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Vertical price transmission in Swiss dairy and cheese value chains

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Abstract

In Switzerland, there are separated value chains for dairy and cheese products, which differ in terms of industry concentration, value chain governance, and product characteristics. We analyze how milk prices are passed on along these different value chains. Using detailed price data on farm gate, wholesale, export, and retail levels, we apply asymmetric vector autoregressive and vector error correction models to study vertical price transmission in Swiss dairy and cheese chains. Contrary to most existing literature, we find almost no long-run price relationships and no significant asymmetries between the different stages and products and discuss the potential reasons.

Keywords: Price transmission, Value chains, Switzerland, Milk prices

Introduction

Vertical price transmission in milk markets has received considerable research attention in the past decades, as prices are a main link between different market levels and are an important factor for agricultural efficiency (Serra and Goodwin 2003). Also, in Switzerland, there is a long-lasting and vivid public debate about milk prices, especially at the producer level, with strong opinions about "fair" or "unfair" milk prices (e.g., Cornall 2017). Lately, Swiss dairy market organizations and agricultural consultants have given some attention to how more value can be retained by producers (SBV 2013; Reviron et al. 2017). Yet, the relationships between prices at different stages of the dairy and cheese value chains have not yet been analyzed systematically and quantified. Therefore, this study analyzes vertical price transmission in the Swiss milk market.

For other countries, numerous studies have examined the price relationships in different milk and dairy markets. Table 1 provides an overview of existing studies dealing with vertical milk price transmission.[1] More than 60% of these 22 studies focus exclusively on farm gate and retail prices; the remaining also include wholesale or processor levels, but only two studies include the three stages (farm gate, processing/wholesale, and retail) (Jaffry and Grigoryev 2011; Kharin et al. 2017). While the specific focus differs among these studies, the majority finds long-run price transmission elasticities

[1]Studies analyzing multiple products are not included, nor are unpublished studies with unclear results or low numbers of observations and studies published before the year 2000.

Table 1 Literature review of existing vertical milk price transmission studies

Authors	Time period	Method	Region	Level	Products	Frequ.	Coint.	Asymm.
Acosta and Valdés (2014)	1991–2011	Asymm. ECM	Panama	F, W	Milk	Monthly	Yes	Positive
Antonioli et al. (2019)	2001–2015	Asymm. VECM (TAR/MTAR)	Italy	Pr, R	Milk (organic)	Monthly	Yes	No
Antonioli and Santeramo (2017)	2000–2016	Asymm. ECM	Italy	Pr, R	Milk	Monthly	Yes	Positive
Bakucs and Fertő (2008)	1992–2007	Gregory-Hansen cointegration	Hungary	F, R	Milk	Monthly	Yes	Positive
Bakucs et al. (2012)	1995–2007	Asymm. VECM	Poland and Hungary	F, R	Milk	Monthly	Yes	Partly
Bittmann et al. (2017)	2005–2011	Panel four-regime ECM	Germany	W, R	Milk	Weekly	Yes	n/a
Bolotova and Novakovic (2012)	1991–2008	MUM (Houck 1977; Heien 1980)	5 New York State cities	F, R	Milk	Monthly	Yes	Positive
Bor et al. (2014)	2003–2012	Asymm. ECM	Turkey	F, R	Milk	Monthly	Yes	Positive
Capps and Sherwell (2007)	1994–2002	Asymm. ECM	Seven US cities	F, R	Milk	Monthly	Yes	Positive
Chavas and Mehta (2004)	1980–2001	Asymm. ECM	USA	W, R	Butter	Monthly	Yes	Positive
De Oliveira et al. (2015)	2001–2011	VECM/VAR in first differences	Portugal mainland and Azores	Feed, F, R	Milk	Monthly	Partly	n/a
Falkowski (2010)	1995–2006	Asymm. VECM	Poland	F, R	Milk	Monthly	Yes	Positive
Fernández-Amador et al. (2010)	1996–2010	TVECM	Austria	F, R	Milk, butter, cheese	Monthly	Yes	Positive
Jaffry and Grigoryev (2011)	1989[a]–2010	Asymm. ECM	UK	F, W, R	Milk, cheddar	Monthly	Yes	Partly
Kharin (2015)	2002–2014	ADL	Russia	F, R	Milk	Monthly	No	n/a
Kharin et al. (2017)	2010–2016	VECM	Slovak Republic	F, Pr, R	Milk	Monthly	Yes	Partly
Lass (2005)	1982–2001	MUM (Kinnucan and Forker 1987)	Boston, MA; Hartford, CT	F, R	Milk	Monthly	Yes	Positive
Liu et al. (2017)	2006–2011	Asymm. VECM	USA	F, R	Milk	Monthly	Yes	Positive
Loy et al. (2015)	2005–2008	Panel TVECM	Germany	W, R	Milk, butter	Weekly	Yes	Positive
Serra and Goodwin (2003)	1994–2000	Asymm. TVECM	Spain	F, R	14 products	Weekly	Yes	Positive
Stewart and Blayney (2011)	2000–2010	Linear, threshold, and cubic polynomial ECM	USA	F, R	Milk, cheddar	Monthly	Yes	Positive
Zeng and Gould (2016)	2001–2011	Asymm. ECM	16 US cities	F, R	Milk	Monthly	Yes	Partly

ADL autoregressive distributed lags model, *(M)TAR* (momentum) threshold autoregressive model, *MUM* mark-up model, *(T)(V)ECM* (threshold) (vector) error correction model, *VAR* vector autoregressive, *F* farm gate, *Pr* processor, *R* retail, *W* wholesale, *n/a* not tested
[a]Varying starting points from 1989 to 2007, depending on availability. For a more detailed overview on US milk price transmission studies, see US Government Accountability Office (2004, pp. 136–149)

with positive asymmetries in the long- and/or short-run. This implies that price increases are passed on at a greater magnitude/speed than price decreases. Only one study finds no vertical long-run relationship (Kharin 2015); this is for Russian farm and retail milk prices. Also, the findings regarding the direction of price transmission are consistent across most case studies, which find that prices are passed on downstream, that is, either from producer or wholesale to retail prices. This is in line with the concept of mark-up pricing (Tirole 1988). Only Bakucz et al. (2012) find that in Poland, retail price changes cause farm-gate price changes.

Despite the large number of case studies available, we want to add another one for Switzerland for the following reasons. First, highly detailed price data are available. We are able to include four value chain levels: farm gate, wholesale, export, and retail prices. These data are available for a large number of products, including cheese, dairy, and organic products at the retail level and corresponding producer prices, separated by processing use, at the farm-gate level. Hence, we are able to analyze and compare price transmission along different value chains in the dairy, cheese, and organic sector. A second reason is that in Switzerland, those chains are strictly separated and differ in terms of industry concentration, value chain governance, and product characteristics. This allows us to derive insights on the reasons for different magnitude, speed, and (a)symmetry of price transmission.

Framework

The milk sector is of key importance for Swiss agriculture, representing about 25% of the national agricultural production value (SBV 2013). As about 44% of all Swiss farms engage in milk production, the milk price is highly relevant for farm income (SBV 2013).

Structure of the Swiss milk market

In Switzerland, the processing channels for cheese and other dairy products are strictly separated; about 43% of Swiss raw milk is processed into cheese, and the remaining 57% is processed into other, non-cheese dairy products (SMP 2019). Figure 1 illustrates the different stages of the Swiss milk market value chains and the share of the different products.

