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Comovement of dairy product futures and firm value: returns and volatility

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This study investigates the exposure of dairy firm stock prices to the prices of dairy product futures, in terms of returns and volatility, from May 2013 to April 2018. Stock price returns are regressed against an index of the futures price returns to four dairy products – milk, cheese, butter and dry whey – to isolate the effects of the dairy futures price returns. Dairy product futures price returns are found to be significant in the regression in the first three years of the sample period, with a mean coefficient of −0.024. Using the Diebold-Yilmaz volatility spillover method of forecast error variance decomposition, we show that the volatility of the four dairy product futures accounted for an average of 5.49 per cent of the volatility of dairy stock prices. These results suggest that the prices of dairy firms have minimal exposure to dairy product futures prices. This has implications for dairy firms and investors, who seek to understand volatility and returns in the dairy products and the stocks they trade in, and for policymakers, who seek to control or mitigate undesirable dairy product price volatility.

Key words: comovement, equity, returns, volatility, dairy.

1. Introduction

Significant commodity price shocks have occurred throughout history, with earliest records of supply shocks in the 1930s and the 1970s, through to the commodity price boom after year 2000 and the Global Financial Crisis (GFC) of 2007–08 (Jacks *et al*. 2011). This is followed by sudden price declines of iron ore and coal in 2011 (Dwyer *et al*. 2011) and global dairy products in 2015 and 2016, which resulted in an overall slowdown in economic growth, affecting business profits and household income (Piot-Lepetit and M'Barek 2011; Devlin *et al*. 2011; Reserve Bank of Australia 2015).

There are two key motivations to this study. First, literature has largely focused on the exposure of the returns and volatility of more economically pervasive commodities, such as gold and oil, against their respective producer firms (Blose and Shieh 1995; Huang *et al*. 1996; Jones and Kaul 1996; Tufano 1998; Sadorsky 1999; Faff and Brailsford 1999; Ciner 2001; Twite 2002; Park and Ratti 2008; Baur 2014). In agricultural commodities, Declerck (2014) has shown a low correlation between wheat prices and agricultural stock prices, with the result being attributed to the low bargaining power of food

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processors, and the stickiness of food prices. This paper fills the gap in the literature by studying the volatility spillover between the returns of dairy product futures and dairy processing firms.

Second, the ownership structure of the dairy processing industry may be distinguished between cooperatives and non-cooperatives. Farmer cooperatives are not listed on exchanges and are structured based on dairy processing firms owned by farmers (Chaddad and Cook 2004). Hence, the cooperative supplier–producer value chain is tightly integrated and a high level of share value exposure to dairy product price risks is expected because fluctuations in input milk prices will be directly passed on to changes in dairy product prices. This mechanism is similar to the industrial organisation of non-dairy commodities, where the share value of non-dairy producers, such as mining companies, will fluctuate when the volatility of commodity prices increases. In the case of this study, which focuses on dairy processing firms within a non-cooperative ownership structure, the value chains and the industrial organisation of dairy products are based on suppliers (e.g. the farmers) who do not own the processing companies (Australian Competition and Consumer Commission 2017, p. 32). Hence, higher input milk prices will be passed on by farmers to dairy processing firms as costs, but the volatility relation between the returns of dairy processing firms and dairy product futures are expected to be low because in a non-cooperative ownership structure, dairy processing firms can independently absorb much of the increase in input milk prices through internal operational changes that reduce costs elsewhere in the dairy processing firm.

Insights into the relationship between dairy product prices and dairy firm stock prices are useful for both investors and policymakers seeking to manage financial market risk. Investors include a wide range of private economic actors seeking to trade in dairy or dairy products and manage their price risk, such as dairy farmers and dairy processing firms, and other third parties seeking to speculate on commodity price and stock price movements, such as investment companies. Investors' decisions are influenced by the expected returns and expected volatility of futures and equities markets, as they seek to maximise returns and minimise risk (Staugaitis 2019). Therefore, an understanding of the cross-market relationship between dairy product futures and dairy stocks, in terms of returns and volatility, may help guide investors on achieving their goals moving forward.

2. Institutional setting

The nature of value chain and industrial organisation of the dairy sector is different to other types of non-perishable commodities such as gold, silver or oil. Such differences include the structure of dairy suppliers (farmers), processing firms, the structure of dairy product futures and spot markets and government regulations. Dairy market products include milk, cheese, butter, cream, dairy desserts, yogurt, drinkable yogurt and sour cream. Figure 1

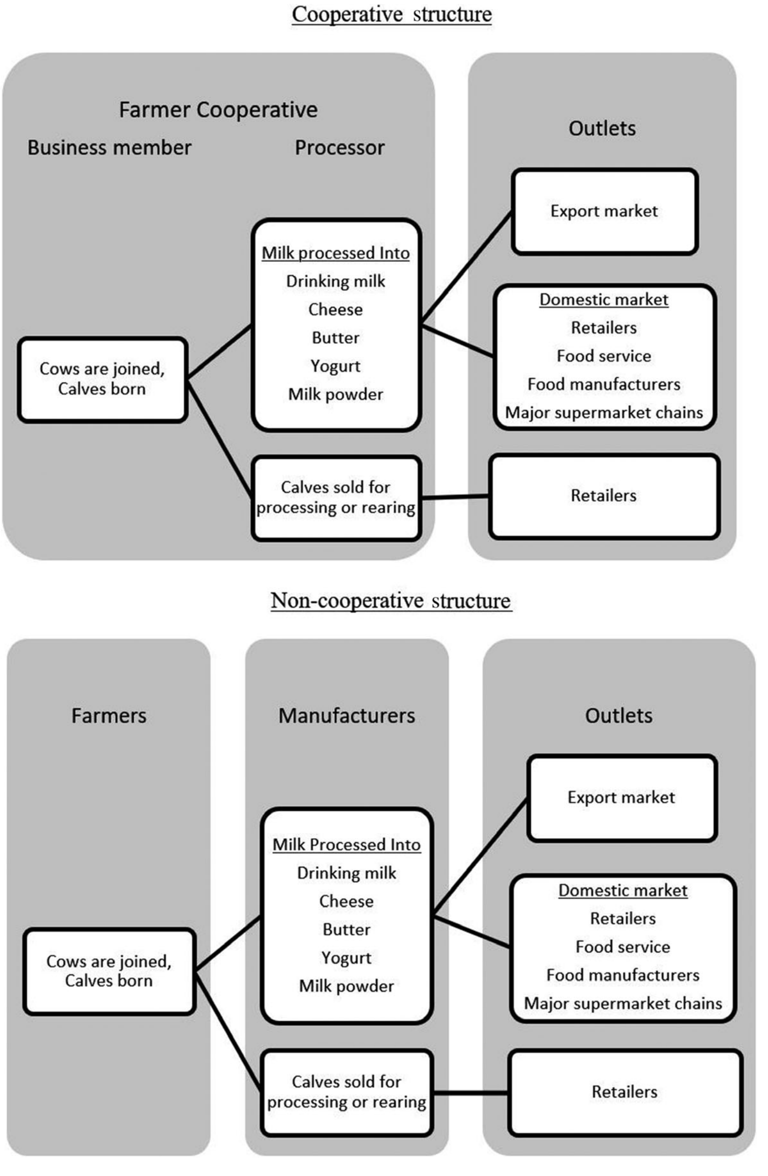

Figure 1 Cooperative versus non-cooperative dairy sector value chain.

