. In the case of perfect competition, it is assumed that the cost change is passed on to consumers one-to-one. Product or brand-specific differences are modelled using dummy variables or interaction terms. Here, the variable that indicates whether the product is an organic product ($Bio_i$) is introduced as an example. Since this variable only varies in the cross-section and not in time, the time indicator $t$ does not exist. The estimator of this variable indicates whether the prices of organic products differ on average from those of conventional products. Since the production of organic products causes higher costs, we would expect a positive coefficient. Whether and to what extent the cost pass-through for organic products differs can be determined using an interaction term between the dummy and the wholesale price ($Bio_i p_{t}^W$). A significantly positive estimator for this term indicates that the cost pass-through is higher for organic products. Finally,
\( \nu_i \) is a random effect, which is assumed to be uncorrelated with the error term, \( e_{it} \), and the other variables on the right-hand side of the equation.

In a second step, a restricted panel error correction model is estimated, which is used to determine the short-term dynamics (speed of adjustment). We assume that shocks are transmitted from wholesale to retail without feedback. As we show later, Granger causality testing supports this assumption. Here, simple panel error correction models are estimated, which additionally consider other variables, some of which have an explanatory character and some of which have a control character in order to account for systematic differences in the panel:

\[
dp_{it}^R = a_0 + \alpha_1 ECT_{i,t-1} + \gamma_1 Bio_i ECT_{i,t-1} + \gamma_2 dp_{i,t}^W + \gamma_3 Bio_i dp_{i,t}^W + \ldots + \nu_i + u_{it}. \tag{B2}
\]

The dependent variable in equation (B2) is the first differenced retail prices. On the right side of equation (B2), the error correction term (ECT) is the central variable. The ECT variable corresponds to the residual from the first stage estimation (equation (B1)). The estimator for the ECT indicates the rate at which deviations from the long-term equilibrium in equation (B1) are reduced. The estimator must lie in the open interval from \(-1\) to \(0\). For example, an estimator of \(-0.5\) indicates that a deviation from equilibrium is reduced by 50% in each period after its occurrence. The closer the estimator is to \(-1\), the faster the adjustment to equilibrium. To determine whether these processes deviate for different products, interaction terms are again included in the model. The interaction with the dummy for the organic products, for example, indicates whether the speed of adjustment to equilibrium for organic products is faster or slower than the adaptation in the reference group.

**Research results**

We begin with testing Granger-causality and weak exogeneity between international skim milk powder prices and butter prices, respectively. The results indicate that butter prices in Oceania Granger-cause prices in the EU, Germany and the US. We find no Granger-causality between the United States and the EU. Price shocks between the US and the EU are, if at all, only indirectly transmitted via Oceania due to possible feedback relationships. The tests for weak exogeneity largely confirm the Granger-causality results. The prices of skim milk powder show the same causal structures for Oceania, Germany, EU and US. However, more often we find feedback relationships. This also holds for the weak exogeneity tests.

To analyze the relationship between producer and wholesale prices, the wholesale prices of butter and SMP are aggregated using technical coefficients of processing. For 1 kg of butter we need to process about 22 litre of raw milk with 4% fat; for 1 kg of SMP it is about 11 litre\(^1\). The Granger-causality tests confirm that the price index determines the

\(^1\) Agra Europe. (2008). Cap Monitor: A Continuously Up-dated Information Service on the Common Agricultural Policy of the European Union. Tunbridge Wells, Kent, UK.
producer prices and not vice versa. This supports the hypothesis that the world market prices for the standard dairy products (butter and SMP) determine the producer price of raw milk in Germany. Thus, the relationship between supply and demand on international markets determine the producer price for the raw milk in Germany. The price index also Granger-causes the German wholesale price for drinking milk, which we use later as input costs for retailers selling drinking milk. The results are robust for different significance levels and different lag lengths.

We also test Granger causality for retail and wholesale prices. Loy, Glauben and Weiss [2016] show for a similar data set that for the majority of cases wholesale prices cause retail prices but not vice versa. We repeat the tests for the extended data set under study and come to similar conclusions. We also apply the panel unit-root test by Hadri [2000], for which the null hypothesis is rejected. The retail price series are integrated of order 1. For the panel co-integration test by Westerlund [2007], we obtain that retail and wholesale prices (costs) indicate a linear long-term equilibrium relationship.