The farm level is characterized by many small-scale farmers, even though some structural change with decreasing numbers of dairy farms and increasing farm sizes has occurred in the past decades. In 2018, dairy farms had on average 26 cows and produced 169 tons of milk per year (TSM et al. 2019). Yet, there is large heterogeneity on the farm level; farms that supply raw milk to artisanal cheese dairies, especially those under

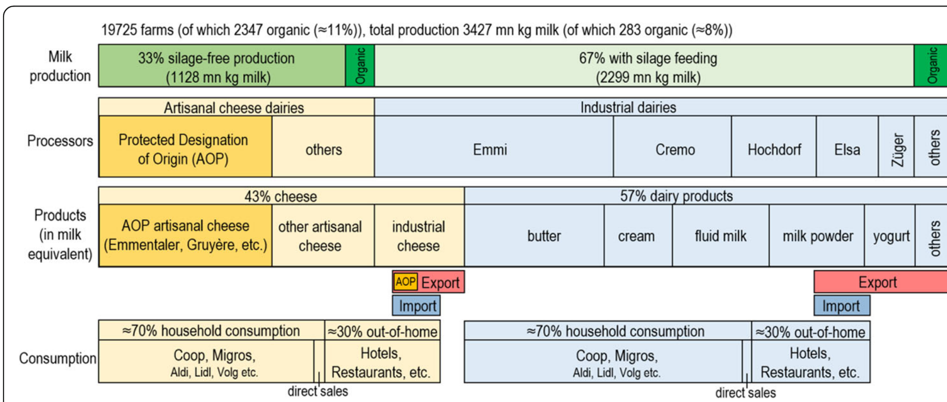

Fig. 1 Schematic representation of the Swiss milk value chains. Source: own representation based on Reviron et al. (2017) (with data for the year 2018, as published by TSM et al. 2019)

protected designation of origin (36% of all dairy farmers), must fulfill certain specifications regarding production region and feeding, for example, not feeding dairy cows silage fodder. Farms that supply milk to industrial dairies produce rather homogeneous raw milk without such restrictions (Flury et al. 2014). Therefore, producer prices depend on the processing used and are generally higher for milk processed into cheese, partly thanks to a targeted subsidy payment for cheese processing.[2] Besides this payment, no other subsidies are coupled to specific processing channels. The most important instrument in terms of transfer size is general direct payments determined by farm size (Meier 2013). Additionally, there are targeted payments for animal welfare measures (see, e.g., Odermatt et al. 2019) and alpine pasturing (Schulz 2015).[3]

The structure, concentration, and governance of the milk processing industry also differ between the "artisanal" cheese and the "industrial" dairy processing systems. In the artisanal cheese production of matured hard and semi-hard cheese, only raw milk from silage-free production is used. There are several hundred regional and artisanal cheese dairies of varying sizes. These dairies usually belong to the local producer association and work as cooperatives, or at least there is a close link between producers, dairies, and maturing companies, as they are jointly organized in brand associations (Reviron et al. 2004). Among those artisanal cheese types, 12 are under the protected designation of origin (*AOP*, *Appellation d'Origine Protegée*) and therefore restricted to specific geographic regions. Emmentaler and Gruyère are the most well known and most produced AOP cheese varieties (TSM et al. 2019). Artisanal processors depend on a reliable supply of raw milk that fulfills the specific regional and quality criteria. Therefore, they need to provide producers with sufficient incentives to stay in milk production and to make the specific investments necessary to deliver the required quality. In contrast, the dairy processing industry is dominated by a few large public companies, mostly with the legal form of a stock corporation. They are supplied by "generic" raw milk producers, who only need to fulfill national quality standards. They produce all kinds of standardized (e.g., butter, milk powder) and specialty dairy products (e.g., deserts, ice cream) and some industrial cheese types made from pasteurized milk, such as mozzarella and cream cheese. Producers deliver their milk either to a producer association or directly to one of the dairies. Either way, after selling to this first milk buyer, producers cannot trace how their milk is processed and marketed.

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[2]The Swiss payment for milk processed into cheese was introduced in 1999 to help farmers and processors dealing with the liberalization of the cheese market with the European Union, enhancing competitiveness with EU producers and stabilizing income. The Swiss government pays this subsidy (initially 0.20 CHF, currently 0.15 CHF per liter) to the cheese dairies who are supposed to pass it on to the milk producers. As the Swiss dairy markets, that is, all non-cheese milk products, are still protected by tariffs and tariff rate quotas, this payment is meant to offset this difference in border protection (for details, see Finger et al. 2017).

[3]For a detailed explanation of the Swiss subsidy system, consult the agricultural report by the Swiss Federal Office for Agriculture (2019). During this study's observation period, there were only minor adjustments in these subsidies. We do not model any of these subsidies in more detail, as they may explain a level difference in prices, but not different degrees of price transmission along the value chains. Still, they are worth considering for an evaluation of farmers' overall situation because these direct payments reduce revenue risk and may cushion price effects (El Benni and Finger 2013). For details on the trade policy in the Swiss dairy sector, and their implications for spatial price transmission, see Hillen and von Cramon-Taubadel (2019).

At the retail stage, concentration is very high, often described as a duopoly, because two retailers (Coop and Migros) account for more than 70% of the market share (EDA 2017). Migros has its own dairy processor (Elsa), while Coop is mainly supplied by Emmi, Switzerland's largest dairy company. In the mid-2000s, two discounters (Aldi and Lidl) entered the Swiss market, but in 2016, they jointly reached only 2.8% of the overall retail market share and 8.3% of the food retail market share (EDA 2017).

Potential influence on vertical price transmission

The different characteristics of the Swiss dairy and cheese processing chains could have an influence on price transmission along the value chains. Our hypothesis is that there is high and symmetric price transmission in artisanal cheese processing, and low and asymmetric price transmission in industrial dairy processing chains.

In the artisanal cheese chain, one would expect high price transmission because of the high price transparency between different stages; most cheese dairies produce one or few specific types of cheese. Hence, producers or cheese processors can trace down the price at which their products are sold at downstream stages and can detect increased margins. The predominant cheese value chain governance structures are hybrid forms classified as "relational networks" and "leadership" (Reviron et al. 2017), with close coordination between the different sellers and buyers. This allows for intensive producer participation in downstream decision-making processes, for instance, regarding marketing channels or quantity control, and, hence implicitly, pricing decisions. However, in contrast to spot markets, where prices coordinate supply and demand (and vice versa), in these hybrid governance forms, there are longer-term relational contracts between buyer and seller (Ménard 2004, 2018). Such contractually fixed prices, or price spans, may prohibit an immediate pass-through of changing costs or prices. Finally, the cheese value chain is characterized by many small cheese dairies and low firm concentration. However, this relationship between concentration, market power, and price transmission behavior is not yet fully understood. Whereas some early literature argued that high industry concentration caused imperfect, asymmetric price transmission (Kinnucan and Forker 1987), this direct relationship has been questioned theoretically (McCorriston et al. 2001; Weldegebriel 2004) and empirically (Peltzman 2000; Aguiar and Santana 2002).

In the industrial dairy processing chain, one would expect imperfect (i.e., low and asymmetric) price transmission because of the following characteristics. There is almost no price transparency along the value chain. Especially for dairy farmers, traceability stops at first milk purchaser, that is, either to a producer organization or directly to an industrial dairy. Loose governance forms (classified as "Trust" according to Reviron et al. 2017) foster this problem of asymmetric information. Producers are not involved in any downstream activities and therefore do not know how their milk will be processed and sold further, and at what price. The milk they deliver could be processed into cheap milk powder for world market export or into premium ice cream. The high concentration at the processor level presumably allows for the execution of market power, but again, the direction and strength of the effect on price transmission are not so clear, and empirical evidence is mixed (e.g., Cutts and Kirsten 2006; Loy et al. 2018).