depicts the difference between a cooperative versus a non-cooperative ownership structure. Unlike non-perishable commodities, the manufacturers in a non-cooperative dairy sector heavily rely on their suppliers (farmers) for input supplies given the two are independently owned.

Figure 2 provides a framework for the determination of dairy product spot, futures and farm gate prices, and can be viewed in conjunction with the value chain system depicted in Figure 1 in order to understand the effects of the organisational structure of the dairy sector on companies' values and

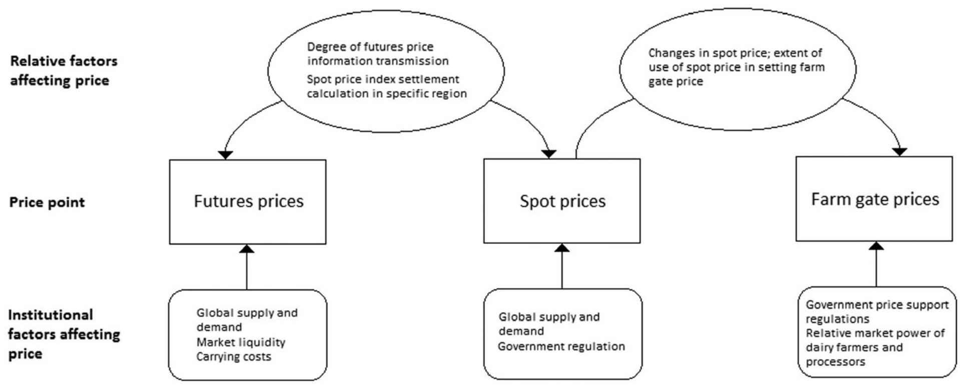

Figure 2 Dairy price formation framework.

price transmission effects. The connection between futures prices and spot prices of the underlying asset is determined by the mechanism of price discovery, where the proper value (thereby price) of an asset is established through the interactions between buyers and sellers and the information they have on hand.

The price of a dairy or dairy product futures contract at settlement is primarily based on the spot market index for the contract's underlying asset and differs between regions. New Zealand (NZX) dairy product futures are based on an index reflecting the average of the two prices at which the underlying asset was traded at biweekly auctions, which are conducted by Agrifax and GDT (GlobalDairyTrade). US (CME) dairy product futures are based on an index of a weighted moving average of the National Dairy Product Sales Report (NDPSR) weekly announced prices from up to the past two months (Białkowski and Koeman 2018). European Energy Exchange (EEX) dairy product futures are based on an index of the unweighted average of traded prices established in Germany, France and the Netherlands (European Energy Exchange 2018). However, the question that remains is on which market, futures or spot, price discovery takes place. In a literature review of agricultural commodities and derivatives, Garcia and Leuthold (2004) conclude that price discovery takes place, to a large extent, on futures markets, with information being transmitted to the spot market. However, this relationship may be constrained by low liquidity and trading volume. This finding supports Crain and Lee (1996), who suggest that futures prices are the preferred source of price data for calculations of returns and volatility because volatility is primarily transferred from futures to cash prices.

The relationship between dairy product spot prices and farm gate prices varies internationally due to differences in firm structure and government regulations. The New Zealand (NZ) government is not involved in the setting of farm gate prices for dairy products. The largest dairy processor in NZ is Fonterra, a cooperative owned by NZ dairy farmers. Fonterra's farm gate prices are calculated retrospectively, meaning the final price is connected to the prior period's sales, rather than current spot prices. This retrospective price setting is not only conducted by cooperatives, but also conducted by corporate processors (Australian Competition and Consumer Commission 2018, p. xxii). Specifically, prices are calculated by taking the total revenue if all milk collected was sold as standard dairy commodities in the world market at GDT prices, less reasonable costs associated with the distribution and marketing of the milk (Fonterra 2018). Auditor Ernst & Young oversees this price-setting process. In the United States, while a large portion of dairy farmers are also in cooperatives, the US government has a significant influence on farm gate prices received by US dairy farmers, in contrast to NZ. The Federal Milk Marketing Orders establish agreement terms between US dairy farmers and processors, as well as a minimum farm gate price (Agricultural Marketing Service 2018). In most regions, the minimum farm gate milk price is established based on the value of the products made from it. For example, in Australia, approximately 40 per cent of the milk production is exported as manufactured products (Australian Farm Institute 2019). Thus, the global market, through international market prices, becomes the biggest driver of the farm gate price in Australia. Further, it implies that farm gate milk prices are positively connected to the spot and futures prices of dairy products, but only to a limited extent due to the price rigidity and asymmetric price transmission in the dairy product market.

The disconnect between spot prices and farm gate prices for dairy products may also be exacerbated by the large market share of cooperatives, as opposed to corporate dairy processors. In theory, in a situation with a large number of suppliers and a small number of buyers, the buyers will hold monopsonistic price setting power. However, cooperatives challenge the price setting power of their buyers by cooperating together and can therefore negotiate higher prices (Liang and Hendrikse 2016). Empirical evidence provides support for this theory when applied to the dairy sector. In the United States, dairy cooperatives were found to utilise their market power to increase their farm gate price by 9 per cent above their marginal cost (Cakir and Balagtas 2012). The high market share of dairy cooperatives in Europe has likewise resulted in dairy firms paying higher farm gate prices with their specific region (Müller *et al.* 2018).

It should be noted that asymmetrical price transmission effect may be specific to regions where dairy cooperatives do not hold high degrees of market power in that region. For instance, the farm gate price in Australia is predominantly driven by international market prices (Australian Farm Institute 2019), which in turn reduces the market power of farmer cooperatives. Another case is the US government, which utilises its regulatory power to intervene in farm gate prices and this is expected to reduce the market power of dairy cooperatives. However, Cakir and Balagtas (2012) have presented evidence which suggested otherwise.

