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An empirical investigation of the linkages between conventional and organic milk markets in Austria

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ABSTRACT

This work investigates the strength and the pattern of linkages among the three markets of qualitatively differentiated milk (i.e., conventional, organic without heymilk, and organic with heymilk) in Austria using the flexible TVP-VAR frequency connectedness approach and information on prices from 2018 to 2023. The main empirical findings are: (a) Taken together, the markets have maintained a moderate degree of connectedness to each other. (b) Price linkages have been frequency-dependent; much of the adjustments to incoming information have been completed within 3 months. (c) Connectedness has been asymmetric; the highest quality (organic with heymilk) has been a net transmitter of price shocks to organic without heymilk. (d) The intensity of connectedness has been time-varying; however, the internal structure of the market network (i.e., the net transmitters and receivers of price shocks) has remained fairly stable.

KEYWORDS

Milk; Conventional; Organic, Austria; Connectedness

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1. Introduction

Austria is among the leading member states in the EU's efforts to make the transition from conventional to organic farming[1]. In 2021, the organic share of total agricultural land in Austria was 26.5 per cent and the organic retail market share was 11.6 per cent compared to 9.6 and 4.7, respectively, for the EU27 (Willer *et al*, 2023). For the dairy sector, in particular, the organic share in total raw milk production in Austria in 2021 was 19 per cent and the organic retail market shares of fluid milk, yoghurt, and butter were 30.2, 26.3 and 12 per cent, respectively (Willer *et al*., 2023). The drive for organic milk production in Austria has been facilitated by climatic and geomorphological factors. Grassland accounts for more than 50 per cent of the agricultural land and it is mainly located in mountainous regions. Intensive (feed-grain-based) farming systems are not very suitable there; extensive (grass-feed-based) ones offer an attractive alternative that is healthy for animals, well-adapted to the local conditions, and environmentally friendly (Knaus *et al*., 2014). More importantly, grass-feed-based farming systems are, relative to intensive, easier and cheaper to convert to organic due to stricter rules and higher organic feed expenses (European Commission, 2023).

Organic milk is more costly to produce largely because the yield per cow is, typically, lower than in conventional farming; in Austria, the yield gap is currently 18 per cent (European Commission, 2023). Conventional and organic milk are substitutes for each other and quality differentiated. Part of milk consumers are willing to pay a higher price for the latter because of potential health benefits and interest in the ethical, environmental, and animal welfare issues associated with organic farming. The organic premium (i.e., the spread between organic and conventional prices) is crucial for the economic viability of the organic dairy sector. The spread, in turn, depends on the strength, the mode, and the dynamics of the price link between conventional and organic milk.

The number of empirical works on the price relationship between conventional and organic foods is, surprisingly, rather small. Wurriehausen *et al*. (2015), Nemati and Saghaian (2018), and Kim *et al*. (2019) focused on wheat in Germany and apples and vegetables in the US, respectively. Dolgopolova and Roosen (2017) and Kim and Seok (2022) investigated the milk markets in Germany and Austria, respectively. The econometric/statistical tools (such as Johansen Cointegration, Markov Switching Vector Error Correction model (MSVEC) model, Threshold Vector Error Correction (TVEC) model, and Threshold VAR (TVAR)) employed by the earlier works on the topic are suitable for analysis in the time-domain. All emphasized the existence of long-run relationships, asymmetric linkages, and causality. Asymmetry is of special importance for two reasons. First, although an organic food commodity can be always sold as conventional, a conventional one cannot be sold as organic (supply asymmetry) (Wurriehausen *et al*., 2015). Second, part of consumers in organic food markets are loyal, regular, and price-insensitive whereas the rest are occasional and price-sensitive (demand asymmetry). For the intensity of price linkages, Wurriehausen *et al*. (2015) suggested that as the market of an organic food matures (i.e., its retail market share becomes sufficiently large and its marketing channels change from traditional such as direct marketing and special shops to general retailers) co-movement between conventional and organic prices is likely to become stronger.

