Received: 8 September 2023 | Accepted: 11 July 2024

DOI: 10.1002/aepp.13467

SUBMITTED ARTICLE

AAEA Agricultural & Applied Economics Association WILEY

Product differentiation, quality, and milk price stability: The case of the Swiss cheese market

Yanbing Wang[1,2] | Simon Hug[2,3] | Judith Irek[1] | Robert Finger[2]

[1]Economic Modelling and Policy Analysis Group, Agroscope, Tänikon, Switzerland

[2]Agricultural Economics and Policy Group, ETH Zürich, Zürich, Switzerland

[3]Syngenta Crop Protection, Stein, Switzerland

Correspondence
Yanbing Wang, Tänikon 1, 8356 Ettenhausen, Switzerland.
Email: yanbing.wang@agroscope.admin.ch

Editor in charge: Alessandro Bonanno

Abstract

We investigate potential linkages between product and quality differentiation in the cheese markets and raw milk producer prices. We analyze the co-movements of producer prices of milk delivered to cheese processing channels with different differentiation strategies, namely industrial, artisanal, and artisanal cheese with geographical indications (GI) in the Swiss dairy market. We find that overall, product and quality differentiation in cheese markets helps milk producers achieve higher and more stable prices. Additional GI protection does not guarantee further enhancement of producer prices. Rather, its effectiveness may depend largely on the strength of GI protection and the governance of producer organizations.

KEYWORDS

cheese markets, geographical indications, market-based risk management, product and quality differentiation, raw milk price

JEL CLASSIFICATION

Q13, Q18

The economic viability and resilience of the dairy industries are indispensable to the agri-food sector. The dairy sector in Europe represents over 12% of total agricultural output (Augère-Granier, 2018), and dairy processing is of key economic significance in the European food sector (e.g., Hirsch et al., 2020). In Europe, dairy industries have seen decreasing raw milk prices and increasing price volatility over time (e.g., Schulte et al., 2018; Thorsøe et al., 2020). Meanwhile, the dairy industries are under pressure to size down production to reduce greenhouse gas emissions and meet climate change targets (Hedenus et al., 2014), which also affects farmers' income. One measure to address these issues is product and quality differentiation. Differentiated products are expected to be less substitutable and to create price premia along the value chain, allowing producers to maintain revenue with lower production volumes. Particularly relevant is differentiation through nonindustrial, artisanal production, which can be further combined with geographical indications (GIs), a labeling system that signals quality by associating the products with their origin. However, little is understood about how raw milk producers can benefit from such product and quality differentiation strategies and what factors are related to their effectiveness.

We provide such analyses here by examining the movements and co-movements of producer prices of raw milk supplied to cheese processing channels that represent a gradient of underlying product and quality differentiation strategies, namely industrial cheese, artisanal cheese in general, and artisanal cheese with GI. Our analyses focus on the Swiss dairy market and the period between January 2010 and January 2022.

Previous literature has documented that milk price risks have become more pronounced in Europe following a series of market liberalization and deregulation measures from the 1990s to 2015 (e.g., Finger & El Benni, 2021; Schulte et al., 2018; Thorsøe et al., 2020). These measures increasingly expose milk prices to shocks from energy and food markets, as well as from international dairy markets through trade. Milk price risks can negatively affect dairy producers' income (El Benni & Finger, 2013), which further leads to a lack of incentives to innovate and invest (Schulte et al., 2018) and affects farm survival (Zimmermann & Heckelei, 2012). Therefore, effective strategies to manage price risks are crucial for the viability of dairy industries. In markets where price risk management tools, such as futures and forwards, are not formally available, product-based strategies are particularly relevant. One set of product-based strategies is product and quality differentiation, which includes differentiation in the production process (e.g., artisanal production), geographically differentiated production, and combinations thereof (Saitone & Sexton, 2010).

Prior literature suggests that product and quality differentiation may benefit milk producers by increasing and stabilizing producer prices. For example, in the French fluid milk sector, organic milk producers obtain higher shares of total margins from sales (Bonnet & Bouamra-Mechemache, 2016). In Switzerland, government payment reductions for milk processed into cheese to raw milk prices are transmitted to a lesser extent to artisanal cheese prices than to industrial cheese prices (Finger et al., 2017). Studying price transmission between Swiss and German dairy product markets, Hillen and von Cramon-Taubadel (2019) argue that a quality differentiation strategy that reduces product substitutability can be more effective in stabilizing milk producer prices against international price pressure than protectionist measures, such as trade restrictions. Specific to GI labeling, the literature shows that GI can enhance producer welfare by collectively defining product quality and restricting supply (e.g., Lence et al., 2007; Moschini et al., 2008). Producers can also benefit from a higher consumer willingness to pay for products with GI labels (Menapace et al., 2011). For wine, Panzone and Simões (2009) show that GIs contribute differently to producer prices, depending on the region. Poetschki et al. (2021) find that GI labeling in olive and wine sectors significantly increases farm income. These findings provide indirect evidence that product and quality differentiation, and GI, in particular, could help producers achieve higher and more stable prices. However, to our knowledge, there is no direct investigation of the co-developments of milk prices across processing channels characterized by different degrees of quality and product differentiation.

Our contribution to the literature is twofold. First, we add empirical evidence of the benefits of product and quality differentiation strategies for raw milk producers, particularly in terms of higher price levels and stability. Rather than focusing on particular sources of price shocks, such as international trade or policy changes, we examine the movements and co-movements of producer prices of raw milk supplied to cheese processing channels that represent different differentiation strategies and, for GI-labeled cheeses, different levels of protection and governance structures of producer organizations. Since raw milk producers face similar exogenous shocks (e.g., climate, policy, and trade) for all types of cheese production, examining co-movements in producer prices provides direct, albeit descriptive, evidence of how the prices of raw milk supplied to each processing channel respond differently to common shocks. Second, our study addresses market-based risk management tools in agriculture—that is, quality and product differentiation—as a strategy to stabilize raw agricultural product prices and protect farmers from price risks. Our findings shed light on the potential of quality and product differentiation as a market-based risk management tool to complement government regulation, and have implications for policies to support and regulate differentiation strategies such as artisanal production and GI labeling. In this regard, our study complements Slade et al. (2019) by taking the perspective of policymakers with an interest in protecting domestic producers of GI-labeled products. By discussing the potential drivers of differentiation strategy success, namely GI protection strength and producer organization governance, our analyses contribute to identifying the optimal combination of differentiation strategies in dairy markets and best practices in GI label management.