Table 2 Data description of all used Swiss dairy and cheese prices

Variable	Description	Measure	Time period	Source	Mean	SD
Farm-gate producer price						
P_dai	For production of any non-cheese products	Rp./kg	1/2004–3/2018	FOAG	64.10	7.30
P_che_art	For artisan cheese production, silage-free feeding	Rp./kg	1/2004–3/2018	FOAG	73.29	2.82
P_emm	For Emmentaler AOP cheese production	Rp./kg	1/2004–3/2018	FOAG	66.91	5.03
P_gru	For Gruyère AOP cheese production	Rp./kg	1/2004–3/2018	FOAG	80.75	2.32
P_che_ind	For cheese production by industrial dairies[a]	Rp./kg	1/2004–3/2018	FOAG	65.39	6.87
P_org	Organic raw milk for any processing channel, standards defined by Bio Suisse (2015)	Rp./kg	1/2004–3/2018	FOAG	79.72	4.80
Export price[b]						
E_hard	All hard cheese, TL 0406.9099	CHF/kg	1/2004–3/2018	FCA	9.66	0.69
E_semi	All semi-hard cheese, TL 0406.9091	CHF/kg	1/2004–3/2018	FCA	10.74	1.55
E_emm	Emmentaler cheese (AOP)	CHF/kg	1/2004–5/2017	FCA	8.59	0.83
E_gru	Gruyère cheese (AOP)	CHF/kg	1/2004–5/2017	FCA	12.81	0.74
E_melt	Melted cheese, not grated or powder, TL 0406.30	CHF/kg	1/2004–3/2018	FCA	7.50	0.68
Wholesale price						
W_but	Butter, salted, or unsalted	CHF/kg	1/2004–3/2018	FOAG	10.08	0.70
W_wmp	Whole milk powder, 26% fat, for food preparation	CHF/kg	1/2004–3/2018	FOAG	6.33	0.34
W_smp	Skimmed milk powder, < 1.5% fat, for food preparation	CHF/kg	1/2004–3/2018	FOAG	4.44	0.42
Retail price						
R_milk	Pasteurized whole milk	CHF/l	1/2004–3/2018	FOAG	1.46	0.06
R_but	Butter for cooking ("die butter")	CHF/250 g	1/2004–3/2018	FOAG	2.98	0.15
R_emm	Emmentaler surchoix	CHF/kg	1/2004–3/2018	FOAG	19.03	0.90
R_gru	Gruyère surchoix	CHF/kg	1/2004–3/2018	FOAG	19.89	0.72
R_app	Appenzeller surchoix	CHF/kg	1/2004–3/2018	FOAG	18.96	0.93
R_mozz	Mozzarella	CHF/150 g	1/2004–3/2018	FOAG	1.74	0.27
R_racl	Raclette (block)	CHF/kg	1/2004–3/2018	FOAG	19.59	1.21
R_milk_org	Organic pasteurized whole milk	CHF/l	1/2006–3/2018	FOAG	1.77	0.04
R_but_org	Organic butter ("vorzugsbutter")	CHF/200 g	1/2006–3/2018	FOAG	3.84	0.12
R_emm_org	Organic Emmentaler	CHF/kg	1/2006–3/2018	FOAG	20.20	1.03

Table 2 Data description of all used Swiss dairy and cheese prices *(Continued)*

Variable	Description	Measure	Time period	Source	Mean	SD
R_gru_org	Organic Gruyère	CHF/kg	1/2006–3/2018	FOAG	21.01	0.71
R_mozz_org	Organic mozzarella	CHF/150 g	1/2006–3/2018	FOAG	2.27	0.17

AOP protected designation of origin (Appellation d'Origine Protegée), *CHF* Swiss francs, *FCA* Swiss Federal Customs Administration, *FOAG* Swiss Federal Office for Agriculture, *Rp.* rappen (0.01 CHF), *TL* tariff line

[a]*Industrial cheese* includes all non-artisanal cheese production by large dairies, such as mozzarella and numerous semi-hard, fresh and soft cheese types made from pasteurized milk. In contrast to raw milk for artisan cheese production, raw milk for industrial cheese production is not subject to strict specifications: the use of silage fodder is allowed und there are no geographic origin restrictions. In fact, the requirements are the same as for the production of other dairy products. Hence, this producer price is closely related to the producer price for dairy milk: the farmers deliver their milk to one of the large dairies (either directly or via an intermediary first milk buyer), where it is pooled and processed into various dairy products, including industrially processed cheese. These large dairies (or other first milk buyers, such as producer organizations) report how much milk was processed into cheese. This is well-documented, because with some minor exceptions (small amounts of low-fat cheese), the processors receive the cheese processing aid for these quantities.

[b]Export prices for dairy products (e.g., fluid milk, butter, milk powder) are available, but excluded from the analysis due to high product heterogeneity and very low trading volumes leading to highly volatile export unit values

Data and methods

Data

We used monthly Swiss prices from January 2004 to March 2018, collected at producer (P), wholesale (W), export (E), and retail (R) levels, as far as available (Table 2).

All farm-gate producer prices represent monthly weighted averages of the prices received by the farmers for raw milk.[4] To ensure comparability across different producer prices, prices include only the processing aid for cheese and no other duties or bonuses such as the subsidy for silage-free production. We included six different producer prices. Export prices are included for cheese types with significant export shares: about 50% of Swiss hard and semi-hard cheese production goes into export, for Emmentaler, it is almost 60%, for Gruyère, ca. 40% of the annual production (TSM et al. 2019). Retail prices are national average prices of domestic products[5] based on price surveys at retailers, discounters, and specialty stores weighted by market shares. Figure 2 shows how the included prices are related, and how they can be grouped into different value chains. Those prices connected by an arrow are jointly analyzed regarding price transmission. Figures A1–A5 in the Additional file 1 illustrate the nominal price development over time.

Methodology

Seeking consistency and allowing for better comparability with other case studies (see Table 1), we followed the most widely used methodology for vertical price transmission analysis: pairwise Johansen tests and subsequent vector error correction models

[4]There is a private market quota mechanism in place, with indicative prices for A and B quota milk published on a monthly basis by the private Swiss national milk market organization, IP Lait. However, these prices are non-binding, and effectively paid prices do not follow them strictly (Federal Office for Agriculture 2017). Hence, we only analyze the official price quotes as reported by the Swiss Federal Office for Agriculture.

[5]Milk products labeled as Swiss must contain 100% Swiss milk. Hence, there is no international arbitrage in inputs.

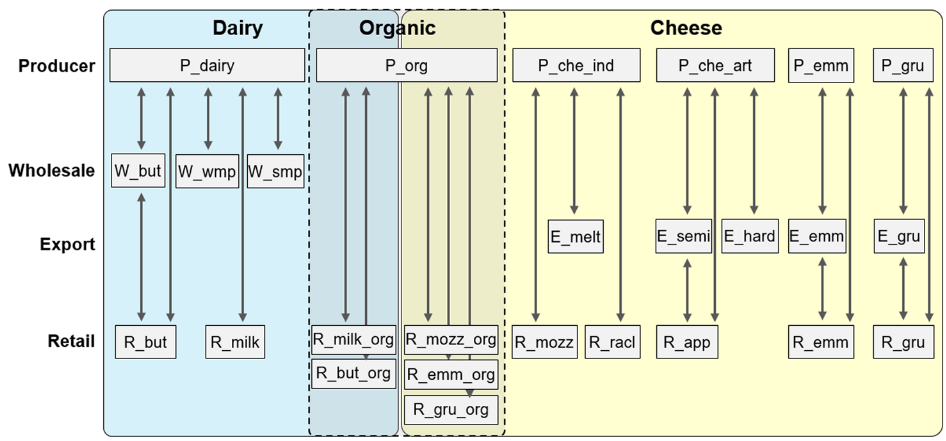

Fig. 2 Relationships between milk, dairy, and cheese prices. Source: own representation

(VECM) for cointegrated prices, or vector autoregressive models (VAR) in first differences for non-cointegrated prices. Additionally, we tested for non-linear threshold cointegration, as well as for short- and long-run asymmetry (for detailed information on asymmetric price transmission models and their specifications, see review papers by Frey and Manera 2007; Meyer and von Cramon-Taubadel 2004).