This work revisits the linkages between conventional and organic milk prices in Austria by employing a recently developed econometric tool and by taking fully into account the diversity of milk farming systems in the country. The econometric tool, the Time-Varying Parameter-VAR (TVP-VAR) frequency connectedness approach (Chatziantoniou *et al*., 2023), has three distinct advantages: (a) it is highly suitable for modeling networks of interrelated markets; b) it offers a more accurate description of connectedness dynamics relative to the rolling-window VAR analysis; and (c) it decomposes linkages at the time-domain into meaningful time-scale (frequency) components such as the short- and the long-run. The strength of connectedness at different time-scales provides

[1] The rules for the production and labelling of organic foods are specified by the Regulation 2018/848.

valuable information on how much time it takes for markets in a network to adjust to incoming shocks or in other words, how fast trades process new information about the state of markets (Chatziantoniou *et al*., 2023). Frequency-dependence is very common in Food Economics it is often behind asymmetric connectedness (e.g. Miller and Hayenga, 2001; Fousekis and Grigoriadis, 2016).

With regard to milk production in Austria, because of the country's climatic and geomorphological characteristics, there are three instead of two dairy farming systems; namely, the conventional, the organic "without heymilk", and the organic "with heymilk". The difference between the last two lies in the content of silage in fodder; for organic "with heymilk", silage cannot exceed 25 per cent of the annual ration (EU Regulation 2016/304). The organic "with heymilk" is considered to be of superior quality and its price has a premium over that of "without heymilk". The analysis of all three markets (i.e., conventional, organic "without heymilk", and organic "with heymilk") together is likely to offer additional insights into price linkages relative to earlier works (e.g., Dolgopolova and Roosen, 2017; and Kim and Seok, 2022) which relied on simple bivariate analysis.

To the best of my knowledge, this is the first work in the field of Food Economics that employs the dynamic frequency connectedness approach to assess market linkages[2]. In what follows, section 2 presents the analytical framework, and section 3 the data and the empirical models. Section 4 presents the empirical results while section 5 offers conclusions.

2. Methodology

The TVP-VAR frequency connectedness approach combines the TVP-VAR connectedness model (e.g., Antonakakis *et al*., 2018; Broadstock *et al*., 2022) and the frequency connectedness model (Barunik and Krehlik, 2018)[3]. The central notion in it, is the typical element of the Generalized Forecast Error Variance Decomposition (GFEV) matrix, $\theta_{ij,t}(r,H)$, where t=1, …, T denotes time, i, j = 1, 2, …, N the stationary stochastic processes involved, r stands for a frequency range (e.g. short-run), and H for the forecast horizon. $\theta_{ij,t}(r,H)$ (with $i \neq j$) is the spillover from j to i at the *frequency-domain*; that means, it stands for the portion of the forecast error variance of the ith process that can be explained by shocks (innovations) to process j, at time t, frequency range r, and forecast horizon H. Based on $\theta_{ij,t}(r,H)$ (i, j = 1, 2, …, N) one may develop several connectedness measures in the frequency-domain.

The difference

$$NPDC_{ij,t}(r,H) = \theta_{ij,t}(r,H) - \theta_{ji,t}(r,H) \qquad (2)$$

is the *net-pair directional spillover* (connectedness); when negative (positive) the process i is a net-receiver (transmitter) of shocks from (to) process j at t, r, and H. The sum

$$TO_{i,t}(r,H) = \sum_{\substack{i=1,\\ i\neq j}}^{N} \theta_{ij,t}(r,H) \qquad (3)$$

is *the total directional spillover* from i to all other N-1 processes whereas the sum

[2] The empirical applications of the connectedness approach to agricultural and food commodities are less than a handful. Szabo *et al*. (2023) applied the standard connectedness model (Diebold and Yilmaz, 2014) to EU pig prices. Fousekis (2023) relied on the TVP-VAR model to investigate connectedness among dairy futures markets in the US. However, his empirical analysis was confined to the time- domain only.
[3] For technical details please see Chatziantoniou *et al*., (2023) and Barunik and Krehlik (2018).

$$FROM_{i,t}(r,H)=\sum_{\substack{j=1,\\ i\neq j}}^{N}\theta_{ij,t}(r,H) \qquad (4)$$

is the *total directional spillover* from all other N-1 to i. The difference

$$NET_{i,t}(r,H)=TO_{i,t}(r,H)-FROM_{i,t}(r,H) \qquad (5)$$

is the *net directional spillover* (connectedness); when positive (negative) process i is a net-transmitter (receiver) of shocks to (from) the remaining N-1 processes. The sum

$$TCI_t(r,H)=\frac{N}{N-1}\sum_{i=1}^{N}TO_{i,t}(r,H)=\frac{N}{N-1}\sum_{i=1}^{N}FROM_{i,t}(r,H) \qquad (6),$$

stands for the *total connectedness index*; it measures the average shock spillover from one stochastic process to the others (Stenfors *et al.*, 2022). High (close to 1), values of the TCI indicate that the linkages among the N stochastic processes are strong; low (close to 0) values suggest that the linkages are weak. The measures of connectedness at the *time-domain* are readily recovered by summing up their counterparts at the frequency-domain for all frequency ranges employed (Chatziantoniou *et al.*, 2023).