Figure 3 summarizes the main findings regarding the price relationship between international skim milk powder markets, butter markets and the national value chain in Germany. Some results may slightly vary with respect to the level of significance, the lag structure, or the functional form.

Table 5 shows estimation results for equation (B1) for drinking milk. The reference group in this estimation is private label milk. The dairy wholesale price is the main independent variable. In addition, there are dummies for organic products, for national brands and for cooperative brands. The fat content of the milk is also considered in the model. For all control variables, interaction terms with the wholesale price are also considered. The dummies for organic milk and private national brands reveal a coefficient of

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1 Source: own representation.
0.4; thus, these brands are 40 ct per litre higher priced than private label milk. Cooperative brands, on the other hand, only indicate a price premium of 10 ct per litre. For the reference group (private labels, not organic) the cost pass-through for milk with 3.6% fat (0.728 + 3.6 × 0.023 = 0.81) is 0.81. The cost pass-through for organic products is 0.23 and for cooperative (private) manufacturer brands 0.39 (0.29) higher than for private labels. The higher price mark-up for private versus cooperative manufacturer brands is mainly due to a high price private dairy in southern Germany.

Table 5. Random effects panel estimates of long-term cost pass-through for milk in 2005–2011

| Variable                        | RPrice (r.s.e.) | RP without sale (r.s.e.) |
|---------------------------------|-----------------|--------------------------|
| WPrice                          | 0.728*** (0.016) | 0.721*** (0.016)         |
| Bio                             | 0.419*** (0.025) | 0.428*** (0.025)         |
| Private National Brand (PNB)    | 0.388*** (0.015) | 0.374*** (0.015)         |
| Cooperative Brand (Coop.)       | 0.094*** (0.009) | 0.081*** (0.009)         |
| Fat in %                        | 0.032*** (0.004) | 0.032*** (0.004)         |
| Bio × WPrice                    | 0.227*** (0.026) | 0.210*** (0.026)         |
| PNB × WPrice                    | 0.287*** (0.017) | 0.323*** (0.017)         |
| Coop. × WPrice                  | 0.393*** (0.013) | 0.424*** (0.013)         |
| Fat % × WPrice                  | 0.023*** (0.006) | 0.022*** (0.006)         |
| Constant                        | 0.025* (0.011)   | 0.030** (0.011)          |
| N                               | 896532 –        | 896532 –                 |
| R2-Within                       | 0.414 –        | 0.456 –                  |
| R2-Between                      | 0.738 –        | 0.741 –                  |
| R2-Overall                      | 0.718 –        | 0.725 –                  |

Note: * p < 0.05, ** p < 0.01, *** p < 0.001; Robust standard errors in brackets (r.s.e.); RPrice: Consumer price; RP without sale: Consumer price without promotional prices.

Source: own calculations with Stata Version 15 based on data obtained from SIG. (2012). SymphonyIRI Group. Retail Scanner Data. Duesseldorf: SymphonyIRI Group GmbH. (in German); BMEL. (various years). Bundesministerium für Ernährung und Landwirtschaft: Statistische Monatsberichte. Bonn. https://www.bmel-statistik.de/. (in German)

Across all products, the fat content of drinking milk averages 2.6%, while the average fat content of private labels is only 2.4%. This explains to some part the small price difference between the wholesale price (3.5% fat) and private labels (Figure 4). To analyze the retail format differences, the long-term cost pass-through of full fat milk is estimated for the different store formats separately. The price level and the CPT for private labels is almost the same across all formats (discounters, supermarkets, hypermarkets). Prices
in discount stores and hypermarkets are slightly lower on average by about 2 ct for private labels. The cost pass-through is 0.8 for all formats; for manufacturer brands, the pass-through is between 1.1 and 1.2 and the prices of these brands in discount stores are about 15 ct lower than in supermarkets and hypermarkets. Figure 4 shows an example of the price-cost relationships for a private label, a cooperative manufacturer brand and a private manufacturer brand.

Fig. 4. Weekly retail and wholesale prices of drinking milk in 2005–2011

In the next step, we estimate the speed of CPT by a panel error-correction model (see Equation B2). The same control variables enter the model as for B1. We find only small differences in the speed of dynamic CPT for the various formats. Private labels adjust to cost changes more quickly and mostly in the same period. Consumer markets react faster; supermarkets show a higher delay compared with discounters.