Unit root and cointegration tests

First, we analyzed the individual price series properties by applying lag-order selection criteria, standard augmented Dickey-Fuller (ADF) unit root, and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) stationarity tests. Second, for each potentially related price pair in one value chain (compare Fig. 2), we tested the null hypothesis of no cointegration against linear cointegration by applying Johansen (1988) trace and eigenvalue tests and accounted for seasonality. However, this approach requires symmetric relationship between the prices. As we were also interested in potential asymmetries, we further tested for threshold cointegration as developed by Balke and Fomby (1997) and Enders and Granger (1998). We followed a model specification by Enders and Siklos (2001) with two-regime threshold cointegration. Like the linear Engle-Granger (1987) two-stage approach, it first models a long-run cointegrating relationship between the two prices:

$$p2_t = \beta_0 + \beta_1 p1_t + \varepsilon_t \qquad (1)$$

In contrast to the linear model, the residuals of this cointegrating relationship can differ between the two regimes by including a Heaviside indicator I_t:

$$\Delta\hat{\varepsilon}_t = \rho_1 I_t \hat{\varepsilon}_{t-1} + \rho_2 (1 - I_t)\hat{\varepsilon}_{t-1} + \sum\nolimits_{i=1}^{k} \phi \Delta\hat{\varepsilon}_{t-i} + \mu_t, \text{ with} \qquad (2)$$

$$I_t = 1 \text{ } if \text{ } \hat{\varepsilon}_{t-1} \geq 0, \text{and 0 otherwise; or} \qquad (3)$$

$$I_t = 1 \text{ } if \text{ } \Delta\hat{\varepsilon}_{t-1} \geq 0, \text{and 0 otherwise} \qquad (4)$$

k is the number of lags, selected by minimizing the Akaike information criterion (AIC). The Heaviside indicator for the threshold can be specified in two different ways. If it depends on the lagged residual in levels (Eq. 3), we get a threshold autoregression (TAR) model. If it depends on changes of the lagged residual (Eq. 4), we get a momentum threshold autoregression (MTAR) model. While the TAR model accounts for asymmetric "deep" movement, the MTAR model is more concerned with asymmetries in "steep" variations and adjustments (for a detailed discussion on the two models, see Enders and Granger 1998; Enders and Siklos 2001; Sun 2011). We specified both TAR and MTAR models and decided based on AIC, which one was more accurate, as recommended by Enders and Siklos (2001). For both cases, we set the threshold value equal to zero because we were interested in comparable asymmetries across product pairs.[6]

These models allow for asymmetric long-run adjustment. To test whether this long-run relationship is significant, we applied F tests with the null of no cointegration ($H_{01}: \rho_1 = \rho_2 = 0$) against the estimated threshold cointegration.[7] Additionally, we tested the null of linear, symmetric cointegration ($H_{02}: \rho_1 = \rho_2$) with a standard F-test.[8]

VECM and VAR models

Depending on the outcome of the linear and threshold cointegration tests, we chose different models to estimate the pairwise price transmission. For linearly cointegrated price pairs, we first estimated symmetric VECMs (Eq. 5).

$$\begin{bmatrix} \Delta p1_t \\ \Delta p2_t \end{bmatrix} = \begin{bmatrix} \theta_{p1} \\ \theta_{p2} \end{bmatrix} + \begin{bmatrix} \alpha_{p1} \\ \alpha_{p2} \end{bmatrix} [ECT_{t-1}] + \sum_{i=1}^{k} \begin{bmatrix} \delta_{p1j} & \rho_{p1j} \\ \delta_{p2j} & \rho_{p2j} \end{bmatrix} \begin{bmatrix} \Delta p1_{t-i} \\ \Delta p2_{t-i} \end{bmatrix} + \begin{bmatrix} \omega_{p1} \\ \omega_{p2} \end{bmatrix} \times [M_t] + \begin{bmatrix} \varepsilon_{p1t} \\ \varepsilon_{p2t} \end{bmatrix} \quad (5)$$

$p1$ and $p2$ represent the two respective prices (in logarithms), Δ denotes changes in first differences, M_t are monthly dummy variables (1–11) to capture seasonality,[9] and lag length k is chosen according to a minimized AIC. The error correction term (ECT) measures how previous periods departed from the long-run equilibrium, including a constant in cointegration ($ECT_{t-1} = p2_{t-1} - \beta_0 - \beta_1 p1_t$). The ECT hence represents the cointegrating vector and is zero in the long-run. Over time, however, positive or negative deviations can occur, as the prices can meander loosely around this equilibrium. Given the construction of the ECT, for an adjustment towards the joint equilibrium zero, we expect α_{p1} to be negative and α_{p2} to be positive. For threshold-integrated price pairs, and to account for asymmetries, we re-specified Eq. 5 into Eq. 6.

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6 Alternatively, there are search methods to determine consistent estimates for the threshold value (Chan 1993).

7 Due to a non-normal test statistical distribution, we used the critical values listed in Enders and Siklos (2001) and extended by Wane et al. (2004).

8 We chose this procedure over the Hansen-Seo test (2002), which also tests the null hypothesis of linear cointegration against the alternative of threshold cointegration, because of its low power in the presence of asymmetric adjustment. Indeed, for our sample, the Hansen-Seo test did not reject the null of linear cointegration for any of the price pairs (see Additional file 1: Table A4).

9 As we work with monthly data, monthly dummies are included to account for seasonal pricing patterns, which are not related to an overall trend, but to seasonal production patterns. *January* serves as the reference category, the remaining 11 months are included as dummy variables, measuring the effect of that respective month relative to the omitted category *January*. We identify some significant seasonal effects, yet, for the sake of readability and conciseness, we do not report all estimates for all products and months in this paper.

$$\begin{bmatrix} \Delta p1_t \\ \Delta p2_t \end{bmatrix} = \begin{bmatrix} \theta_{p1} \\ \theta_{p2} \end{bmatrix} + \begin{bmatrix} \alpha_{p1}^{+} \\ \alpha_{p2}^{+} \end{bmatrix} E_{t-1}^{+} + \begin{bmatrix} \alpha_{p1}^{-} \\ \alpha_{p2}^{-} \end{bmatrix} E_{t-1}^{-} + \sum_{i=1}^{k} \begin{bmatrix} \delta_{p1j}^{+} & \rho_{p1j}^{+} \\ \delta_{p2j}^{+} & \rho_{p2j}^{+} \end{bmatrix} \begin{bmatrix} \Delta p1_{t-i}^{+} \\ \Delta p2_{t-i}^{+} \end{bmatrix} + \sum_{i=1}^{k} \begin{bmatrix} \delta_{p1j}^{-} & \rho_{p1j}^{-} \\ \delta_{p2j}^{-} & \rho_{p2j}^{-} \end{bmatrix} \begin{bmatrix} \Delta p1_{t-i}^{-} \\ \Delta p2_{t-i}^{-} \end{bmatrix} + \begin{bmatrix} \varepsilon_{p1t} \\ \varepsilon_{p2t} \end{bmatrix} \tag{6}$$