3. The data and the empirical models

The data for the empirical analysis are monthly farm-gate real fat content milk prices (measured in cents per kilo) for conventional, without heymilk organic, and with heymilk organic in Austria from January 2018 to December 2023[4]. Table A.1, in the Appendix, presents descriptive statistics. Figure 1 shows the evolution of the three prices (in natural logs). There is considerable evidence of co-movement. All prices dropped sharply during (most of) 2018, they remained relatively stable during 2019 and early 2020; they increased at a very high pace (as a result of the uncertainties concerning dairy demand and input supply due to the COVID-19 pandemic and the war in Ukraine) until mid-2022; since there has been a downward trend. Figure 2 presents the evolution of premiums. They are calculated as natural logs of price ratios; thus, they show how much more expensive is, in percentage terms, one milk quality relative to another. The premium of organic with heymilk relative to that without haymilk has been fairly stable; that of organic without heymilk relative to conventional, however, exhibited a strong downward trend from mid-2021 to late-2022.

The natural logarithms of the three price series are non-stationary but their returns are (Table A.2, in the Appendix). Therefore, the empirical analysis is subsequently conducted using the price returns. The lag length for the estimation of the TVP-VAR frequency connectedness model has been selected using the Bayesian Information Criterion and the forecast horizon (H) has been set equal to 12 months[5]. The time scales employed are [1-3] months (high-frequency range) and >3 months (low-frequency range)[6].

4. The empirical results

Table 1 presents the *averaged* (i.e., those total-sample) dynamic connectedness measures at the time domain along with their respective p-values[7]. The diagonal elements stand for own-spillovers while the off-

[4] Obtained by clal.it (https://www.clal.it/en/index.php?section=latte_bio_austria). January 2018 is the earliest period for which information on all three price series is available.
[5] It has been already established in the relevant literature (e.g. Diebold and Yilmaz, 2014 and *Ando et al*., 2022) that the choice of H has negligible impact on the empirical results.
[6] Since connectedness at the time-domain is the sum of connectedness at the two time-scales, expanding one of the frequency ranges increases the contribution of that range to connectedness in the time-domain at the expense of the other range.
[7] The estimations have been carried out using the package *ConnectednessApproch* in R (Gabauer, 2022).

diagonal ones for pair (cross-) spillovers; the off-diagonal row sums stand for total directional FROM spillovers while the off-diagonal column sums for total directional TO spillovers; the bottom row gives the net total directional connectedness and the bottom-right element is total connectedness. The own-spillover estimates range from 52.57 for conventional to 74.81 for organic without heymilk. These suggest that 47 per cent of price volatility for conventional milk is explained by idiosyncratic (own-) spillovers and 25 per cent of price volatility for organic without heymilk can be attributed to cross-spillovers. There are no statistically significant spillovers from the organic without heymlk market to the other two; also, the organic without heymilk market receives spillovers only from the conventional one.

Table 1. Time domain.

Averaged dynamic connectedness (%)

Markets	Without heymilk	With heymilk	Conventional	Total directional FROM others
Without heymilk	74.81	12.26	12.93	25.19
	(<0.01)	(0.13)	(<0.01)	(<0.01)
With heymilk	3.06	53.14	43.79	46.86
	(0.75)	(0.01)	(<0.01)	(<0.01)
Conventional	3.65	43.77	52.57	47.43
	(0.56)	(0.01)	(<0.01)	(<0.01)
Total directional TO others	6.72	56.03	56.73	
	(0.55)	(<0.01)	(<0.01)	
				Total connectedness
Net total directional	-18.48	9.18	9.30	**39.85**
	(0.06)	(0.25)	(0.30)	**(<0.01)**

Notes: p-values in parentheses; obtained using a Wald-type statistic (Patton, 2013) and block bootstrap (Politis and Romano, 1994) with 2500 replications.