Figure 3 illustrates this theory, where P_p^+ is an increasing farm gate price; P_p^- is a decreasing farm gate price; P_r^+ is the retail price resulting from the

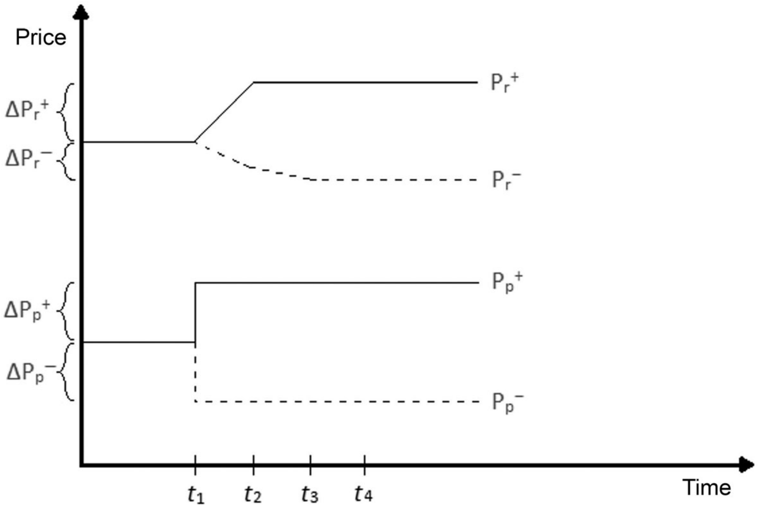

Figure 3 Illustration of asymmetric price transmission from farm gate to retail.

farm gate price increase; and P_r^- is the retail price resulting from the farm gate price decrease. As shown, a farm gate price increase results in a quick and complete increase in the retail price, whereas a farm gate price decrease results in a slow and incomplete decrease in the retail price. Early research finds this theory of asymmetrical price transmission to be accurate in describing the US dairy sector (Kinnucan and Forker 1987). In an examination of the US butter market, Chavas and Mehta (2004) find strong evidence of retail price response asymmetry in both the short term and the long term. However, in contrast, weak evidence of wholesale price response asymmetry was found. These authors suggest multiple causes of this asymmetry, beyond only improving earnings. The Dairy Price Support Program enforced at the time was thought to play a significant role during milk price shocks. The slow downward adjustment of retail prices may also occur due to search costs, the costs incurred by consumers finding the best price. Rational consumers are thought to search less when prices are falling. Menu costs – the costs incurred by firms from changing their prices – have also been proposed.

Recent research largely corroborates the earlier findings on price asymmetry and market power. Awokuse and Wang (2009) find strong evidence of asymmetric price transmission from producers to retailers for fluid milk and butter, but not for cheese. These results used different data, from 1987 to 2006, and confirmed previous findings, despite using a different empirical methodology. Hahn *et al.* (2016) show that dairy price transmission occurs from farm milk to retail cheese prices in an empirical application of their vector error correction model. Further evidence of asymmetry in US dairy markets has been observed (Stewart and Don 2011). The nature of price transmission in European countries has also been examined. In Poland, from 1995 to 2006, evidence suggested significant short-term and long-term asymmetries in price transmission for fluid milk from producer to retail level (Fałkowski 2010). Similar results were found in the Greek milk sector (Rezitis and Reziti 2011). Contrary results were found in the Turkish milk sector, however, with researchers observing retail prices responding to milk price reductions faster than increases (Tekgüç 2013). In a meta-analysis of price transmission in the general agriculture sector, Bakucs *et al.* (2014) find asymmetries are greater in the presence of highly fragmented farm production, that is a large quantity of farms, operational restrictions on retailers and government intervention. On the other hand, symmetries are associated with greater market power of retailers and higher entry barriers into the retail sector.

3. Literature review

3.1 Perishable commodities

Declerck (2014) shows an insignificant effect between wheat index futures returns from the Chicago Board of Trade (CBOT) on the stock returns of a total of 49 agricultural processing companies primarily from the United States and Japan over a period of January 1996 through February 2007. The study suggests that firms being examined were not primary producers, but rather processors that use other inputs and a variety of operating processes, which may possibly dilute the effect of the wheat price changes on the earnings of the firms. Further, the study highlights that perfect competition, specifically a lack of bargaining power on the part of food processors, and food price stickiness, may explain the reduction in the correlation between returns of wheat index futures and agricultural processing firms.

3.2 Non-perishable commodities

Tufano (1998) studies the effects of changes in the price of gold on the share price returns of 48 North American gold mining firms from January 1990 to March 1994 and reveals that the returns of gold mining stocks move 2 per cent for every 1 per cent change in the gold price. In addition, the exposure to gold price fluctuations varies significantly across firms and is found to be related to a firm's own hedging or diversification behaviour, and also their degree of financial leverage. Gold miners which hedged their production were less exposed to gold price fluctuations, and firms with higher leverage were more exposed. Additionally, larger firms with larger market value of equity tend to have higher exposure, possibly due to their lower information asymmetry compared with smaller firms. Other research into gold prices and firm value was found to produce consistent results. These findings are consistent with Blose and Shieh (1995), who find that the price of gold, along with the miner's production costs and gold reserves, determines the value of the firm.

Studies of Australian gold mining firms yield inconsistent evidence on their sensitivity to the movements of gold prices. Fang *et al.* (2007) use data on Australian gold mining firms from 1995 to 2000, which is a period of high gold price volatility, to show that a 1 per cent change in the gold price resulted in a 1.85 per cent, 1.78 per cent and 1.02 per cent change in the gold stock index from 1995-96, 1997-98 and 1999-2000, respectively. Twite (2002) shows that twelve Australian gold mining firms from January 1985 to December 1998 were found to be less volatile than the gold price, with the average gold mining stock moving 0.76 per cent for every 1 per cent change in the gold price. Similarly, Baur (2014) finds that a 1 per cent change in the gold price causes a 0.7 per cent and 1.1 per cent change in the share price of gold mining firms using weekly and monthly returns, respectively, over the period of 1980 through 2010.

Huang *et al.* (1996) examine the effects of oil price changes on three specific firms in the oil industry, namely Chevron, Exxon and Mobil, and on the overall US market through the S&P 500 index from 1979 to 1990. They find that returns to oil futures demonstrate significant correlation with the returns to individual oil companies, but not with the aggregate US stock market. Jones and Kaul (1996) examine quarterly market index data of four countries – the United States, Canada, Japan and the United Kingdom – from 1947 to 1991 to show that oil price changes significantly affect aggregate real stock return. Park and Ratti (2008) find that countries which are exporters of oil, such as Norway, experience significant positive impacts on real stock returns from oil price increases.