The error correction term is based on threshold cointegration (see Eqs. 2–4) and therefore defined slightly differently and denoted as E, instead of ECT. We split it into $E_{t-1}^{+} = I_t\,\hat{\varepsilon}_{t-1}$ and $E_{t-1}^{-} = (1-I_t)\,\hat{\varepsilon}_{t-1}$, with the Heaviside indicator depending on the model specification (TAR or MTAR) and the threshold set equal to zero. To account for asymmetries, we split E into positive and negative values and estimated separate error correcting coefficients α^{+} and α^{-} to see whether the adjustment took place at a different speed for positive and negative deviations. We tested whether this difference was significant for each equation by testing H_{03}: $\alpha_{p1}^{+} = \alpha_{p1}^{-}$ and H_{04}: $\alpha_{p2}^{+} = \alpha_{p2}^{-}$.

Also, autoregressive effects and lagged variables of each price can incorporate asymmetries. Therefore, we tested for a cumulative asymmetric effects of the lagged price values of one variable on the other: H_{05}: $\sum_{i=1}^{k}[\delta_{p1j}^{+}\,\rho_{p1j}^{+}] = \sum_{i=1}^{k}[\delta_{p1j}^{-}\,\rho_{p1j}^{-}]$ for the influence of lagged $p1$ changes on $\Delta p2_t$; and H_{06}: $\sum_{i=1}^{k}[\delta_{p2j}^{+}\,\rho_{p2j}^{+}] = \sum_{i=1}^{k}[\delta_{p2j}^{-}\,\rho_{p2j}^{-}]$ for lagged $p2$ changes on $\Delta p1_t$. One can also test for asymmetric effects of individual price lags (see Frey and Manera 2007; Sun 2011), but because of the large number of price pairs tested, we did not apply such a test here.

For non-cointegrated prices, we set up VAR models in first differences (Eq. 7). In this case, there was no long-run relationship between the prices, implying that there is no long-term price transmission between the analyzed variables. Investigating short-term effects, we allowed for asymmetric short-term effects by splitting the lagged values into positive and negative values (Eq. 8). As in the VECM specification above, we then tested for cumulative asymmetric effects.

$$\begin{bmatrix} \Delta p1_t \\ \Delta p2_t \end{bmatrix} = \begin{bmatrix} \theta_{p1} \\ \theta_{p2} \end{bmatrix} + \sum\nolimits_{i=1}^{k} \begin{bmatrix} \delta_{p1j} & \rho_{p1j} \\ \delta_{p2j} & \rho_{p2j} \end{bmatrix} \begin{bmatrix} \Delta p1_{t-i} \\ \Delta p2_{t-i} \end{bmatrix} + \begin{bmatrix} \omega_{p1} \\ \omega_{p2} \end{bmatrix} [M_t] + \begin{bmatrix} \varepsilon_{p1t} \\ \varepsilon_{p2t} \end{bmatrix} \tag{7}$$

$$\begin{bmatrix} \Delta p1_t \\ \Delta p2_t \end{bmatrix} = \begin{bmatrix} \theta_{p1} \\ \theta_{p2} \end{bmatrix} + \sum\nolimits_{i=1}^{k} \begin{bmatrix} \delta_{p1j}^{+} & \rho_{p1j}^{+} \\ \delta_{p2j}^{+} & \rho_{p2j}^{+} \end{bmatrix} \begin{bmatrix} \Delta p1_{t-i}^{+} \\ \Delta p2_{t-i}^{+} \end{bmatrix} + \sum\nolimits_{i=1}^{k} \begin{bmatrix} \delta_{p1j}^{-} & \rho_{p1j}^{-} \\ \delta_{p2j}^{-} & \rho_{p2j}^{-} \end{bmatrix} \times \begin{bmatrix} \Delta p1_{t-i}^{-} \\ \Delta p2_{t-i}^{-} \end{bmatrix} + \begin{bmatrix} \omega_{p1} \\ \omega_{p2} \end{bmatrix} [M_t] + \begin{bmatrix} \varepsilon_{p1t} \\ \varepsilon_{p2t} \end{bmatrix} \tag{8}$$

For price pairs with weak or nearly significant cointegration, we tried different model specifications to see ex post whether or not there was an economically meaningful long-run (threshold) cointegration and reported the model with the best fit.[10]

[10]For value chains with prices of three stages available, we also tested for joint cointegration and price transmission among all three prices simultaneously, including producer, export or wholesale, and retail price as endogenous variables. As the results were qualitatively the same and parameter comparison and interpretation was easier for price pairs, we only reported pairwise model results here. Results for the overall value chain models are available on request.

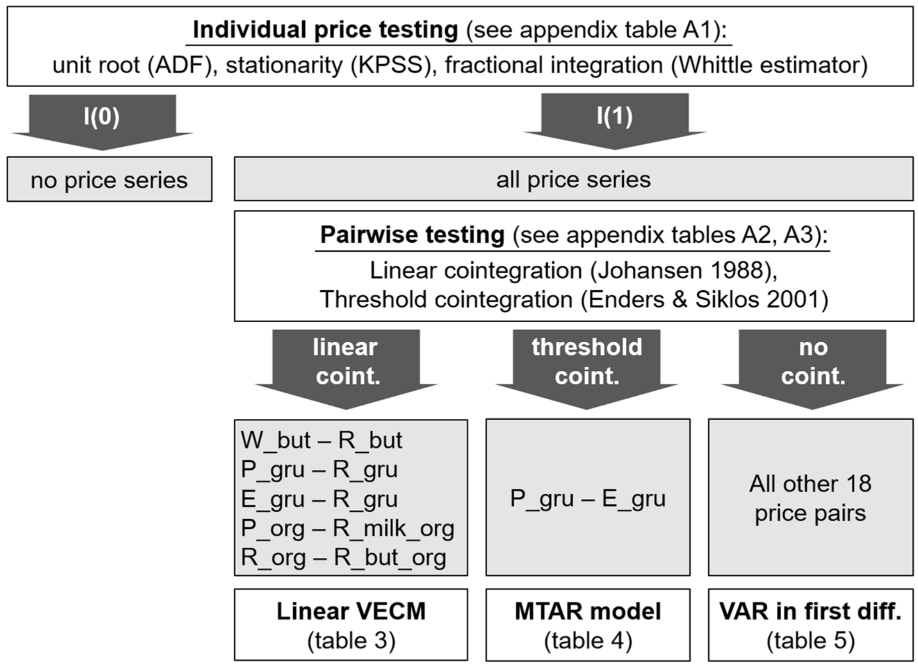

Fig. 3 Schematic summary of unit root and cointegration tests. ADF augmented Dickey-Fuller, KPSS Kwiatkowski-Phillips-Schmidt-Shin, MTAR momentum threshold autoregressive (model), VAR vector autoregressive, VECM vector error correction model. Source: own representation

Results

Unit root and cointegration test results

Before specifying the models, we carefully tested all price series individually and then pairwise on their statistical properties. Figure 3 illustrates the testing procedure and the results schematically, while the detailed test results are documented in Additional file 1: Tables A1–A3.