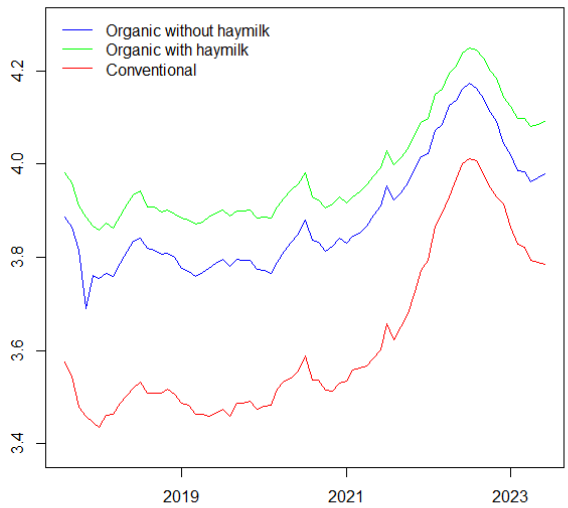

Figure 1. The evolution of prices.

In contrast, all spillovers between the organic with heymilk and the conventional markets are statistically significant. This pattern of connectedness implies that the organic without heymilk market is, largely, isolated from the developments in the other two markets. The conventional and the organic with haymilk markets have by far the highest directional TO and FROM spillovers; they are responsible for the propagation of price shocks in the three-market network and they may, thus, be thought of as *price risk connectors* (Nguyen *et al.*, 2020). The TCI value suggests that the average shock spillover is important as it accounts for almost 40 per cent of the forecast error variance for the network.

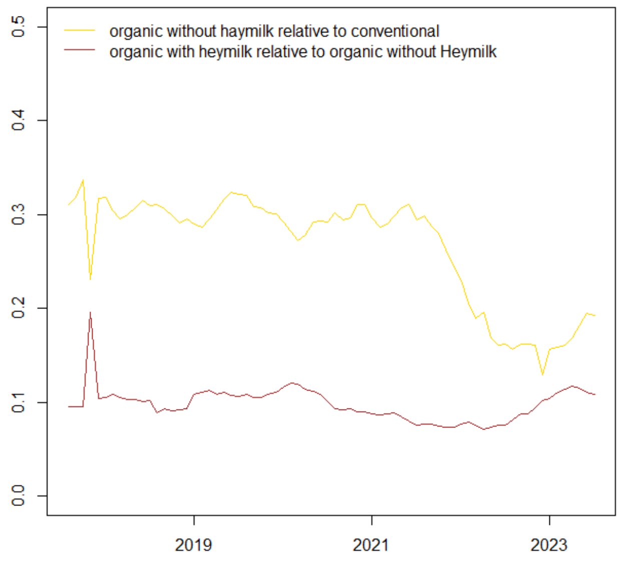

Figure 2. The evolution of premiums

The net total directional spillover for organic without heymilk is statistically significant at the conventional levels; from the perspective of the network, there is asymmetric connectedness and the organic without heymilk is a net-receiver of shocks from the other two markets taken together. Table 2 shows the test results on net-pair spillovers; none of the estimates is statistically significant; there is no evidence for asymmetric connectedness between pairs. Dolgopolova and Roosen (2017) reported Granger causality from conventional to organic milk price in Germany whereas Kim and Seok (2022) found exactly the opposite for Austria.

Table 2. Time domain.
Net-pair spillovers

Market pairs	Test statistic
Without heymilk, with heymilk	-9.2
	(0.13)
Without heymilk, conventional	-9.28
	(0.11)
With heymilk, conventional	-0.02
	(0.99)

Note: The test statistic is spillover from the first to the second market in a pair; p-values in parentheses; obtained using a Wald-type statistic (Patton, 2013) and block bootstrap (Politis and Romano, 1994) with 2500 replications.

Table 3 presents the averaged dynamic connectedness measures at the high-frequency along with their respective *p*-values. The pattern of connectedness is very similar to that in Table 1. The allocation of TCI at the time-domain to different time-scales allows one to determine how fast shocks are transmitted within a network (or, equivalently, how fast incoming information is processed by market participants). The TCI value at the high-frequency is 25.45 and at the time-domain is 39.85 implying that (almost) 2/3 of the adjustments to innovations are likely to be completed within three months.