Our analyses are based on the prices for raw milk ("milk" hereafter) that is delivered in Swiss cheese markets. The latter are highly heterogeneous, ranging from large-scale industrial cheeses to small-scale artisanal cheeses with strong GI protection. This heterogeneity provides a unique setting to compare milk price movements with different differentiation strategies in cheese products and to draw implications for how such differentiation strategies could protect milk producers against price risks. We summarize the development of producer prices of milk used for the production of industrial cheese, artisanal cheese, and two specific artisanal cheeses with GI labels (Gruyère AOP and Emmentaler AOP),[1] which represent a gradient of product and quality differentiation, and we analyze price and volatility transmission between these price series.

We find overall evidence that product and quality differentiation in cheese markets helps milk producers achieve higher and more stable prices. Yet, there are heterogeneous linkages between differentiation strategies and milk price developments. Our results suggest that the effectiveness of GI-based differentiation in achieving higher and more stable producer prices may depend on the strength of GI protection and the governance structures of producer organizations.

CONCEPTUAL BACKGROUND AND HYPOTHESES

In this section, we discuss the relevant literature on how quality and product differentiation, GIs, and the coordinated and collective management of the value chain in GI producer organizations could influence producer prices in agricultural markets. We then develop a conceptual framework based on the literature, and discuss the Swiss milk and cheese markets within this framework. Finally, we present our empirical hypotheses.

Quality and product differentiation in cheese markets

Deviations from the assumption of perfect competition are common in agricultural markets (Sexton, 2013). Here, we discuss a set of important drivers of such deviations, namely product and quality differentiation and the associated collective and coordinated value chain management, and how they may influence retail and raw product producer prices. In agricultural markets, "quality" can encompass many dimensions of a food product, beyond taste, appearance, and brand appeal. In particular, consumers increasingly consider dimensions related to the underlying production process to be differentiating quality attributes (Saitone & Sexton, 2010). These dimensions include a product's place of origin, processing inputs, and marketing arrangements. According to the product attribute framework developed by Nelson (1970) and Darby and Karni (1973), these product and quality attributes can be categorized as follows: (i) search attributes, about which consumers have perfect information at the time of purchase; (ii) experience attributes, which consumers can evaluate after consumption; and (iii) credence attributes, which consumers cannot evaluate accurately even after consumption due to the high cost of obtaining relevant information.

In the modern agri-food sector, food production has been industrialized to a large extent. Artisanal production, typically characterized by traditional craftsmanship, is only maintained for a small fraction of food products and therefore has become an important type of process-based differentiation strategy (Rivaroli et al., 2020). Artisanal cheeses differ from industrial cheeses in their adherence to cheese-making traditions, handcraft techniques, and small-scale production, resulting in distinct flavors and regional characteristics (Wang et al., 2015). Thus, artisanal cheeses are differentiated from industrial cheeses in terms of search attributes (e.g., size, shape, and color) and experience attributes (e.g., texture and taste), which lead to price premia in retail markets. Such process-based differentiation further affects the distribution of price premia in input procurement markets (Sexton, 2013). Processors of artisanal cheeses procure a differentiated farm product, namely raw milk. Due to substantial sunk investments in the end product and high transaction costs to find alternative suppliers of the farm product, processors have inelastic demand and are interested in fostering a stable long-term supply, which can lead to a symbiotic relationship between processors and farmers (Crespi et al., 2012). These conditions encourage processors to offer long-term contracts to farmers and to refrain from exercising buyer market power, so that farmers are offered favorable shares of the market surplus (Crespi et al., 2012; Sexton, 2013). That is, farmers may benefit from more stable prices due to long-term, forward-looking contractual arrangements and higher prices due to inelastic demand and relative bargaining power.[2]

In Figure S1, we summarize the discussion above into a conceptual framework to illustrate how product and quality differentiation could influence milk producer prices. On the one hand, a price premium in retail markets can be achieved through differentiated products, entry barriers due to specialized production techniques, sunk investment in equipment, and reduced information asymmetry through signaling quality. On the other hand, the structure of the input procurement markets, particularly contractual arrangements between milk producers and processors and their relative bargaining power, influences the extent to which milk producers can benefit from the price premium.

As a framework for certifying product specifications such as the geographical origin and the associated quality and reputation, GIs have become increasingly important in agricultural markets (Rippon, 2014).[3] Products with GI labels benefit from the reputation of their area of origin, with which their quality attributes are associated (Deselnicu et al., 2013). By protecting reputation as an asset, GI functions as a producer protection measure (OECD, 2000). GI is particularly relevant for food products, as agricultural markets are often characterized by many small producers who are unable to individually signal product quality. Thus, GI is an application of collective reputation (Winfree, 2023) and enhances producer welfare by collectively defining product quality and restricting supply (e.g., Lence et al., 2007; Moschini et al., 2008). Due to consumers' higher willingness to pay for GI-labeled products, producers could benefit from higher rents for the respective agricultural products (Menapace et al., 2011).[4] According to a 2015 survey of Swiss consumers, more than 60% of respondents said that a product's specific region of origin is a strong criterion in their purchasing decision (Federal Office for Agriculture and Demo Scope, 2015). Therefore, in the context of cheese markets, the certification process for GI-labeled artisanal cheeses further reduces information asymmetry, thereby differentiating them from general artisanal cheese in terms of credence attributes.

The extent to which producers can benefit from GI depends on the GI's strength of protection, for example, the extent to which imitation by competing products is possible (Barjolle et al., 2007; Menapace & Moschini, 2014). A country's overall policy on GI, such as restricting copycat marketing and sales, has an impact on the overall strength of GI protection, particularly when facing international competition (Slade et al., 2019). The strength of a GI label is also determined by its producer organization (Lence et al., 2007; Moschini et al., 2008), which allows members to collectively regulate product quality, create brand images (and thus create differentiation), and control supply (Saitone & Sexton, 2010). The product quality associated with a GI label influences the extent to which a price premium can be achieved (Haeck et al., 2019). In geographically differentiated agricultural markets, producer organizations may also allow members to collectively exercise market power and limit entry by restricting supply and production techniques (Lence et al., 2007; Zago & Pick, 2004). The specific approaches used by producer organizations to create product differentiation and their ability to control supply vary greatly, which ultimately influences price premia (Zago & Pick, 2004).