Unit root and stationarity tests clearly identified most price series as integrated of order one ($I(1)$). For some prices, however, both the null of stationarity (KPSS) and of a unit root (ADF) could not be rejected. For these cases, we checked for fractional integration by applying the Whittle estimator, introduced by Künsch (1987), and tested for consistency in the unit root case by Phillips and Shimotsu (2004). We found that on a 1% significance level, a rank = 1, that is, a unit root, could not be rejected and therefore continued to treat all prices as $I(1)$ processes.

Next, we executed Johansen trace and eigenvalue tests for linear cointegration, including a constant in cointegration, seasonal dummies, and lag length according to AIC. Only for one out of 24 price pairs, the null of no cointegration ($r = 0$) could clearly be rejected at the 1% significance level in both test specifications: for the relationship between butter wholesale and retail prices. For the three Gruyère price pairs and for the relationship between organic producer prices and retail prices of organic milk and butter, the results were not clear. Here, the null of no cointegration was rejected between the 1 and 10% level, depending on the test specification.[11] For these

[11]In both trace and eigenvalue tests, in small samples, the trace tests can be more distorted, whereas the maximum eigenvalue tests can have a lower power (Lütkepohl et al. 2001). In our case, both tests led to very similar conclusions.

cases, we set up VECMs and check ex post whether there is meaningful cointegration. For all other price pairs, the Johansen test found no long-run cointegration.

Threshold cointegration with asymmetric adjustment, as described in "Data and methods," was only found between Gruyère producers and export prices, and is best specified by the MTAR model. Between butter wholesale and retail prices, the test rejected the null of no cointegration (H_{02}: $\rho_1 = \rho_2 = 0$) for both the TAR and MTAR specification, but without significant threshold effects or asymmetric adjustment. Hence, we consider this price pair linearly cointegrated, as found by the Johansen test. For some other price pairs in the MTAR model, the symmetric adjustment hypothesis (H_{02}: $\rho_1 = \rho_2$) was rejected at the 5% level, but the cointegration link itself was not significant.

Vector error correction model results

Table 3 shows the linear VECM specialization for the price pairs considered cointegrated by the Johansen test. In the dairy chain, we estimated a linear price transmission elasticity of 0.79 from butter wholesale to retail prices, with the retail price adjusting to the joint equilibrium (α_{p2} = 0.19), and some weak reaction by the wholesale price (α_{p1} = 0.04), but into an error amplifying, rather than error correcting direction. In the cheese chain, Gruyère producers and export prices both seemed to follow the retail price (α of − 0.16 and − 0.10), implying an upstream price transmission. For organic prices, retail milk and butter adapted to a joint equilibrium with the organic producer price, but also at a rather low speed (milk: 8% error correction per month; butter: 12% error correction per month) and at a negative price transmission elasticity, indicating that prices would move into opposite directions, which was surprising and did not make sense economically. Therefore, we additionally estimated VAR models, assuming

Table 3 Key parameters of linear VECM specification for cointegrated price pairs

Tested variable pair			Coint. vector		Adjustment parameters		Model fit		Asymmetry test	
***p*1**	***p*2**	**Lags**	**PT elast.**	**Const.**	α_{p1}	α_{p2}	**Adj. R^2 *p*1-equ.**	**Adj. R^2 *p*2-equ.**	$\alpha_{p1}^+ = \alpha_{p1}^-$	$\alpha_{p2}^+ = \alpha_{p2}^-$
Dairy chain										
W_but	R_but	4	0.79	0.52	0.04*	0.19***	0.00	0.23	n.s.	n.s.
Cheese chain										
P_gru	R_gru	4	0.35	− 5.44	− 0.16***	0.02 (n.s.)	0.28	0.47	n.s.	n.s.
E_gru	R_gru	4	1.94	− 8.37	− 0.10***	0.00 (n.s.)	0.24	0.51	n.s.	n.s.
Organic chain										
P_org	R_milk_org	2	− 1.48	− 3.53	− 0.03 (n.s.)	0.08***	0.68	0.09	n.s.	n.s.
P_org	R_but_org	2	− 0.89	− 3.17	− 0.04 (n.s.)	0.12***	0.68	0.18	n.s.	n.s.

Model with prices in logarithms, incl. 11 seasonal dummies, lag selection acc. to AIC. Split pos. and neg. ECT not listed here, as none of the differences proved significant (see Additional file 1)
(*n.s.*) not significant at 10% level, *ECT* error correction term
*/**/*** represent 10/5/1% significance level

no meaningful cointegration. For all the linearly cointegrated price pairs, splitting the ECT into positive and negative values and applying *F*-tests revealed that there were no significant asymmetries in adjustment (Additional file 1: Table A5). Therefore, we adhered to the more parsimonious symmetric model.

The threshold cointegration test identified only one price pair to be threshold cointegrated and asymmetrically related, the Gruyère producer and export price, for which the threshold VECM specification is reported in Table 4. The adjustment parameter α of both the producer and export price is only partly significant, with significant adjustment by the producer price and no significant asymmetry in the export price adjustment. This means that producer prices respond faster to price increases than to decreases in export prices. Further, some short-term asymmetries were found; while negative past producer price changes influence the export price ($\Delta p1\_l1.neg$ = 0.35), positive changes do not. Even through the cointegrating relationship and these parameters are statistically significant, the overall model fit is quite weak (Adj. R^2 = 0.11 and 0.15 for both response equations), hinting at weak cointegration and adjustment processes.

Vector autoregressive model results

For the remaining non-cointegrated price pairs, we set up VAR models in first differences. Table 5 summarizes the key parameters. We can see that there are only few cross-effects between the price pairs ($\Delta p1$.lagged influencing $\Delta p2$ and vice versa). Along the dairy chain, past producer price changes positively influence wholesale prices (butter and milk powder), and the organic producer price positively influences the organic butter and mozzarella price. Further, we tested for short-term asymmetries through cumulative asymmetric effects of past $p1$-changes on $\Delta p2_t$ (H_{05}) and of past $p2$-changes on the $\Delta p1_t$ (H_{06}) but could not detect any asymmetries. For none of the price pairs in either direction, the null

Table 4 Asymmetric threshold VECM results for Gruyère producer—export prices

Item	p_1 estimate (E_gru)	p_2 estimate (P_gru)
(Intercept)	0.00	0.01
$\Delta p1$_l1.pos	− 0.03	− 0.26
$\Delta p1$_l1.neg	0.05	0.35*
$\Delta p2$_l1.pos	− 0.16*	− 0.35***
$\Delta p2$_l1.neg	0.04	− 0.31**
α^+	− 0.17***	0.06
α^-	0.03	0.12**
$\alpha^+ = \alpha^-$ (H_{03} and H_{04})	16.26***	0.60
Cumulative $\Delta p1^+$ = cumulative $\Delta p1^-$ (H_{05})	0.12	3.86*
Cumulative $\Delta p2^+$ = cumulative $\Delta p2^-$ (H_{06})	1.28	0.02
Adj. R^2	0.11	0.15

Model specification based on previous threshold cointegration tests: MTAR model with 1 lag and threshold set to zero. Cointegrating vector: $p_2 - 1.13p_1 + 2.41$. To test for cumulative asymmetric effects, the effect on the respective other price matters (H_{05}: column 2, H_{06}: column 1). We changed the ECT signs from the original *R* output, based on package APT, to be consistent with the sign interpretation of the linear VECM output in Table 3 (for the R package documentation, see https://cran.r-project.org/package=apt)

*/**/*** represent 10/5/1% significance level

Table 5 Key parameters of VAR in first difference model for non-cointegrated price pairs