The net total directional spillover is negative and statistically significant for organic without heymilk implying that, from the perspective of the network, the market is a net receiver of innovations. Table 4 shows the test results on net-pair spillovers. At the 10 per cent level of significance, there is evidence that the organic with heymilk market is a net transmitter of shocks to that without heymilk.

Table 5 presents the averaged dynamic connectedness measures at the low-frequency along with their respective *p*-values. In line with the earlier evidence that the bulk of adjustments is completed at the high-frequency, the connectedness estimates are small and many of them (especially those related to the organic without heymilk) are not statistically significant. There is no evidence of asymmetric spillovers (Table 6).

Table 3. [1, 3] months frequency range.
Averaged dynamic connectedness (%)

Markets	Without heymilk	With heymilk	Conventional	Total directional FROM others
Without heymilk	64.27	8.17	7.74	15.91
	(<0.01)	(0.23)	(<0.01)	(0.02)
With heymilk	1.78	34.84	29.36	31.14
	(0.82)	(0.01)	(<0.01)	(<0.01)
Conventional	2.07	27.23	33.32	29.31
	(0.61)	(0.01)	(<0.01)	(<0.01)
Total directional TO others	3.85	35.41	37.10	
	(0.66)	(<0.01)	(<0.01)	
				Total connectedness
Net total directional	-12.06	4.26	7.8	**25.46**
	(0.03)	(0.38)	(0.17)	**(<0.01)**

Notes: p-values in parentheses; obtained using a Wald-type statistic (Patton, 2013) and block bootstrap (Politis and Romano, 1994) with 2500 replications.

Table 4. [1, 3] months frequency range.
Net-pair spillovers

Market pairs	**Test statistic**
Without heymilk, with heymilk	-6.39
	(0.08)
Without heymilk, conventional	-5.67
	(0.12)
With heymilk, conventional	-2.133
	(0.45)

Notes: The test statistic is spillover from the first to the second market in a pair; p-values in parentheses; obtained using a Wald-type statistic (Patton, 2013) and block bootstrap (Politis and Romano, 1994) with 2500 replications.

Table 5. [1, 3] months frequency range.
Averaged dynamic connectedness (%)

Markets	Without heymilk	With heymilk	Conventional	Total directional FROM others
Without heymilk	10.54	4.09	5.19	9.28
	(0.09)	(0.42)	(<0.01)	(0.09)
With heymilk	1.28	18.3	14.43	15.17
	(0.84)	(0.01)	(<0.01)	(0.02)
Conventional	1.58	16.54	19.25 (<0.01)	18.12
	(0.64)	(0.01)		(<0.01)
Total directional TO others	2.86	20.63	19.62	
	(0.72)	(<0.01)	(<0.01)	
				Total connectedness
Net total directional	-6.42	4.92	1.50	**14.37**
	(0.33)	(0.39)	(0.77)	**(<0.01)**

Notes: p-values in parentheses; obtained using a Wald-type statistic (Patton, 2013) and block bootstrap (Politis and Romano, 1994) with 2500 replications.

Table 6. > 3 months frequency range. Net-pair spillovers.

Market pairs	**Test statistic**
Without heymilk, with heymilk	-2.81
	(0.57)
Without heymilk, conventional	-3.61
	(0.28)
With heymilk, conventional	2.11
	(0.41)

Notes: The test statistic is spillover from the first to the second market in a pair;: p-values in parentheses; obtained using a Wald-type statistic (Patton, 2013) and block bootstrap (Politis and Romano, 1994) with 2500 replications.

Even a small (three-market) network produces a large number of statistics. Presenting the evolution of each one of them will involve a large number of figures. Here, the focus is on the evolution of the TCI, the net total directional spillovers, and the net-pair spillovers. These three measures are, in any case, central to the present work as they are related to the dynamics of total connectedness and to the internal structure of the network (i.e., receivers and transmitters of shocks and potentially asymmetric linkages).

Figure 3 shows the evolution of the TCI by frequency range. Increasing values of it point to a more intense transmission of shocks (and, thus, to higher degree of market integration). The TCI at the time-domain peaked in mid-2018 (a period in which the trend for all prices in Figure 1 turned from strongly negative to strongly positive), it remained fairly stable from 2019 to early-2022 and, since then, it showed an upward trend. It appears that the COVID-19 pandemic had no notable impact on total connectedness. However, the war in Ukraine that created turmoil in international dairy markets worked towards tighter connectedness among milk markets in Austria. From 2019 to mid-2022 the TCI at the high-frequency increased at the expense of that at the low-frequency. In mid-2022, in particular, the contribution of the large time-scale to total connectedness fell to (almost) zero. It is clear that during the COVID-19 pandemic and at the beginning of the war in Ukraine, milk markets in Austria tended to process information very fast (in other words, only very recent innovations mattered for connectedness; past innovations had a very small influence on current market developments).