Within producer organizations, the governance structure and contractual arrangements may further influence the extent to which milk producers benefit from the price premium of the end product (see Bonanno et al. (2018) on connections between governance and market power). In the case of Swiss GI cheese, milk producers are connected to downstream actors in the value chain, such as processors and traders, through producer organizations (also known as brand organizations).[5] The extent to which milk producers are represented in the producer organization, their bargaining power, and the commitment of both milk producers and cheese processors to future contracts affect the distribution of the retail price premium (Réviron et al., 2003). We summarize these abovementioned aspects of GI protection in our conceptual framework in Figure S1.

Swiss milk and cheese markets

The economic importance of ruminant-based milk products is extremely high in a country with large areas of natural grasslands such as Switzerland. Dairy farming accounts for a quarter of Switzerland's total agricultural production value (2.47 billion Swiss francs [CHF], Figure S2). In terms of milk utilization in Switzerland (Figure S3), cheese is the most important product, with about 46% of raw milk processed into cheese in 2020 (Federal Office for Agriculture, 2021).

Since the beginning of the 2000s, a series of gradual liberalization and deregulation in the Swiss dairy markets has exposed milk producers to increasing price risks (e.g., Huber et al., 2024). For example, starting in 2002, the cheese market with the European Union was gradually liberalized until full liberalization in 2007, when all trade restrictions for cheese, such as quotas or tariffs, ended. By contrast, the markets for raw milk and all other milk products remain highly protected. Furthermore, the milk quota system was abolished in 2009. There are two subsidy schemes for milk processed into cheese: (i) a general premium for milk processed into cheese (i.e., there is a governmental price markup if milk is transformed into cheese) and (ii) a premium for silage-free milk production (i.e., there is a governmental price markup if farmers do not use grass or maize silage)[6] (see Finger et al., 2017). In the last two decades, Swiss dairy markets have been characterized by increasing price fluctuations and overproduction (Forney & Häberli, 2014). Price risks have become a major source of farmers' revenue risks (El Benni & Finger, 2013). However, price developments in the dairy market have been characterized by large heterogeneity, that is, some prices (e.g., for milk for specific cheeses) remained stable while others decreased (e.g., Finger et al., 2017). A primary source of price shocks arises from international trade. Price transmission from the European Union, the most important trade partner for dairy products, has been found to be significant to Swiss milk markets (Swiss Federal Council, 2017). Other policy measures also affect Swiss dairy markets. For example, production is affected by agri-environmental schemes, such as the grassland-based milk and meat program, a voluntary governmental program that could shelter farmers from milk price fluctuations (Mack & Kohler, 2019). Increasing international pressure to reduce direct governmental payments in dairy markets has also led to policy adjustments (Huber, 2022). Therefore, an orientation toward more market-based risk management tools could become key to sustainably withstand the challenges of price risks in milk markets.

Swiss cheese markets are highly heterogeneous. Based on processor type, cheese products can first be divided into industrial cheese and artisanal cheese. For industrial cheese processing, raw milk only needs to fulfill national quality standards. Stricter quality standards apply to the raw milk used to make artisanal cheese. For example, farmers are not allowed to feed silage to dairy cows. Furthermore, artisanal cheese is usually handcrafted in small batches. Within artisanal cheeses, certain varieties are protected by GI labels. In the Swiss dairy markets, the relevant GI label is "Appellation d'Origine Protégée" (AOP), equivalent to the European "Protected Designation of Origin" (PDO). Figure S4 shows that about one third (32%) of the total Swiss cheese production is GI-labeled, another third (34%) is artisanal cheese without GI protection (see Figure S5 for more detailed production shares), and the final third (34%) is considered industrial cheese. Our study focuses on Gruyère AOP and Emmentaler AOP (hereafter "Gruyère" and "Emmentaler"). These two are the leading GI-labeled cheeses in terms of production quantities, accounting for 17% and 9% of the total Swiss cheese production in 2021 (see Figure S6 for the main production areas), while all other Swiss GI-labeled cheeses make up 6%. For a product to be certified with an AOP label, everything from the raw materials for processing to the end product must come from an explicitly specified region of origin (Swiss Association of AOP, 2022).

For the two GI-labeled varieties in our study, Gruyère and Emmentaler, differences in the strength of GI protection and the governance of producer organizations may influence their ability to protect producers from price risks. The name Gruyère is restricted solely to the production area within Switzerland.[7] Emmentaler, by contrast, was registered as a GI in Switzerland in 2006, but it is not recognized internationally and is excluded from the mutual recognition agreement with the European Union (Annex 12 of the Agreement on Trade in Agricultural Products). Hence, Emmentaler continues to compete with similarly named Emmental cheese from other regions.[8] To differentiate it from non-Swiss Emmentaler cheese, Swiss

Emmentaler is sold under the registered trademark "Emmentaler Switzerland" as an attempt to strengthen the brand. As such, the two GI labels, Gruyère and Emmentaler, represent different strengths of GI protection. While the Gruyère AOP label can effectively restrict competing products from using or imitating the label, Emmentaler AOP is not able to restrict the supply of similar products, namely those from international markets that carry the name Emmentaler. Referring to our conceptual framework in Figure S1, we expect Gruyère to outperform Emmentaler in terms of generating a higher price premium.

Furthermore, the two cheeses differ in the governance of their respective producer organizations (see Table S1 for details). The requirement that Gruyère processors must be members of the producer organization imposes an explicit barrier to entry and ensures that the producer organization is able to effectively plan, coordinate, and control the quantity of cheese produced, and that the collective decisions apply to all cheese processors in the region. By contrast, Emmentaler's producer organization is known to be less stringent in its governance and less effective in uniting all producers, processors, and retailers (Hunt, 2012). Because membership in the producer organization is not a prerequisite to produce Emmentaler, the producer organization struggled with supply planning and imposing quantity restrictions on nonmembers in the region, and even faced the risk of price collapse.[9] Both organizations have long-term relational contracts between milk producers and cheese processors (Hillen, 2021), although differences lie in the contractual details. In particular, the requirements that Gruyère processors can only procure milk from milk producers affiliated with their cheese dairy and that they are allowed to access the dairy farms for traceability of milk quality (which do not apply to Emmentaler) indicate a closer and more stable connection between milk producers and cheese processors (see Table S1). In general, within the producer organization of Gruyère, milk producers are well represented in the value chain, have a strong presence in downstream decision-making processes such as marketing and quantity control, and could ultimately influence pricing (Hillen, 2021). Referring to our conceptual framework in Figure S1, we expect Gruyère to outperform Emmentaler in terms of higher fractions of the price premium distributed to milk producers as well as more stable producer prices.