Tested variable pair		p_1-equation				p_2-equation				Model fit	
p_1	p_2	ΔP1.l1	ΔP1.l2	ΔP2.l1	ΔP2.l2	ΔP1.l1	ΔP1.l2	ΔP2.l1	ΔP2.l2	Adj. R^2 p_1-equ.	Adj. R^2 p_2-equ.
Dairy chain											
P_dai	W_but	0.18**	0.18**	− 0.03	− 0.23	0.16***	0.01	0.00	0.10	0.46	0.05
P_dai	W_smp	0.14	0.15*	0.12*	− 0.02	0.12	0.17*	− 0.12	0.05	0.47	0.02
P_dai	W_wmp	0.20**	0.15	− 0.09	0.01	0.10*	0.16***	− 0.06	0.07	0.46	0.14
P_dai	R_milk	0.16*	0.17**	0.08	− 0.12	0.01	0.09*	0.11	0.06	0.46	0.04
P_dai	R_but	0.18**	0.18**	− 0.02	− 0.13**	0.17*	0.09	− 0.33***	− 0.27***	0.47	0.14
Cheese chain											
P_che_ind	R_mozz	− 0.07	0.14	0.03	0.08	0.12	− 0.07	− 0.17**	0.07	0.64	0.04
P_che_ind	R_racl	− 0.05	0.18**	0.10**	0.07	− 0.13	0.21	− 0.70***	− 0.39***	0.65	0.42
P_che_ind	E_melt	− 0.09	0.14*	− 0.01	− 0.02	0.31	0.12	− 0.64***	− 0.41	0.64	0.29
P_che_art	E_hard	0.10	0.04	0.02	0.01	0.00	0.09	− 0.22***	− 0.14*	0.29	0.22
P_che_art	E_semi	0.09	0.04	0.03*	0.00	0.13	0.50	− 0.25***	− 0.19**	0.30	0.27
P_che_art	R_app	0.09	0.03	− 0.05	− 0.05	− 0.03	0.18	− 0.62***	− 0.13	0.29	0.29
E_semi	R_app	− 0.25	− 0.20	0.05	0.08	0.05	0.06	− 0.62***	− 0.11	0.26	0.31
P_emm	E_emm	− 0.01	0.12	0.12*	− 0.02	0.18	0.21*	− 0.12	− 0.01	0.25	0.12
P_emm	R_emm	0.02	0.13	− 0.04	0.00	0.04	− 0.01	− 0.63***	− 0.11	0.23	0.31
E_emm	R_emm	− 0.07	0.03	0.08	0.00	0.17**	0.12	− 0.65***	− 0.14*	0.10	0.34
Organic chain											
P_org	R_milk_org	− 0.17*	0.14	0.06	0.10	0.11*	0.08	− 0.39***	− 0.25***	0.68	0.08
P_org	R_but_org	− 0.15*	0.15*	0.13	− 0.04	0.11*	0.24***	− 0.32***	− 0.16**	0.69	0.20
P_org	R_emm_org	− 0.16*	0.17*	0.04	− 0.01	− 0.18	− 0.05	− 0.47***	− 0.07	0.68	0.21
P_org	R_gru_org	− 0.15*	0.16*	− 0.03	0.02	− 0.07	0.12	− 0.43***	− 0.33***	0.68	0.17
P_org	R_mozz_org	− 0.15*	0.16*	0.12*	0.12*	0.31***	0.19*	− 0.49***	− 0.23***	0.69	0.24

Included variables: logged variables, monthly dummies for raw milk, 2 lags (following AIC), constant as deterministic regressor
*/**/*** represent 10/5/1% significance level; lag selection acc. to AIC

hypothesis of symmetric cumulative lag effects can be rejected at a 5% significance level (see Table A6 in the Additional file 1 for details).

Discussion

Summary and integration of the results

The analysis of price transmission along Swiss dairy and cheese chains revealed only weak price links between prices at different value chain levels, as Fig. 4 illustrates. We found no convincing evidence for long-run vertical price transmission, neither in dairy nor in cheese chains. Even the few price pairs (six out of 24), which seem (threshold) cointegrated, do not allow us to draw clear conclusions; they are partly found in the dairy chain (W_but, R_but), cheese chain (all Gruyère levels), and organic chain (P_org, R_milk/but_org). In all cases, the estimated speed of price transmission is rather low, with less than 20% of the temporary disequilibrium corrected for within 1 month, and rather poor model fit for the response equation of the adjusting price (Adj. R^2 < 0.3). For the case of organic products, this low price transmission may be because consumers are less price sensitive, allowing retailers to adjust at a slow speed, as argued by Antonioli

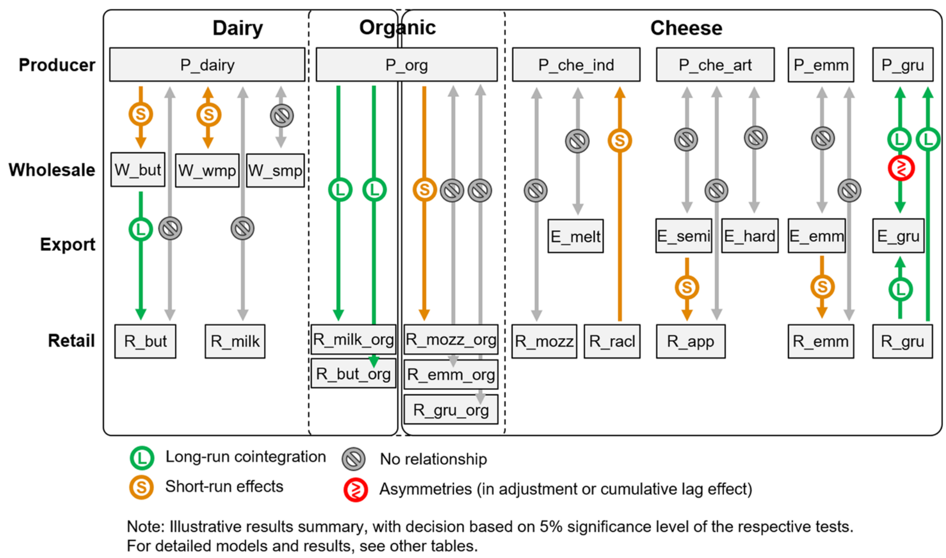

Fig. 4 Illustrative result summary of price transmission along Swiss milk chains

et al. (2019). An asymmetric relationship was only identified between Gruyère producers and export prices, with positive asymmetric adjustment by the producer price. This means that increases in export prices are passed on to producer prices more strongly than decreases in export prices. Both domestically and internationally, Gruyère has been extending market shares and is considered a success story (Federal Office for Agriculture 2017). Our results suggest that producers benefit from rising prices in retail and export markets.

Our results are contrary to previous findings for milk markets in several developed and developing countries, as most of them find long-run asymmetric price transmission (see Table 1). Often, such imperfect or lacking price transmission is interpreted as a consequence of market power exercised by highly concentrated, rent-capturing processors or retailers. However, we could not confirm that price pass-through is less complete in the highly concentrated dairy sector than in artisanal and AOP cheese value chains with less and more closely linked actors. Also higher price transparency between different stages in specialized artisanal cheese processing than for the industrial dairy processing does not lead to systematic differences in vertical price transmission behavior. Hence, our analysis could not confirm our initial hypothesis of faster and more complete price pass-through in cheese than in dairy markets. In the following, we discuss other potential reasons for the weak price transmission links in Swiss milk and cheese chains.