Figure 4 shows the evolution of net total directional spillovers by time-scale. The organic without heymilk market was a net-receiver of shocks from the other two in every time period while the markets for organic with heymilk and conventional milk were net-transmitters of shocks in (almost) all time periods. For the conventional and the organic without heymilk markets the importance of the low-frequency rose from 2020 to 2022 while for the organic with heymilk the contributions of the short- and the long-run were about the same.

Figure 5 shows the evolution of net pair spillovers. The organic without heymilk market was a net-receiver of innovations from both the conventional and the organic with heymilk in all periods and frequency ranges. There is no evidence of asymmetric spillovers between the conventional and the organic with heymilk markets.

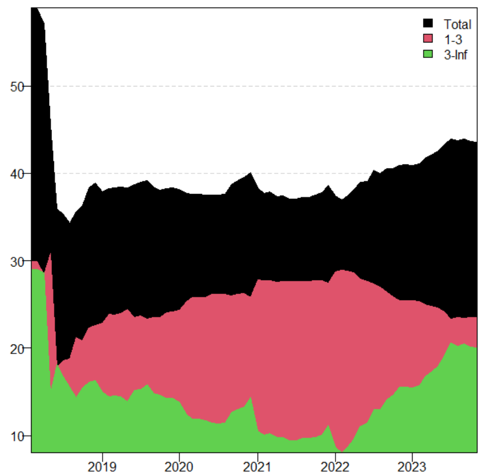

Figure 3. Dynamic TCI by frequency range.

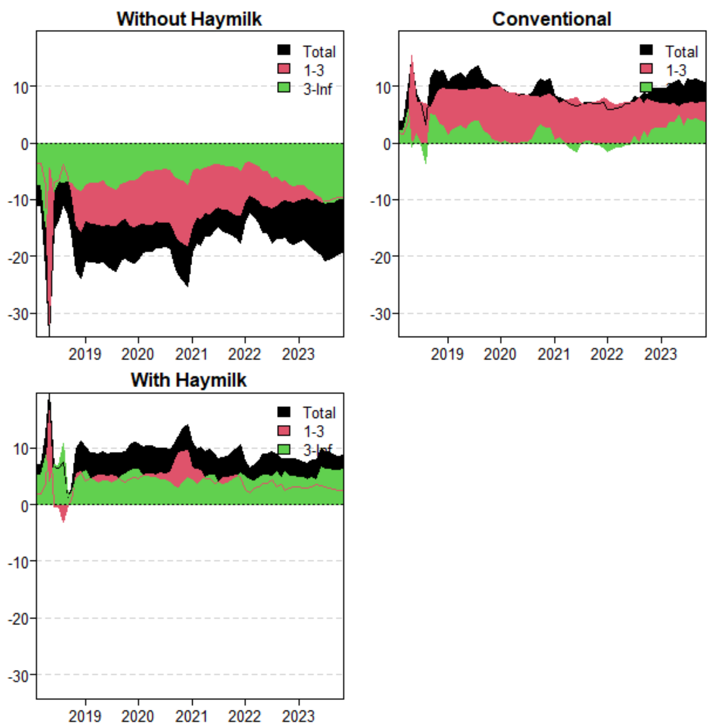

Figure 4. Net total directional spillovers by frequency range.