3.3 Volatility spillover

Volatility spillover is a phenomenon whereby the volatility in one market or commodity causes volatility in another market or commodity. Literature focuses on the volatility spillover between commodities, including gold, oil and agricultural futures, and between financial markets, which consists of futures and equities. Beckmann and Czudaj (2014) show that throughout the GFC, volatility in corn futures returns significantly affects the volatility of wheat and cotton returns. This linkage is attributed in part to potential speculation in the corn market, which has spread to other agricultural markets due to the increasing interdependency between markets in recent decades.

Du *et al.* (2011) show that shocks to the price of crude oil during the GFC appear to cause significant volatility in agricultural commodity markets, particularly in corn and wheat markets. Figure 4 shows oil, corn and wheat prices over the GFC period. While crude oil price volatility is explained by scalping, speculation and low levels of crude oil inventories, its effects on the corn and wheat markets are explained by a greater interdependency between the two commodity markets. This interdependence results from the use of corn as a substitute in the production of ethanol, an alternate source of energy. Therefore, higher crude oil prices increase the need for more

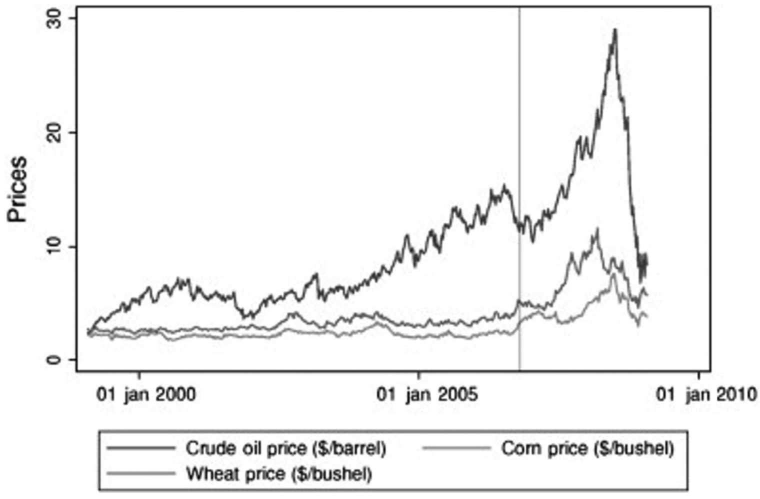

Figure 4 Crude oil, corn and wheat prices during the GFC (Du *et al.* 2011).

investment in ethanol production, and subsequently the demand and price of corn. Serra *et al.* (2011) confirm these findings and observe that the prices of corn, cotton and soya beans are linked to energy prices. With a focus on the Brazilian market, Serra (2011) finds significant links between the volatility in crude oil, ethanol and sugar prices.

Creti *et al.* (2013) find that coffee and cocoa, but not sugar, are highly correlated with the US S&P 500 index during a bullish stock market, but the level of these correlations reduces in the very short run when US markets become bearish. Kim (2015) investigates energy and agricultural futures, including wheat, soya bean, cotton, corn, live hogs, cocoa, coffee and sugar, and finds that speculation has no effect on volatility or may aid in the stabilisation of commodity futures markets. The stabilisation effect of speculators is also found in other agricultural and energy futures (Büyükşahin and Harris 2011; Brunetti *et al.* 2016).

Mensi *et al.* (2013) find that S&P 500 returns have a significant causal effect on the returns of gold, WTI crude oil and wheat, in descending order. This is consistent with Thuraisamy *et al.* (2013), who show that, amongst mature equity markets, volatility spillover occurs from equity markets to commodity markets, while emerging markets exhibit spillover effects from commodity markets to equity markets.

4. Methodology and data

4.1 Methodology

To empirically examine the relationship between dairy product futures returns and the share price returns of firms, a suitable asset pricing model must be established. All returns are holding period returns based on the difference between the closing prices at *t* and *t-1* divided by the closing price at *t-1*. A model that accurately represents share price determination must also include other factors affecting share price returns beyond the dairy price factor as controls. The Carhart four-factor model – an extension of the Fama–French three-factor model – identifies four factors which together can largely explain the equities pricing and returns (Carhart 1997). These factors include market risk MKT (*m*), firm size, or market capitalisation SMB (*s*), book-to-market ratio HML (*h*) and monthly momentum MOM (*n*). With the inclusion of the dairy price factor (*d*), the model becomes a five-factor model, expressing share price returns as a function of these five factors. Firm fixed effects are specified in the regressions to account for variation amongst firms. The firm fixed effect model is presented in Equation 1:

$$R_{it} = \alpha_i + \beta_{im}R_{mt} + \beta_{is}R_{st} + \beta_{ih}R_{ht} + \beta_{in}R_{nt} + \beta_{id}R_{dt} + €_{it} \tag{1}$$

where

R_{it}, is the periodic return of stock *i* between time $t-1$ and *t*; α_i, is the mean return of stock *i* explained by other factors not accounted for, where $i = 1...n$; β_{im}, is the market beta, a measure of the sensitivity of the stock *i* returns to market returns; R_{mt}, is the periodic excess return of the market between time $t-1$ and *t*; β_{is}, is the firm size beta, a measure of the sensitivity of the stock *i* returns to firm size; R_{st}, is the periodic excess return of small firms over large firms between time $t-1$ and *t*; β_{ih}, is the book-to-market beta, a measure of the sensitivity of stock *i* returns to the firm's book-to-market ratio; R_{ht}, is the periodic excess return of high book-to-market firms over low book-to-market firms between time $t-1$ and *t*; β_{in}, is the monthly momentum beta, a measure of the sensitivity of stock *i* returns to the firm's monthly momentum; R_{nt}, is the periodic excess return of positive momentum firms over negative momentum firms between time $t-1$ and *t*; β_{id}, is the commodity beta, a measure of the sensitivity of stock *i* returns to the dairy returns; R_{dt}, is the periodic return of dairy product futures between time $t-1$ and *t*; $€_{it}$, is a statistical error term, in which $\sum €_{it} = 0$.

Although the Carhart four-factor model is commonly used in asset pricing finance literature, its limitations should be noted. First, all other things being equal, a higher market beta (β_{im}) implies a higher expected return. However, this assumption refutes the existence of a low beta or low-volatility premium, when low-volatility stocks have higher returns than high-volatility stocks (Black 1972). Second, the market risk factor in the model is localised to the region in which the firm is listed. For instance, Bega, an Australian dairy processing firm listed on the ASX, would utilise the Asia Pacific market factor from the Kenneth French data library (French 2018a). Third, the model does not control for idiosyncratic (firm-specific) risk factors which may have affected the periodic expected return of the stock independent of changes in the prices of its products or input supplies. For example, Australian dairy firm Bega Cheese acquired Vegemite brand owned by Mondelez International (formerly Kraft Foods Inc.) in January 2017. Another case is the Canadian dairy processing firm Saputo Inc., which acquired Dairy Crest Group in the UK, and Lion-Dairy and Drinks in Australia in April 2018.