Empirical hypotheses

We form the following hypotheses based on our conceptual discussion. First, we expect that differentiation in search and experience attributes between industrial and artisanal cheeses protects raw milk supplied to the latter from price shocks, resulting in higher producer prices and greater price stability. Second, we expect that milk supplied to Gruyère and Emmentaler benefits from higher and more stable prices compared with general artisanal cheese, given the additional differentiation in credence attributes. Third, we expect that the Gruyère label is more effective in helping milk producers achieve higher and more stable prices than Emmentaler, due to stronger GI protection and stronger governance in the producer organization. Specifically, we hypothesize:

Hypothesis 1. Milk producer prices for artisanal cheese are higher in level and stability and are less prone to price level and volatility transmission from other markets compared with industrial cheese.

Hypothesis 2. Milk producer prices for artisanal cheeses with GI protection are higher in level and stability and are less prone to price level and volatility transmission from other markets compared with general artisanal cheese.

Hypothesis 3. Milk producer prices for Gruyère are higher in level and stability and are less prone to price level and volatility transmission from other markets compared with Emmentaler.

DATA AND EMPIRICAL METHODS

Data

We analyze monthly weighted average milk prices used for the production of industrial cheese, artisanal cheese (which contains all artisanal cheese, including those with GI label), and two specific artisanal cheese brands Gruyère and Emmentaler from January 2010 to January 2022, provided by the Swiss Federal Office for Agriculture.[10] To ensure comparability across different milk prices, the subsidy for silage-free production and other duties and benefits are not part of the price data.

Figure 1 presents the evolution of milk prices in all use channels. Milk prices for industrial and artisanal cheeses both show similar trends and seasonal effects over time, although the milk price for artisanal cheese is higher in level and displays lower volatility. The price movement of milk used for the two GI-protected cheeses follows very different patterns. Milk prices for Gruyère are much higher in level than Emmentaler, with the latter even falling below milk prices for industrial cheese in some periods. Except for the beginning of the study period and around 2019, the milk prices for Gruyère also display lower volatility than the other price series.

Empirical methods

We address the empirical hypotheses via descriptive and time series analysis. The descriptive analysis provides direct descriptive evidence of the price level and variability of raw milk prices

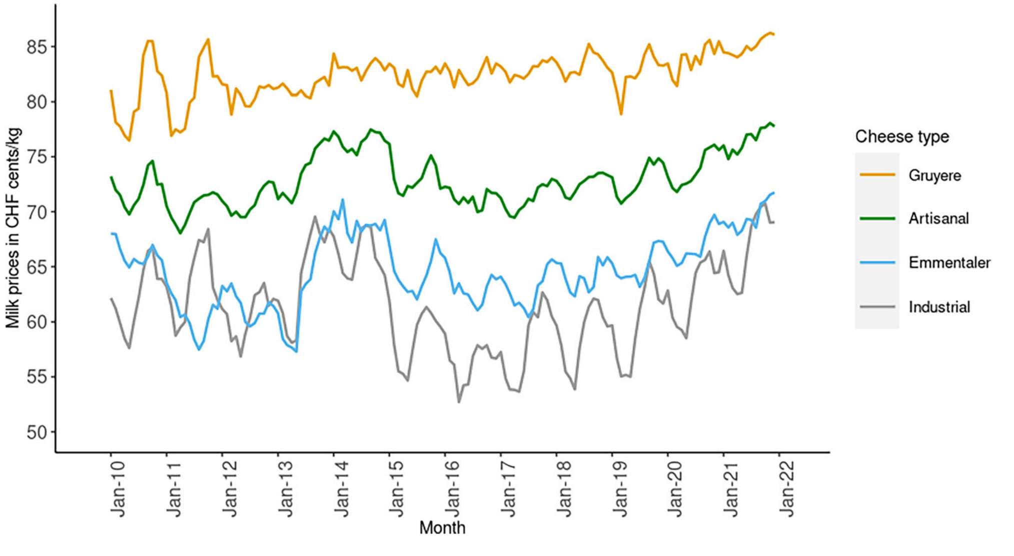

FIGURE 1 Monthly raw milk producer prices by cheese processing channel, 2010–2022.

with different underlying differentiation strategies in the cheese markets. The time series analysis concerns the co-movements of these milk prices. Because raw milk supplied to different processing channels is exposed to the same exogenous shocks in terms of sectoral policy, climate, international trade, etc., long-run equilibria (i.e., cointegrating relationships) are expected between pairs of prices. However, we expect such long-run equilibria only if the milk prices are part of an integrated market. If, however, one cheese product is perceived as very different from another, the two products could be such weak substitutes that they are no longer considered part of the same market, which further implies a low dependence between milk prices. Consequently, there would no longer be a direct price relationship through arbitrage and the so-called "Law of One Price" but rather an indirect link via cross-price elasticities (Shaked & Sutton, 1982). In this case, we would only observe short-run relationships between pairs of milk prices. This may also have implications for price variability, for example, if spillovers from one market to the other are reduced due to differentiation.

Descriptive statistics

For each price series, we calculate the mean, range, and coefficient of variation to compare the average price levels and volatilities. For pairs of price series, we apply two nonparametric tests of differences in mean and variability: the Mann–Whitney–Wilcoxon and the Siegel–Tukey tests.