Potential reasons for low or weak price transmission

In the literature, several reasons for weak price transmission besides market power have been identified including the existence of inventory stocks, menu costs to changing prices, or contracts with fixed prices (e.g., Vavra and Goodwin 2005). All of them may apply in our case as in any other case. Additionally, there are factors that apply specifically to our analysis, such as statistical properties of the used price data, and Switzerland-specific factors, which we will discuss next.

Statistical properties of price series

The most straightforward explanation may be our limited data availability. Our sample size of 171 observations per price series is rather small. Especially if error correction is slow, markets spend long periods out of equilibrium, making the equilibrium, i.e., a cointegrating relationship, itself harder to detect. This is even more the case when non-linearities and structural breaks are present, i.e., when there is not one constant long-run relationship. Moreover, we work with monthly price data. Hence, any variation that takes place within a month is averaged away and with it much possible evidence of error correction at higher frequencies.

Further, the statistical properties of the included export and retail price series may bias the results of cointegration and adjustment estimates.

For retail data, there are two major issues influencing price transmission estimation: temporary sales promotions and aggregation across retailers. In food retail, promotional sales are a frequent phenomenon, that is, significant temporary price reductions that are unrelated to cost changes (Hosken and Reiffen 2001). As such promotions are marketing tools and not part of the cost pass-through, they can bias the results of price transmission analysis or at least decrease the efficiency of estimation by adding unexplained price variations. Hence, it has been suggested they be filtered out (Tifaoui and von Cramon-Taubadel 2017). Yet, even then, scanner data studies have shown that the remaining reference prices follow discontinuous jump processes and thus do not allow for cointegration models, which assume continuous adjustment (Chahrour 2011; Loy et al. 2015). The downward spikes in our price series (see Additional file 1, especially Figures A4, A5) and the observable pricing strategies of Swiss retailers hint at such temporary promotions. However, we used aggregate data and cannot clearly identify and remove promotional sales prices. Further, the prices are aggregated across several retailers. As von Cramon-Taubadel et al. (2006) showed, this can lead to miss-specified estimations of the actual price transmission at the individual store level. The Swiss retail price data do not include discount stores, such as Aldi and Lidl, but only the largest retailers. While the discount market share is still rather low (jointly 8.3% in food retail, EDA 2017), they may still convey important price signals to the other players (Ailawadi and Keller 2004).

Also export prices are not necessarily good representatives of the overall price development. One issue is that export prices depend on the quality of the exported products (Hallak 2006). Therefore, we only included export prices for narrow product groups with comparable qualities, such as the AOP cheese brands, Emmentaler and Gruyère, or melted cheese. Still, we observed large short-term variations in export prices, which may depend on the quantities traded, package sizes, and remaining heterogeneity within the product categories, such as different age and ripening processes.

Consequently, for price transmission involving export or retail data, it is not surprising to see such little evidence of cointegration and adjustment. Yet, a visual inspection of the price series (Additional file 1: Figures A1–A5) shows there is no apparent comovement. Hence, it cannot be only due to data issues that we found no links between most of the prices.

Industry structure

In "Framework," we described the structure and characteristics of Swiss dairy and cheese value chains, and how this may influence vertical price transmission. However, we did not find systematical differences by processing use; they do not seem to be the decisive factors. Rather, the general characteristics of the Swiss milk sector may be relevant. According to Bakucs et al. (2014), a fragmented farm structure and high governmental support, as present in Switzerland, can contribute to low, asymmetric price transmission. Moreover, perishability has been identified as another driver of imperfect price transmission (Peltzman 2000; Serra and Goodwin 2003; Santeramo and von Cramon-Taubadel 2016), which might be relevant for highly perishable raw milk, that is, transmission between producer and wholesale or export prices.

At the retail level, the high concentration is frequently blamed for increasing market power and hindering price transmission, as described in "Framework." Additionally, milk products, especially fluid milk, are considered "signaling products" (Dickson and Urbany 1994; Binkley and Connor 1998). These prices are the reference on which consumers evaluate the overall retailer's price level. Therefore, irrespective of market power, retailers may make pricing decisions based on strategic considerations and not based on the own purchase price of a specific good. Sexton and Xia (2018) stressed that pricing strategies are not set up and optimized for just one specific good, but for a larger basket of goods. There is empirical evidence that retail price setting accounts for interactions within and across product categories (Thomassen et al. 2017).

High income and cost level in Switzerland

Switzerland is a very high-income and hence high-cost country, with an overall price level 59% above EU average (Eurostat 2018). Therefore, it may also be that costs of non-commodity input prices are so high that they outweigh the changes in the agricultural input prices. This includes costs directly and indirectly linked to the dairy and cheese value chains, such as labor costs, transport, and rent. Iten et al. (2003) and SECO (2008) showed that these costs are indeed higher in Switzerland than in EU countries. The fact that especially non-tradable goods and services are expensive can be explained by the Balassa-Samuelson effect Balassa (1964).[12] Sax and Weder (2009) showed that this effect also holds for Switzerland. BAK Basel (2017) demonstrated that Swiss food retailers face significantly higher input, infrastructure, and labor costs than their EU neighbors and pass them on to consumers through food prices. For "perfect" milk price transmission along the value chain, we therefore do not expect price transmission elasticities to be unity,

[12] The Balassa-Samuelson effect states that a high productivity in the tradable, relative to the non-tradable sector causes a wage increase in both sectors and, consequently, a price increase for non-tradable goods and services.

but equal to the share of the agricultural input raw milk in the industry's or retailer's cost function (McCorriston et al. 1998), which can be low in Switzerland. Yet, despite a lower numerical price transmission elasticity, we would expect to see a long-run relationship.

Conclusion

Our study analyzed vertical price transmission in the Swiss milk market by examining a total of 24 price pairs in dairy, cheese, and organic value chains. We found almost no evidence of long-run price transmission and no significant asymmetries for most price pairs. This result differs from the majority of studies in other countries, which found significant, asymmetric long-run price transmission, mostly from farm to retail milk prices.

We could not identify systematic differences between different chains. Our initial hypothesis that prices are passed on more fully and quickly in artisanal cheese value chains with high price transparency than in industrialized, highly concentrated dairy chains could not be confirmed. Industry concentration and value chain governance structures do not seem to be the decisive factors for whether or not prices are passed on between different value chain levels. Therefore, we could not clearly identify the reason for the lack of vertical price transmission in Swiss milk markets. Besides data limitations, more general conditions of the Swiss market, such as the high cost levels, a fragmented farm structure, high governmental support, and contractually fixed prices, could hinder price transmission along the value chains. We understand this study as a first attempt to study vertical price transmission in the Swiss milk market. Additional insights could be gained by looking at these prices as a network, allowing for price transmission between different processing lines and products, especially between joint products such as butter and skimmed milk powder (Antanova et al. 2011). An alternative approach would be to examine the effect of supply and demand curvature on price transmission (Xia 2009).

Abbreviations

ADF: Augmented Dickey-Fuller (test); ADL: Autoregressive distributed lags (model); AIC: Akaike information criterion; AOP: Appellation d'Origine Protegée (protected designation of origin); CHF: Swiss francs (currency); ECT: Error correction term; EU: European Union; FCA: (Swiss) Federal Customs Administration; FOAG: (Swiss) Federal Office for Agriculture; KPSS: Kwiatkowski-Phillips-Schmidt-Shin (test); MTAR: Momentum threshold autoregressive (model); MUM: Mark-up model; Rp: Rappen (a hundredth of a Swiss franc); TAR: Threshold autoregressive (model); TL: Tariff line; VAR: Vector autoregressive (model); VECM: Vector error correction model

Supplementary Information

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Additional file 1.

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Author's contributions

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