A firm's share price returns are calculated on a daily basis using the period's adjusted closing prices. The returns of the four factors are calculated by Kenneth French according to French (2018b) and French (2018c). Calculations are as follows:

1. R_{mt}, the equity market risk premium, is calculated by subtracting the risk-free rate, the United States one-month T-bill rate, from the growth rate of the market portfolio in the region where the stock is listed;
2. R_{st}, the firm size premium, is the equal-weight average of the returns on the three small stock portfolios for the region minus the average of the returns on the three big stock portfolios
3. R_{ht}, the book-to-market premium, is the equal-weight average of the returns for the two high book-to-market portfolios for a region minus the average of the returns for the two low book-to-market portfolios; and
4. R_{nt}, the momentum premium, is the equal-weight average of the returns for the two winner portfolios for a region minus the average of the returns for the two loser portfolios

The returns to the dairy price factor R_{dt} are calculated on a daily basis. Dairy returns are calculated as an equally weighted geometric average of the daily returns to four dairy product futures traded on the Chicago Board of Trade (CBOT). The four dairy product futures are class IV milk (DK), cash-settled cheese (CSC), cash-settled butter (CB) and dry whey (DWY). All returns data are organised in a panel format. Next, an ordinary least squares linear regression is performed in order to assess the significance of each of the five factors in determining dairy firm stock returns, and to obtain coefficients for each factor. Specifically, we are interested in the significance of the dairy returns factor, the results of which will indicate whether or not dairy product futures returns are a factor in dairy stock price returns. Regressions are run on a year-by-year basis, in order to examine the changes in the significance of the dairy returns over the sample period. Firm fixed effects are specified in the regressions to account for variation amongst firms. Various lags are used to capture whether dairy product futures returns have a delayed effect on dairy stock returns.

Volatility spillover between dairy product futures, dairy equities, and from futures to equities, is examined with an application of the Diebold-Yilmaz spillover method (Diebold and Yilmaz 2012). The model uses forecast error variance decomposition (FEVD) to determine to what extent the forecast error variance of one variable can be explained by its own variance and the variance of other variables. This is used to determine the extent to which volatility in one asset affects volatility in another. In order to use FEVD, a vector autoregressive (VAR) model is estimated with lag order 2 with constant deterministic regressors specified. The VAR model takes the following form:

$$y_t = \emptyset_1 y_{t-1} + \emptyset_2 y_{t-2} + €_t \quad (2)$$

where,
y_t, is a $N \times 1$ vector of futures/equity volatilities; $\emptyset_1$, is a $N \times N$ coefficient matrix; $€_t$, is a $N \times 1$ vector of error terms.

This model is used to determine the spillover from each of the four dairy product futures, individually, to all ten dairy firms listed below, in order to examine the extent of dairy product futures volatility on the volatility of dairy firms. It is also used to determine volatility spillover within the dairy product futures market and within the dairy equities market. Weekly volatility is measured using the asset's realised variance, calculated by summing the daily squared returns.

4.2 Data

Futures, equities and factor data will be sourced on a daily basis over a period of five years, from 1 May 2013 to 30 April 2018. Dairy product futures prices of the four dairy products DK, CSC, CB and DWY will be gathered from the CBOT, sourced from Thomson Reuters Tick History (TRTH). Time series data of returns to each dairy product are created using the final three months of each individual futures contract. A three-month frequency is sufficient as the returns data are most reliable towards the end of the contract life, where liquidity is typically highest and price discovery is most efficient. The reason for using futures prices from CBOT over regional Australian and European exchanges is that the latter do not provide the necessary liquidity to facilitate a dairy product futures market. For example, the Australian Securities Exchange only consists of grain futures under agricultural derivatives[1]. The largest futures market in Europe, the EEX, provides 45 days of historical market data to the public, which is insufficient for the time span required in this study. It is also observed that the liquidity of dairy products traded on the EEX is very low compared with the CBOT. For instance, a high proportion of the 45 days of market data reveals zero open interest for European Liquid Milk Futures[2].

Equities data consist of the adjusted closing prices for each firm's shares. Ten dairy processing firms were chosen based on their market capitalisation, maturity and position within the supply chain. The global dairy production industry is highly fragmented, with 6,787 independent enterprises in 2018 as

[1] See https://www.asx.com.au/prices/asx-futures.htm.
[2] See https://www.eex.com/en/market-data/agricultural-commodities/dairy-products/european-liquid-milk-futures.

reported in the IBISWorld database, with most operators privately owned. Given that this study is limited to publicly listed dairy processing firms, the selection criteria are based on firms which carries large capitalisation, stable earnings and which cater to a large portion of dairy consumers. Further, firms are selected from exchanges around the world covering different regions such as Australia/New Zealand (A/NZ), North America (NA) and Europe (E). Table 1 shows the list of the chosen firms and descriptive statistics of their returns and firm characteristics. Factor data are gathered from the Kenneth French data library (French 2018a). Factor data exist for specific continents and regions, namely the United States, North America, Europe and Asia Pacific excluding Japan. The factor data used for each firm correspond to the location in which the firm is listed publicly.

Table 2 presents the summary statistics of the dairy product futures returns (DK, CSC, CB and DWY) and index return (dairy price factor R_{dt}) data.

5. Results

Table 3 shows the coefficients and significance of each factor in the regression on a year-by-year basis. All results include firm fixed effects to account for variations amongst firms. Given that each firm operates mutually and exclusively in each region (e.g. Lifeway Foods is traded on the NASDAQ in the North American region), the firm fixed effects subsume regional fixed effects, which implies that the regression results also account for variations amongst regions of operation. The presentation of the full set of results including the coefficients and significance of firm fixed effects is shown in Appendix S1. The dairy product futures price factor was shown to be significant in year 1 with a lag of three trading days, and significant in years 2 and 3 with a lag of five trading days. Years 4 and 5 demonstrated no statistical significance for the dairy price factor. Coefficients of the dairy price factor range from −0.029 to −0.019 for years 1 to 3 in which the factor is significant. Little variation in coefficients suggests that the degree to which firm stock prices are exposed to changes in dairy product futures prices is relatively consistent in the first three years. Additionally, negative coefficients suggest that firm stock prices are inversely correlated with movements in dairy product futures prices. A mean coefficient of −0.024 implies that a 1 per cent change in dairy product futures returns causes a −0.024 per cent change in dairy firm stock prices. Furthermore, results demonstrate that the local MKT, SMB, HML and MOM factors are significant determinants of dairy firm returns, but their significance varies year to year. The MKT factor was highly significant in all years examined, with a mean coefficient of 0.504, which suggests dairy firm stock prices are more influenced by the overall market return than movements in dairy product futures prices. Likewise, the SMB, HML, and MOM factors, when significant, had larger coefficients than the dairy price factor.