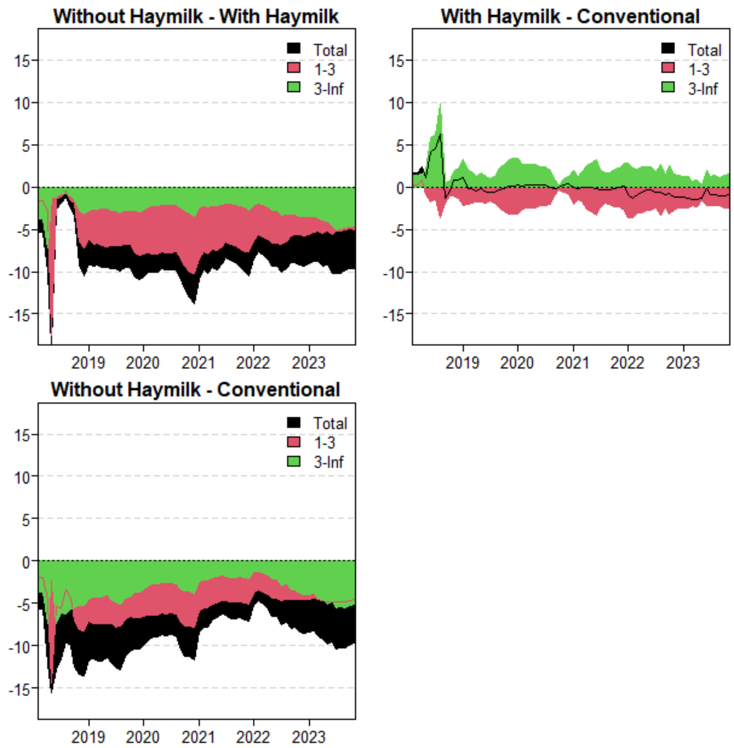

Figure 5. Net-pair spillovers by frequency range.

5. Conclusions

The objective of the present work has been to investigate price connectedness among conventional and organic milk markets in Austria. To this end, it relied on the flexible TVP-VAR frequency connectedness approach and monthly price data from 2018 to 2023.

The markets of the three qualitatively differentiated commodities have, on average, exhibited a moderate (40 per cent) degree of total connectedness. The organic with heymilk and the conventional milk markets were strongly connected; the links of the organic without heymilk market, however, with the other two in the network were much weaker.

Connectedness was frequency-dependent, asymmetric, and time-varying. Concerning frequency-dependence, the largest part of adjustments to incoming innovations were completed within 3 months implying that milk markets in Austria tended to assimilate new information quickly and that past information had limited influence on current decisions. Asymmetric total connectedness involved largely the market of organic without heymilk that was a net receiver of innovations at the time-domain and the high-frequency range. Asymmetric pair connectedness involved the two organic milk markets where the higher quality (with heymilk) was a net transmitter of shocks to lower quality (without heymilk). No statistically significant asymmetric connectedness was detected between any of the organic milk markets and the conventional milk market. This result contrasts with Kim and Seok (2022) who reported the presence of Granger causality from organic to conventional milk prices in Austria and with Dolgopolova and Roosen (2017) who found the opposite for Germany. The two earlier works employed bivariate models and Kim and Seok (2022) did not allow for quality differentiation within the organic milk market in Austria. Except for a notable drop in 2018, total connectedness at the time-domain did not change much with time. The contributions of the high- and the low-frequency ranges to it, however, did. The importance of connectedness at the low time-scale was much higher than that at the large time-scale during periods of economic turmoil (the COVID-19 pandemic and the outbreak of the War in Ukraine). The internal structure of the market network, however, remained quite robust over time.

As mentioned in the Introduction, while the transition to organic farming is a major objective of the EU, our knowledge of the association between organic and conventional food prices is limited. Future research may consider not only how conventional and organic prices are linked within a given national market but also how the prices of a given organic food are related across two or more EU national markets.

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Conflict of interest

The author declares that the manuscript is completely original with no conflict of interest.

APPENDIX

Table A.1. Descriptive statistics.

Statistic	Conventional	Without heymilk	With heymilk
Min	31.06	40.40	47.92
1st Quartile	32.67	44.41	49.32
Median	34.35	46.48	51.05
Mean	38.10	49.26	54.27
3rd Quartile	44.08	53.52	59.51
Max	55.20	64.92	70.02
Standard Deviation	6.46	6.60	7.27

Table A.2. Results from the application KPSS test.

Price levels (in natural logs)	With a constant only	With a deterministic linear trend
Conventional	1.427	0.277
Organic without heymilk	1.387	0.222
Organic with heymilk	1.398	0.256
Price log-returns		
Conventional	0.201	0.131
Organic without heymilk	0.161	0.116
Organic with heymilk	0.188	0.114

Notes: At the 5 percent level the critical values are 0.463 and 0.146 for the model with a constant only and the model with a deterministic trend, respectively (Kwiatkowski et al., 1992).

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