Unit root tests

Before estimating the transmission of price and price volatility, we test each price series individually, applying the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) stationarity test. To account for potential heteroskedasticity in the error term of an autoregressive model, we further apply the Phillips–Perron (PP) test for unit roots. Depending on the outcome, we test the prices pairwise for their interdependencies. For stationary price series (integrated of order 0, or I(0)), we could analyze long-run dependencies between such prices by applying a vector autoregression (VAR) model in levels. For nonstationary price series (integrated of order 1, or I(1)), we apply vector error correction models (VECMs), which also inform whether two given price series are cointegrated (Johansen, 1988). For cointegrated price pairs, the VECM estimates how the prices are connected in the long term (cointegrating vector) and how they react to each other in the short term (adjustment term and autoregressive elements). For non-cointegrated price pairs of order I(1), we further estimate a VAR model in first differences. While these price pairs share no common trend and thus no long-run dependencies, the VAR model allows us to detect potential short-term dependencies.

Multivariate analysis

VEC model

For each pair of nonstationary price series, we estimate the following equation:

Vector error correction model

$$\begin{bmatrix}\Delta P1_t\\ \Delta P2_t\end{bmatrix}=\begin{bmatrix}\theta^{P1}\\ \theta^{P2}\end{bmatrix}+\begin{bmatrix}\alpha^{P1}\\ \alpha^{P2}\end{bmatrix}[P1_{t-k}-\beta_1 P2_{t-k}]+\sum_{i=1}^{k}\begin{bmatrix}\gamma_j^{P1} & \delta_j^{P1}\\ \gamma_j^{P2} & \delta_j^{P2}\end{bmatrix}\begin{bmatrix}\Delta P1_{t-i}\\ \Delta P2_{t-i}\end{bmatrix}+\sum_{m=1}^{11}\begin{bmatrix}\omega_m^{P1}\\ \omega_m^{P2}\end{bmatrix}D_{mt}+\begin{bmatrix}\varepsilon^{P1}\\ \varepsilon^{P2}\end{bmatrix}. \tag{1}$$

Equation (1) represents the vector error correction model, with $\Delta P1_t$ and $\Delta P2_t$ representing the first differences of the two respective milk prices $P1$ and $P2$ in Period t. The model is in first differences, capturing short-term movements, but also includes the long-run equilibrium (cointegrating vector) between both prices, which is zero in the long run and hence can be rearranged as follows:

$$P1_{t-k}=\beta_1 P2_{t-k}.$$

The coefficient β_1 represents the long-run price transmission elasticity, that is, the relative change in $P1_t$ due to a 1% increase in $P2_t$. This long-run equilibrium does not have to hold exactly at all times, but prices may meander around it. The speed and extent to which $P1_t$, $P2_t$, or both return to the common equilibrium is determined by the speed-of-adjustment terms α^{P1} and α^{P2}, which ensure the stability of the equilibrium and describe how quickly the respective price adjusts to the joint equilibrium. γ and δ express the influence of the past first differences of both prices on themselves and on the other price. The lag length k is selected according to the Akaike information criterion (AIC). ω capture seasonality for the monthly seasonal dummies (D_{mt}). θ^{P1} and θ^{P2} are constant terms.

VAR model

For non-cointegrated price pairs of order I(1), we estimate a VAR model to examine the short-term relationships between the first differences of price series.

Vector auto-regression model in first differences

$$\begin{bmatrix}\Delta P1_t\\ \Delta P2_t\end{bmatrix}=\begin{bmatrix}\theta^{P1}\\ \theta^{P2}\end{bmatrix}+\sum_{i=1}^{k}\begin{bmatrix}\gamma_j^{P1} & \delta_j^{P1}\\ \gamma_j^{P2} & \delta_j^{P2}\end{bmatrix}\begin{bmatrix}\Delta P1_{t-i}\\ \Delta P2_{t-i}\end{bmatrix}+\sum_{m=1}^{11}\begin{bmatrix}\omega_m^{P1}\\ \omega_m^{P2}\end{bmatrix}D_{mt}+\begin{bmatrix}\varepsilon^{P1}\\ \varepsilon^{P2}\end{bmatrix}. \tag{2}$$

$\Delta P1_t$ and $\Delta P2_t$ represent the first differences of milk prices $P1$ and $P2$ in period t, respectively. The model includes a constant θ, monthly seasonality indicator $\mathcal{D}_{mt}$, and an error term ε. k denotes the optimal number of lags to consider according to AIC. We report estimates of impulse response functions based on the VAR model in the first differences.

BEKK-MGARCH model

The second part of the multivariate analysis aims to capture volatility transmission effects. Following Engle and Kroner (1995), we estimate the Baba–Engle–Kraft–Kroner (BEKK) parameterization of the multivariate generalized autoregressive conditional heteroskedasticity (MGARCH) by maximizing the conditional nonlinear log-likelihood function. The effect of "news" on variances (the so-called ARCH effects) is determined by the estimated parameters of the own lagged innovations, whereas persistence of volatility (GARCH effects) and volatility spillover effects are quantified by the parameters of the lagged variances and the covariances equations (Rapsomanikis, 2011).

BEKK parameterization

$$\boldsymbol{H}_t = \boldsymbol{CC}' + \boldsymbol{A}\boldsymbol{\varepsilon}_{t-1}\boldsymbol{\varepsilon}_{t-1}'\boldsymbol{A}' + \boldsymbol{BH}_{t-1}\boldsymbol{B}'. \tag{3}$$

In the case of the asymmetric BEKK model, which is the most general form (Rapsomanikis, 2011), the parameter matrices for the bivariate case of $N = 2$ are:

$$H_t = \begin{bmatrix} h_{11t} & h_{12t} \\ h_{21t} & h_{22t} \end{bmatrix},\ C = \begin{bmatrix} c_{11} & 0 \\ c_{21} & c_{22} \end{bmatrix},\ A = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \text{ and } B = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix},$$

where H_t is the conditional variance–covariance matrix, C, A, and B are $N \times N$ matrices of intercept terms, shock transmission effects (ARCH term coefficients), and volatility transmission effects (GARCH term coefficients), respectively, and ε_t is the vector of disturbances. The diagonal elements of H_t denote the conditional variance terms, while the off-diagonal elements of H_t represent the conditional covariance. Thus, the diagonal elements of matrices A and B capture the impact of the own past shocks and volatility, respectively. The off-diagonal elements of matrices A and B capture the cross-market effects of shocks and volatility, respectively, and are particularly relevant for the analysis of volatility spillovers. For instance, the term $b(2, 1)$ captures the effect of the lagged variance of time series 2 on the present variance of time series 1.