Table 1 Descriptive statistics of selected firms: returns and firm characteristics

	Exchange	Region	Mean	Median	SD	Kurtosis	Skewness	Min	Max	Market value (AUD)	Global market share (%)
Adecoagro SA	NYSE	NA	0.0002	0	0.018	2.54	0.09	−0.09	0.08	1,141M	0.16
Dean Foods	NYSE	NA	−0.0003	0	0.020	13.93	−1.05	−0.21	0.14	154M	1.52
Lifeway Foods	NASDAQ	NA	−0.0004	−0.0007	0.026	10.09	0.86	−0.13	0.24	75M	0.02
Saputo	TSX	NA	0.0005	0.0003	0.011	2.97	0.25	−0.06	0.06	16,984M	1.72
Fonterra	ASX/NZX	A/NZ	0.0001	0	0.013	2.94	−0.20	−0.08	0.06	5,915M	2.51
Bega	ASX	A/NZ	0.0010	0	0.020	12.31	0.61	−0.17	0.15	966M	0.20
Parmalat	BIT	E	0.0003	0	0.008	24.16	2.14	−0.04	0.10	8,521M	0.65
Danone SA	EPA	E	0.0003	−0.0002	0.012	1.47	0.02	−0.05	0.04	84,355M	5.40
Savencia SA	EPA	E	0.0005	0	0.011	7.21	0.09	−0.09	0.06	1,470M	1.06
Dairy Crest Group	LSE	E	0.0004	0.0008	0.015	10.36	0.44	−0.08	0.15	1,196M	0.11

Note: This table presents the descriptive statistics of the returns of selected firms, market value, global market share and the region/exchange in which they are listed. Global market share (%) is calculated by dividing the average annual sales by the average annual global industry total sales. Annual sales are obtained from Reuters, and the annual global industry total sales are sourced from IBISWorld. Both measures are averaged across the sample period 2013 through 2018. Firms are selected from exchanges around the world covering different regions such as Australia/New Zealand (A/NZ), North America (NA) and Europe (E).

Table 2 Descriptive statistics of dairy product futures returns and index returns

	Mean	Median	SD	Kurtosis	Skewness	Min	Max
DK	−0.0003	0	0.008	6.30	0.28	−0.04	0.05
CSC	0.0000	0	0.010	2.59	0.33	−0.04	0.05
CB	0.0004	0	0.011	2.37	0.25	−0.05	0.06
DWY	0.0001	0	0.014	4.22	0.07	−0.07	0.07
Dairy Futures Index	0.0003	0	0.028	2.26	0.26	−0.10	0.13

Note: This table presents the returns of the dairy product futures: DK (milk), CB (butter), CSC (cheese), DWY (dry whey) and the index comprised of these four dairy products.

Table 4 shows the results of the FEVD model. From May 2013 to April 2018, the total spillover index, inclusive of both dairy product futures and firms, was 22.53 per cent. The exposure of firm volatility to futures volatility is quantified in the right-most column. The data represent the percentage of the forecast error variance of each dairy firm that can be explained by the variance of the four dairy product futures. The extent of volatility spillover from futures to firms ranges from 1.07 per cent for PLT (Parmalat) to 14.1 per cent for BN (Danone). The average volatility spillover from dairy product futures to firms is 5.49 per cent.

Results also show there exist very low levels of volatility spillover between dairy firms, but higher levels of spillover between dairy product futures, particularly between milk and butter. This result may be due to dairy product futures such as milk and butter being financial contracts that are traded globally in a highly efficient market. In contrast, the returns volatility of dairy firms may be determined by firm-specific and market wide risk factors, which may be dispersed randomly across firms operating within or across regions. 34.34 per cent of volatility in milk futures can be accounted for by volatility in butter futures, and 27.74 per cent of volatility in butter futures can be accounted for by volatility in milk futures. This suggests that the volatility spillover between the two dairy products is bidirectional. Spillover levels between dairy product futures were not consistent over time, but instead showed a slight decline over the sample period from 2013-15 to 2016-18, as shown in Figure 5.

6. Discussion

From May 2013 to April 2016 (years 1, 2 and 3), dairy price returns showed a statistically significant negative effect on the share price returns of firms, but the significance was not observed from May 2016 to April 2018 (years 4 and 5). This indicates that the association between dairy price returns and the share price returns of firms is generally weak across the whole sample and time-varying, which is supported by the structural break in the trends shown in the Global Dairy Trade Price Index in Figure 6. In this figure, the global dairy trade prices generally decreased from 2013 to 2015 and the trend reversed from 2016 to 2018. A mean coefficient of −0.024 suggests that the

Table 3 Year-by-year regression results excluding firm fixed effects coefficients