Table 6 shows the results for the long-term CPT for Butter. The results differ. The long-term CPT is now highest for private labels at about 0.92.

Manufacturer brands and organic products show a lower long-term CPT. The difference is the largest for organic products and the least for cooperative manufacturer brands. The difference in results between milk and butter may be caused by the functional form of the demand. If linear demand would predominate for butter and convex demand for milk, the result matches the theory. On average, the price level of private manufacturer brands is the same as of cooperative brands. Both show significantly higher prices than private labels; organic products are the most expensive. Figure 5 illustrates the relationship for some time series of unsalted full-fat butter for private labels and manufacturer brands. The private label corresponds almost perfectly with the wholesale price and shows a complete CPT. Manufacturer brands are significantly more expensive and CPT appears to be incomplete (less than 1) and lagged.

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1 Source: own calculations with Stata Version 15 based on data obtained from SIG. (2012). SymphonyIRI Group. Retail Scanner Data. Duesseldorf: SymphonyIRI Group GmbH. (in German); BMEL. (2012). Bundesministerium für Ernährung und Landwirtschaft: Statistische Monatsberichte. Bonn. https://www.bmel-statistik.de/. (in German)
Table 6. Panel estimate of long-term cost pass-through for butter in 2005–2012

| Variable               | RPrice     | (r.s.e.) | RP without sale | (r.s.e.) |
|------------------------|------------|----------|-----------------|----------|
| WPrice                 | 0.613***   | (0.010)  | 0.594***        | (0.011)  |
| Bio                    | 1.095***   | (0.082)  | 1.096***        | (0.087)  |
| National Brand         | 0.591***   | (0.009)  | 0.592***        | (0.009)  |
| Cooperative Brand      | 0.535***   | (0.013)  | 0.552***        | (0.013)  |
| Full-fat butter        | 0.069***   | (0.009)  | 0.073***        | (0.009)  |
| Salted butter          | 0.390***   | (0.018)  | 0.376***        | (0.018)  |
| Bio × WPrice           | –0.335***  | (0.081)  | –0.346***       | (0.082)  |
| NB × WPrice            | –0.201***  | (0.008)  | –0.171***       | (0.008)  |
| Coop. × WPrice         | –0.124***  | (0.012)  | –0.121***       | (0.012)  |
| Full-fat × WPrice       | 0.313***   | (0.008)  | 0.332***        | (0.009)  |
| Salted × WPrice        | –0.230***  | (0.015)  | –0.235***       | (0.015)  |
| Constant               | 0.013      | (0.010)  | 0.010           | (0.010)  |
| N                      | 758368     | –        | 758368          | –        |
| R2-Within               | 0.350      | –        | 0.406           | –        |
| R2-Between             | 0.719      | –        | 0.729           | –        |
| R2-Overall             | 0.564      | –        | 0.604           | –        |

Note: * p < 0.05, ** p < 0.01, *** p < 0.001; robust standard errors in brackets (r.s.e.); RPrice: consumer price. RPrice w. Sale: Consumer price without promotional prices.

Source: own calculations with Stata Version 15 based on data obtained from SIG. (2012). SymphonyIRI Group. Retail Scanner Data. Duesseldorf: SymphonyIRI Group GmbH. (in German); SBKB. (2012). Süddeutschen Butter- und Käse-Börse e.V. Kempten. https://www.butterkaeseboerse.de/. (in German)

Fig. 5. Weekly retail and wholesale prices for butter in 2005–2012

Source: own calculations with Stata Version 15 based on data obtained from SIG. (2012). SymphonyIRI Group. Retail Scanner Data. Duesseldorf: SymphonyIRI Group GmbH. (in German); BMEL. (2012). Bundesministerium für Ernährung und Landwirtschaft: Statistische Monatsberichte. Bonn. https://www.bmel-statistik.de/. (in German)
The short-term CPT for butter is very similar for private labels between butter and drinking milk. Deviations from the long-term equilibrium are reduced more slowly in the case of organic products. There are only minor differences in error correction rates between private labels, cooperative brands and national brands. Although, the contemporary cost adjustment is significantly lower for (cooperative and national) brands and bio products compared to private labels. Again, we find no differences in the long-term CPT between the different formats for private labels. For manufacturer brands, the long-term CPT is lower in the range of 0.6 to 0.7. Discounters and hypermarkets show a slightly higher price transmission compared with supermarkets. The prices on the other hand are slightly lower than at supermarkets.