RESULTS AND DISCUSSION

Descriptive statistics

Table 1 presents the summary statistics and the coefficient of variation for each price series. As price variation may reflect a time trend, we also calculate the coefficient of variation with the yearly time trend removed. Removing the time trend slightly reduces the coefficient of variation for all price series. Overall, the prices of milk used for artisanal cheese are higher and less variable than the prices of milk used for industrial cheese. Gruyère's milk price is on average higher than the milk price for overall artisanal cheese, and has a lower variability. For Emmentaler, however, the price only slightly outperforms industrial cheese in terms of higher mean and

TABLE 1 Summary statistics and coefficients of variation; prices in CHF cents/kg.

Channel	Mean	Range	Coefficient of variation	Coefficient of variation (without trend)
Industrial	61.5	52.7–70.7	7.0	6.9
Artisanal	72.9	68.1–78.1	3.2	3.0
Gruyère	82.4	76.5–86.2	2.4	2.0
Emmentaler	64.7	57.3–71.8	5.0	4.8

Note: 1 CHF = €1.04 and 1 CHF = US$ 1.11 (June 2024).

lower variability, and underperforms overall artisanal cheese. The results of the Mann–Whitney–Wilcoxon test (Table S2) confirm differences in the mean values of all price pairs. The results of the Siegel–Tukey test (Table S3) indicate a lower variability of milk prices for Gruyère and Emmentaler than industrial cheese.

The summary statistics provide descriptive evidence that first, product and quality differentiation in cheese products (in terms of search and experience attributes) may help milk producers achieve higher and more stable prices, consistent with the relevant part of Hypothesis 1. Second, for GI-labeled cheeses that further differentiate in credence attributes, we do not find a clear pattern. While in line with Hypothesis 2, milk price for Gruyère outperforms general artisanal cheese in level and stability, we observe an opposite relationship between Emmentaler and general artisanal cheese. As we discuss in the motivation of Hypothesis 3, the difference may be due to the strength of GI protection and governance of the producer organization, which influences the distribution of price premium to milk producers.

Next, we use time series econometric analysis for price level and volatility transmission between prices.

Unit root tests

Table 2 reports the results of the KPSS and PP tests. For all price levels, the KPSS test rejects the null hypothesis that the time series is stationary (i.e., integrated of order I(0)), although only at the 10% significance level for industrial cheese milk. Accounting for unspecified heteroskedasticity, the PP test does not reject the null hypothesis of a unit root in any of the price levels (i.e., integrated of order I(1)). For first-differenced prices, the KPSS test does not reject the null hypothesis of stationarity for any of the differenced series, whereas the PP test rejects the null hypothesis of a unit root in each of the differenced series. Therefore, both tests provide evidence that all price levels are I(1), and all first-differenced prices are I(0).

To check the robustness of the test results, we perform an additional cointegration test on all four prices. According to Johansen (1988), a singular coefficient matrix of the error correction term in a VECM would indicate unit roots in the time series. The results in Table S4 indicate that the coefficient matrix is singular with rank 2, which provides evidence that there are unit roots in our price series.

TABLE 2 Results of the KPSS and PP tests.

	KPSS		PP	
	Price level	First difference	Price level	First difference
	H0: I(0)	H0: I(0)	H0: I(1)	H0: I(1)
Industrial	0.39*	0.05	0.02	−88.8***
Artisanal	0.58**	0.08	0.05	−103***
Gruyère AOP	1.56***	0.02	0.05	−145***
Emmentaler AOP	0.66**	0.14	0.03	−124***

Note: Table reports test statistics from the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test and the Phillips–Perron (PP) test, both with constant and short-term lag of 4. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Multivariate analysis

VECM by price pair

Based on the test results in Table 2, all price series are nonstationary. Accordingly, we estimate a VECM for each price pair, which further informs the cointegrating relationship between the two prices. In addition, we run Johansen's (1988) cointegration test to directly test for cointegration in each price pair. Table 3 reports the results of the VECM estimation for all price pairs. The price transmission elasticity β_1 ranges from 0.35 (for the price pair Industrial–Artisanal) to 0.87 (for Industrial–Gruyère), indicating that if Price 2 in Table 3 is increased by 1%, then Price 1 will increase by 0.35%–0.87% in the long run. In terms of cointegration, there is strong evidence of long-run dependency between industrial cheese and Emmentaler, as shown by the statistically significant speed-of-adjustment terms α. Specifically, these coefficient estimates suggest that industrial cheese milk price follows that of Emmentaler, with 14% of the current disequilibrium corrected within 1 month; vice versa, Emmentaler milk price follows that of industrial cheese, with 8% of the current disequilibrium corrected within 1 month. By contrast, there is strong evidence of no cointegration between the milk prices of artisanal cheese and Gruyère and between industrial cheese and Gruyère. That is, these milk prices do not move together in the long run and do not adjust to price shocks in the other market. For the other price pairs, only one price series adjusts to the other but not vice versa. One emerging pattern is that in all cases, only milk prices of industrial cheese and Emmentaler adjust to the other price, indicating that these two prices are prone to price shocks in other markets. In fact, in all three price pairs that contain Emmentaler, the milk price of Emmentaler follows the other price. By contrast, the milk prices of artisanal cheese and Gruyère never adjust to the other prices, indicating resistance to price shocks in other markets.

The pairwise cointegration test results reported in Table S5 confirm the cointegrating relationship between milk prices for industrial cheese and Emmentaler and further suggest cointegration between industrial and artisanal, and between Emmentaler and artisanal. This is in line with the VECM estimates, indicating unilateral adjustments in these two price pairs. Interestingly, we find no cointegration for the three price pairs that include Gruyère milk, suggesting that Gruyère's milk price is particularly resistant to price shocks in other markets. This finding is consistent with the results from Table S4, which indicate that there are two

TABLE 3 Selected key parameters of VECM estimation.