Independent variables	1/5/2013 to 30/4/2014			1/5/2014 to 30/4/2015			1/5/2015 to 30/4/2016			1/5/2016 to 30/4/2017			1/5/2017 to 30/4/2018		
	Est.	*t*-Stat	Std. Error	Est.	*t*-Stat	Std. Error	Est.	*t*-Stat	Std. Error	Est.	*t*-Stat	Std. Error	Est.	*t*-Stat	Std. Error
A. Lagged, 3 days															
Intercept	0.047	0.457	0.103	0.010	0.108	0.094	0.078	0.691	0.113	0.035	0.334	0.105	−0.128	−1.32	0.096
DAIRY	−0.029**	−2.08	0.014	−0.010	−1.05	0.009	−0.010	−0.908	0.011	−0.011	−0.955	0.011	0.008	0.676	0.011
MKT	0.583***	11.5	0.051	0.494***	11.9	0.041	0.465***	13.1	0.035	0.439***	10.2	0.042	0.551***	11.2	0.048
SMB	0.337***	3.68	0.091	0.248***	3.71	0.066	0.033	0.515	0.063	0.069	0.900	0.076	0.260***	2.99	0.086
HML	0.053	0.566	0.094	−0.132	−1.62	0.081	−0.119	−1.51	0.078	−0.297***	−4.02	0.073	−0.133	−1.63	0.081
MOM	−0.091	−1.182	0.077	0.013	0.209	0.063	−0.035	−0.758	0.046	0.174***	2.90	0.059	−0.415***	−5.58	0.074
Adjusted R^2	0.063			0.056			0.076			0.039			0.053		
F-statistic	12.79***			11.42***			15.48***			8.12***			10.92***		
Number of observations	2407			2412			2423			2429			2431		
B. Lagged, 5 days															
Intercept	0.012	0.115	0.102	−0.014	−0.144	0.094	0.036	0.319	0.113	0.012	0.113	0.106	−0.136	−1.43	0.094
DAIRY	−0.022	−1.56	0.013	−0.025***	−2.57	0.009	−0.019*	−1.69	0.011	0.002	0.207	0.011	0.002	0.185	0.011
MKT	0.550***	10.9	0.050	0.483***	11.8	0.040	0.464***	13.2	0.034	0.449**	10.2	0.043	0.558***	11.6	0.048
SMB	0.317***	3.47	0.091	0.236***	3.57	0.065	0.039	0.625	0.063	0.119	1.53	0.077	0.227***	2.68	0.084
HML	0.110	1.17	0.093	−0.128	−1.58	0.080	−0.095	−1.22	0.077	−0.328***	−4.40	0.074	−0.108	−1.36	0.079
MOM	−0.039	−0.509	0.077	0.003	0.050	0.063	−0.035	−0.780	0.045	0.152***	2.52	0.060	−0.407***	−5.62	0.072
Adjusted R^2	0.057			0.057			0.075			0.039			0.054		
F-statistic	11.59***			11.56***			15.31***			8.217***			11.14		
Number of observations	2413			2420			2430			2432			2437		

Note: This table presents the condensed version of the firm fixed effects results for the year-by-year regression of the firm share price return on the dairy futures index factor and the Carhart four-factors including the coefficients and significance of firm fixed effects. The Carhart four-factors include market risk (MKT), firm size, or market capitalisation (SMB), book-to-market ratio (HML) and monthly momentum (MOM). The coefficients and significance of firm fixed effects are presented in full in Table S1.
*, ** and *** indicate significance at the 5%, 1% and 0.1% levels, respectively.

Table 4 Diebold-Yilmaz spillover results

To	From														Contribution from others	Contribution from dairy futures
	DK	CB	CSC	DWY	AGRO	DF	LWAY	BGA	FSF	BN	DCG	PLT	SAVE	SAP		
DK	52.32	34.34	2.05	5.14	0.5	0.18	0.07	0.21	0.39	1.17	0.26	0.32	0.45	2.61	47.69	
CB	27.74	59.16	2.72	2.66	0.29	0.54	0.29	0.68	0.55	1.74	0.6	0.02	1.09	1.91	40.83	
CSC	2.64	3.79	77.86	5.04	0.96	0.07	0.38	1.56	1.59	0.77	0.33	0.09	3.97	0.95	22.14	
DWY	12.19	7.79	4.31	66.35	0.50	0.22	0.15	0.2	0.49	4.16	0.08	0.50	0.55	2.50	33.64	
AGRO	3.04	3.23	1.15	1.89	80.36	0.20	0.33	1.83	0.83	2.68	0.49	0.68	1.70	1.57	19.62	9.31
DF	0.77	1.06	1.78	1.29	1.23	82.38	0.63	1.24	0.59	1.69	4.62	0.17	0.21	2.36	17.64	4.90
LWAY	0.52	0.43	0.47	0.67	0.30	0.24	80.92	6.73	0.99	3.96	0.25	0.88	1.31	2.32	19.07	2.09
BGA	0.19	0.54	1.94	0.40	1.90	0.60	1.14	90.42	0.38	0.37	0.47	0.17	1.29	0.17	9.56	3.07
FSF	3.52	0.81	3.74	1.19	1.53	0.16	0.26	3.26	81.55	0.87	0.24	0.37	1.31	1.20	18.46	9.26
BN	5.00	4.13	2.83	2.14	1.27	0.26	1.54	0.37	1.93	72.01	1.27	0.52	1.51	5.23	28.00	14.1
DCG	0.81	1.12	1.90	0.19	1.20	0.14	0.19	0.31	0.48	2.99	82.85	0.29	0.57	6.96	17.15	4.02
PLT	0.17	0.01	0.60	0.29	0.66	0.05	0.06	2.75	0.11	0.19	0.36	94.48	0.14	0.11	5.50	1.07
SAVE	0.63	0.32	0.43	0.24	1.13	0.27	0.37	0.66	0.78	0.46	3.45	0.20	89.92	1.13	10.07	1.62
SAP	2.15	0.74	0.49	2.09	0.13	0.33	2.09	3.54	1.52	5.62	5.82	0.55	1.00	73.95	26.07	5.47
Contribution to others	59.4	58.3	24.4	23.2	11.60	3.3	7.5	23.3	10.6	26.7	18.2	4.8	15.1	29.0	315.4	
Contribution to total (others plus self)	111.7	117.5	102.3	89.6	92.0	85.6	88.4	113.8	92.2	98.7	101.1	99.2	105.0	103.0	1400.0	Average Contribution
Percentage of others to total	53.2%	49.6%	23.9%	25.9%	12.6%	3.8%	8.5%	20.5%	11.5%	27.0%	18.0%	4.8%	14.4%	28.2%	22.5%	5.49%

Note: This table presents the Diebold-Yilmaz spillover results for dairy product futures: DK (milk), CB (butter), CSC (cheese), DWY (dry whey). Dairy firms: AGRO (Adecoagro SA), DF (Dean Foods), LWAY (Lifeway Foods), BGA (Bega Cheese), FSF (Fonterra), BN (Danone), DCG (Dairy Crest Group), PLT (Parmalat), SAVE (Savencia SA) and SAP (Saputo).

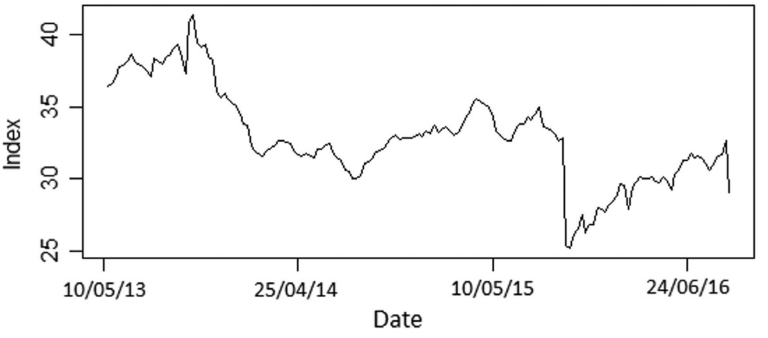

Figure 5 100 weeks ahead moving volatility spillover index between dairy product futures.