Loy, Glauben and Weiss [2016] estimate the cost pass-through for milk and butter in Germany considering possible asymmetric adjustments. The results of a threshold panel error correction model show that there are statistically significant asymmetries, which are insignificant in economic terms. Although cost increases are adjusted faster than cost reductions, the resulting widening of margins is relatively small.

The absolute margins show some time effects. Over the period from 2005 to 2011 and 2012 respectively, the margin for private label drinking milk (butter) fell (rose) by 7 (2) ct per litre (ct per 250 g). Manufacturer brands are able to increase their margins over time. In the case of butter, the cooperative brands increase their margins by 10 ct per 250 g; private manufacturer brands increase margins by 8 ct. For organic products, the increase is highest with 9 ct for milk and 17 ct for butter.

Summarizing, the results for private label butter and drinking milk show a low price level and an almost complete and rapid CPT between dairies and retailers, which signalizes almost perfect competition. Manufacturer brands show significantly higher prices, sluggish, and incomplete CPT. Manufacturer brands appear to execute market power resulting in higher margins, at least in the medium term. Monopolistic mark-ups for manufacturer brands co-exist with more competitive private labels; thus, in contrast to traditional market power, the consumer still has the choice to avoid monopolistic power.

**Conclusion**

The empirical estimations of cost pass-through and price transmission for the world and EU markets as well as the German dairy value chain indicate that price response mainly originate on international markets for standard dairy products. Prices of private label brands pass on almost one to one the price shocks on international markets. Due to the validity of contracts between the dairy industry and retailers and between the dairy industry and farmers, retail prices and farm prices show some time lag compared to prices on international markets.

Manufacturer brands product prices can significantly deviate from the price signals from international markets. This suggests some market power over consumers and opens opportunities for additional revenues across the dairy chain. This enables firms to pass
on idiosyncratic costs or to generate extra profits. The invention and introduction of new brands, however, is costly and risky, and to participate from extra profits one needs to own the brand or provide in-exchangeable inputs to its production or marketing. Over the past years, hard discounters have used their market position to put pressure on manufacturer brand prices. All retailers have introduced high quality price labels (second generation) to further erode the price premium of manufacturer brands. However, the development of high-quality brands is the only opportunity to escape the price dictate of international markets. Digital marketing techniques can make it easier for small start-ups to introduce their own brands. Even single farmers are able to design and establish their own brands; however, this requires skills beyond the production of high-quality produce.

Our study shows some limitations, which provide opportunities for future research. The framework of investigating causal relationships between international markets for skim milk powder and butter could be extended by considering time-varying correlations between international markets. Although, many hedonic price analyses suggest a close relationship between product attributes and consumer perceptions, future research could explicitly consider consumer product perceptions and their impact on mark-ups and pass-through.

**Appendix.** Data sources

| Data                              | Source                                      | Web address                                                                 |
|----------------------------------|---------------------------------------------|------------------------------------------------------------------------------|
| European average prices for butter and skimmed milk powder | Milk market observatory. European Commission | https://ec.europa.eu/info/food-farming-fisheries/farming/facts-and-figures/markets/overviews/market-observatories/milk_en |
| German average prices for butter and skimmed milk powder      | Süddeutschen Butter- und Käse-Börse e.V. Kempten | https://www.butterkaeseboerse.de/                                             |
| German raw milk and wholesale prices                          | BMEL                                        | https://www.bmel-statistik.de/archiv/statistischer-monatsbericht/uebersicht-bisheriger-ausgaben/ |
| Butter and skimmed milk powder prices Oceania                | USDA                                        | https://mymarketnews.ams.usda.gov/public_data                                |
| Prices butter and skimmed milk powder United States           | USDA                                        | https://www.ams.usda.gov/market-news/dairy/mnmonthlyarchive                  |
| Exchange Rate                                                  | Federal Reserve US                          | https://www.federalreserve.gov/releases/H10/hist/dat00_eu.htm                |
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