Price 1	Price 2	β_1	α_{P1}	α_{P2}	Adj. R^2 equation $P1$	Adj. R^2 equation $P2$	Optimal lag length k
Industrial	Artisanal	0.35	−0.19***	−0.03	0.25	0.17	3
Industrial	Emmentaler	0.58	−0.14***	−0.08***	0.18	0.11	2
Industrial	Gruyère	0.87	−0.02	0.03	0.42	0.40	9
Artisanal	Emmentaler	0.62	−0.05	0.30***	0.06	0.20	2
Gruyère	Emmentaler	0.49	−0.10	−0.25**	0.32	0.06	8
Gruyère	Artisanal	0.75	−0.07	0.04	0.37	0.17	9

Note: β_1 is the price transmission elasticity from Price 2 to Price 1 (with signs reversed from the output to be consistent with Equation 1). α_1 and α_2 are coefficient estimates of the error correction term on Price 1 and Price 2, respectively. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively (applicable to α_1 and α_2).

cointegrating vectors (rank = 2) if we link all four price series. These cointegrating vectors likely link the milk prices of industrial cheese, general artisanal cheese, and Emmentaler, but not Gruyère.[11]

VAR model

For the non-cointegrated price pairs, namely milk prices for industrial cheese and Gruyère, and artisanal cheese and Gruyère, we assess potential short-term dependencies between the two prices using a VAR model in first differences. We present the VAR estimates in the form of impulse response functions in Figure S7. Overall, besides an immediate reaction at the time of the shock (Period 1), there are no significant impulse responses between the milk prices in either price pair. One month after the initial shock (Period 2), the reactions are no longer significantly different from zero at a 5% confidence level. Only Gruyère milk price reacts to a shock in itself, with a transitory downward-spike in Period 2, suggesting that whenever there is a price shock, part of it is corrected for with a counter-movement in the following month. This can be seen as an indicator of the stability and shock resistance of Gruyère milk price. Moreover, Gruyère milk price does not show any, even contemporaneous, response to shocks in artisanal or industrial cheese milk prices. This again suggests a strongly differentiated market for Gruyère that protects milk producers from price shocks in other processing channels. By contrast, artisanal cheese milk price displays a positive immediate response to a shock in Gruyère milk price. This response, however, is only significantly different from zero in the period of the shock, and diminishes in the following months. In Figure S8, we further present the impulse response function from the VAR estimation on price levels and discuss the results in Section S3.

In summary, the results of the VAR estimation reveal a distinct short-term price transmission pattern of Gruyère milk compared with industrial and artisanal cheese. In particular, changes in Gruyère milk price are transmitted to other markets, but not vice versa. This indicates that Gruyère milk price could be independent of price shocks that the other processing channels are prone to, and therefore more resilient to price shocks.

BEKK-MGARCH model

Table 4 presents the coefficient estimates of matrices A and B in Equation (3) for each price pair. Overall, we find limited evidence of cross-market transmission of past price innovations to current price volatility, and some evidence of (negative) volatility transmission from industrial cheese milk price to artisanal cheese milk price. Recall that the diagonal a_{ii} elements ($i \in \{1,2\}$) of matrix A in Equation (3) capture the effect of lagged innovations on the current conditional price volatility in market i, and the diagonal b_{ii} coefficients of matrix B capture the dependency of volatility in market i on its own past volatility. Regarding the cross-dynamics, the off-diagonal a_{ij} coefficients measure direct spillover effects of lagged innovations in market i on the current conditional volatility in market j, while the off-diagonal coefficients b_{ij} capture the direct dependence of volatility in market i on that of market j (Rapsomanikis, 2011; Tsuji, 2017).

For the effects of lagged innovations, all diagonal elements in matrix A are significant, indicating the dependency of milk price volatility on past shocks in the own price history. As for the off-diagonal elements in matrix A, for the price pair artisanal versus Emmentaler, both elements are significant, indicating a positive spillover effect of lagged innovations in Emmentaler milk price on the volatility of artisanal cheese milk price (0.33) and a negative, although small

TABLE 4 Estimates of price shock (A(i,j)) and volatility (B(i,j)) transmission effects.

P1 versus P2	Artisanal versus industrial	Artisanal versus Gruyère	Artisanal versus Emmental	Industrial versus Gruyère	Industrial versus Emmental	Gruyère versus Emmental
A(1,1)	0.944***	0.956***	1.000***	0.957***	0.938***	0.927***
A(2,1)	0.0003	0.050	0.334***	0.050*	0.134***	0.123*
A(1,2)	0.036	0.052	−0.074*	0.029	−0.008	−0.034
A(2,2)	0.936***	0.900***	0.743***	0.941***	0.874***	0.921***
B(1,1)	0.000	0.255*	0.434***	0.279**	0.000	0.384**
B(2,1)	−0.500**	0.092	0.171	−0.027	−0.072	0.057
B(1,2)	−0.058	0.011	−0.119	−0.029	−0.160	−0.057
B(2,2)	0.204	0.071	0.000	0.000	0.160	0.000

Note: *, **, and *** represent significance at the 10%, 5%, and 1% levels, respectively.

spillover, vice versa (−0.07). For the price pairs industrial versus Gruyère, industrial versus Emmentaler or Gruyère versus Emmentaler, we find only one-way positive innovation transmission from the latter to the former at a smaller magnitude (0.13 or lower). These results suggest that other than Emmentaler cheese milk, price volatilities tend to increase following price shocks in other channels, although in all cases at small scales. For Emmentaler cheese milk, lagged innovations in its past prices tend to increase the volatility of the other price series, whereas its volatility responds only marginally and negatively to innovations in the artisanal cheese milk price.

For the dependency of volatility between different markets (matrix B in Equation 3), we find some evidence of own past volatility transmission in milk prices for artisanal, industrial, and Gruyère cheeses, but not Emmentaler cheese. In terms of cross past volatility transmission, we find that past volatility of industrial cheese milk price is negatively transmitted to artisanal cheese milk price volatility. That is, an increase in past volatility of industrial cheese milk price is associated with a decrease in the current period artisanal cheese milk price. This provides evidence that product and quality differentiation, although not necessarily GI, may protect the milk price of differentiated cheese from price fluctuations in the industrial cheese market.

CONCLUSIONS AND POLICY IMPLICATIONS

In this study, we use a comparative approach to analyze the price movements and co-movements of milk supplied to cheese processing with different underlying product and quality differentiation strategies. Our results show that overall, differentiation in terms of search and experience attributes in cheese is indeed associated with higher milk price level and stability and lower vulnerability to price level and volatility transmission from other milk markets. Additional credence attribute differentiation through GI labeling may further enhance milk price level or stability, although the additional benefit of GI may depend on the strength and governance of the GI label. In particular, we find heterogeneous links between GI-based differentiation in cheese products and milk price developments. Milk price for GI-protected Gruyère exceeds that of general artisanal cheese, shows no long-term dependence on other prices, and responds primarily to changes in its own past price rather than to shocks in other markets. These characteristics indicate that the milk supplied to Gruyère constitutes a unique market segment that protects milk producers from price risks. By contrast, the milk price for GI-protected Emmentaler is low in level, co-moves closely with industrial cheese milk price, and is prone to shocks from other markets. These characteristics indicate the limited ability of the Emmentaler GI label to protect milk producers from price risks.

Our findings suggest that product and quality differentiation in cheese products, particularly through GI protection, bears great potential to serve as an effective risk management and value-creation tool for milk producers. Nonetheless, the effectiveness of differentiation strategies depends on their implementation. In particular, a GI label alone is not sufficient to ensure higher and more stable prices for milk producers. Rather, the extent to which milk producers could benefit from GI protection depends on the strength of the GI protection and the governance of the producer organization, especially in terms of the relative bargaining power of milk producers vis à vis downstream actors. For industry practitioners, it is important to enhance the ability of GI labels to restrict supply and limit competition from imitation products. This could entail lobbying for regulations that support the overall strength of GI protection against imitators and improving the governance of the producer organization behind a specific GI label to effectively manage supply. Within producer organizations, effectively aligning different stakeholder objectives and maintaining balanced bargaining power would further help milk producers benefit from the differentiation strategy. Policymakers can support these endeavors in several ways. For instance, formalizing the legal framework for GIs and providing legal assistance in enforcing GI protection may be particularly relevant in countries and regions faced with competition from imitation products in international markets. Furthermore, public policy support of milk producers, especially their collective actions (e.g., within GI producer organizations), may help to balance their power relative to processors in the input procurement market and thus increase the extent to which milk producers benefit in terms of higher and more stable prices.

Our analysis has several limitations that have implications for future research. Because we find that the heterogeneous effects of GI depend on the specific cheese production channel, future research may analyze in more depth the governance structure and marketing strategies of Gruyère and Emmentaler to gain a deeper understanding of the linkages between different dimensions in the governance structure of GI labels and producer price. Moreover, our study focuses on milk producer prices and co-movements between prices, whereas production volume is not part of the study. Future research may investigate the adjustment of milk production volume to price movements, which would provide additional insights into whether for farmers who are able to supply to differentiated products, revenue could be enhanced by quality-based higher prices rather than high production volume. These insights would contribute to reducing the climate impact of the dairy industry by reducing the total volume of production. Future research shall also explore up to which scale (e.g., overall market share) of product and quality differentiation the here-identified benefits maintain. The limitations of our study regarding external validity may be addressed by generalizing and transferring our analysis to other markets, products, and regions.

ACKNOWLEDGMENTS

We thank the editor and two anonymous reviewers for helpful comments, and the Swiss Federal Office for Agriculture for providing monthly milk price data for the thesis work that this article is based on. Open access funding provided by Agroscope.

ENDNOTES

[1] The Swiss AOP (Appellation d'Origine Protégée) is equivalent to the European PDO, indicating that the product was produced, processed and refined in the defined region.

[2] See also Section 4 of Bonanno et al. (2018) for the relation between product differentiation and power in input procurement markets and Section 4 of Sheldon (2017) for a review on related vertical contractual arrangements.

[3] The agreement on trade-related aspects of intellectual property rights (TRIPS) of the World Trade Organization defines GI as "indications which identify a good as originating in the territory of a (WTO) member, or a region or locality in that territory, where a given quality, reputation or other characteristic of the good is essentially attributable to its geographical origin" (WTO, 1994).

[4] In the abovementioned literature, producers can refer to raw agricultural input producers and/or processors. That is, producers and processors are not distinguished.

[5] Although producer organization is a strong characteristic for GI products, in Swiss cheese markets, producer organizations are not restricted to GI-labeled products. Other non-GI artisanal cheese brands may also form producer organizations. For simplicity, in the framework in Figure 1, we associate producer organizations only with GI-labeled cheeses.

[6] Silage free production is supported, as this improves suitability to produce raw milk cheese. For GI raw milk cheeses such as Emmentaler and Gruyère, the use of silage fodder is even not permitted.

[7] Note that there is a homonymous designation in France, registered as a Protected Geographical Indication (PGI). Both are mutually recognized in the EU and Switzerland. However, and more generally, many GIs, including Gruyère, are not recognized outside of Europe. A recent US court decision confirmed that in the United States, *Gruyère* is considered a generic name and not a GI (Brittain, 2023).

[8] Under EU law, three Emmentaler cheeses are protected: Allgäuer Emmentaler has a PDO status, and Emmental de Savoie and Emmental français est-central from Franche-Comté both have a PGI status. "Emmentaler" alone is considered a generic name and is hence not protected.

[9] Reported in news articles, for example, https://www.nzz.ch/schweiz_kaese_emmentaler_produktion_mengenbeschraenkung_aufgehoben-ld.574337.

[10] Monthly milk price data by processing channel were provided by the Federal Office for Agriculture for the thesis work that this article is based on via a data use agreement, and are not publicly available. Aggregates data can be found at https://www.agrarmarktdaten.ch/markt/milch-und-milchprodukte.

[11] More precisely, a rank (r) of 2 in an error correction matrix of $n = 4$ prices means that there exists a cointegrating vector for each subset of ($4–2 + 1 = 3$) (i.e., $n - r + 1$) prices (Enders, 2008). In other words, there would be a long-run relationship within each subset of three prices, which would not involve Gruyère in each case (i.e., when Gruyère is included in the subset of three prices, a cointegrating relationship exist between the other two prices, and when the three prices are industrial, artisanal, and Emmentaler, a cointegrating relationship likely exist among all three prices).

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How to cite this article: Wang, Yanbing, Simon Hug, Judith Irek, and Robert Finger. 2025. "Product Differentiation, Quality, and Milk Price Stability: The Case of the Swiss Cheese Market." *Applied Economic Perspectives and Policy* 47(1): 416–435. https://doi.org/10.1002/aepp.13467