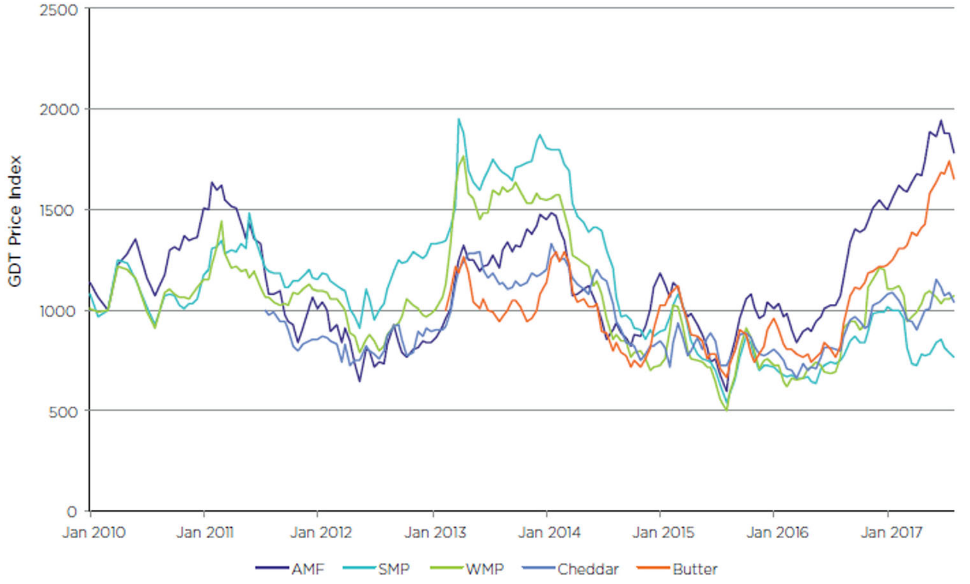

Figure 6 Global dairy trade price index components (Australian Competition and Consumer Commission 2018). [Colour figure can be viewed at wileyonlinelibrary.com]

degree of this effect was largely economically insignificant, consistent with the hypothesis. Likewise, an average volatility spillover contribution from dairy product futures to dairy stocks of 5.49 per cent suggests that dairy product price volatility has little effect on the volatility of dairy stock prices. Contrary to the hypotheses, no significant volatility spillover occurred from dairy equities to dairy product futures. Overall, these results suggest that dairy processors' stock prices are largely insensitive to dairy prices, in terms of both returns and volatility.

Two reasons may explain the lack of sensitivity of the stock prices of dairy processors to dairy product futures prices: firstly, the extent to which dairy product futures returns are correlated with the farm gate prices paid by processors to their suppliers; secondly, the extent to which the changes in farm gate prices influence the profitability and stock price of dairy firms in a non-cooperative organisational structure setting. Refer to Section *2. Institutional Setting* for a description of the dairy value chain and the industrial organisation of the dairy sector. In theory, dairy processing firms, which purchase milk input at farm gate prices for processing and sale, should experience an increase in costs and reduction in profit when farm gate prices rise. Conversely, decreasing farm gate prices should reduce their expenses and increase their profits. This premise, which forms the basis of this experiment, may not offer a sufficient insight into the determinants of dairy firm earnings. The added complication is that earnings are determined by overall revenues and costs. In the case of dairy processing firms, revenues come from a diverse range of output products produced and sold by the firm. In comparison, gold miners' revenue depends highly on their only output; that is, the gold they produce. This may explain the sensitivity of the share price of gold miners to gold prices, but dairy firms' lack of sensitivity to dairy product prices.

These findings have implications for dairy firms, investors and policymakers. Dairy firm's stock prices exhibiting a lack of sensitivity to dairy product prices demonstrate the effectiveness of dairy firm's ability to either hedge against dairy price movements or alter their other operating costs and improve revenues so that input prices do not significantly affect their earnings. Investors seeking to profit from dairy product and firm stock price movements now possess a greater insight into the bidirectional influences across the two asset classes. The finding that dairy stocks and dairy products have little exposure to one another helps inform investors on which investment decisions are optimal to maximise returns and minimise risk. For instance, investors in dairy firms, when managing portfolio volatility, need not focus on dairy product price volatility as it is not a significant factor. Furthermore, a lack of volatility spillover between dairy products and stocks implies that policymakers seeking to control or mitigate future episodes of dairy price volatility may need to look elsewhere to find the source of observed volatility.

It must be noted that the data and methodology used in this paper are not without limitations. Futures data were gathered on a three-month basis, as liquidity was deemed sufficient to give an accurate representation of returns. However, due to futures prices converging towards their underlying spot prices as the maturity date arrives, it may have been an improvement to gather futures data on a monthly basis, using the front-month contract at the time. Additionally, a data time span over five years may not be sufficient to accurately gauge the exposure of dairy stock prices to commodity prices. A longer time span, for example ten years, is typical in the literature. Comparing futures traded on one exchange, the CBOT, to firms traded on multiple regional non-US exchanges may result in noise in the models employed in this study because of the potentially increased bias in the price transmission between regional farm gate milk prices and the prices of dairy product futures. However, it is noted in the *4.2 Data* section that the dairy product futures traded on exchanges other than CBOT are not sufficiently liquidity. Furthermore, an ordinary least squares regression on daily data may produce biased estimates of the factor coefficients (Scholes and Williams 1977). This appears more problematic for less liquid securities, including the dairy product futures and some dairy processing stocks. Daily data may result in factor coefficients being biased downwards, and subsequently an inaccurate estimate of exposure to dairy prices.

7. Conclusions

This paper conducts a preliminary analysis into the relationship between dairy product prices and dairy firm stock prices from May 2013 to April 2018 in terms of returns and volatility. Overall, results indicate that the returns and volatilities of the prices of dairy processing firms have little exposure to the returns and volatilities of dairy product prices. This result may be due to various reasons. First, there exists dissociation between spot/futures prices for dairy products and the farm gate prices paid by dairy processing firms, due to the way farm gate prices are set in different countries, and the heightened market power of dairy suppliers. Second, this study focuses on investor-owned dairy processing firms within a non-cooperative ownership structure, where much of the increase in input milk prices can be offset by operational changes that reduce costs elsewhere in the dairy processing firm. These findings have implications for economic actors involved in the dairy industry, such as firms, investors and policymakers. Finally, farm gate prices may not accurately reflect current spot or futures prices due to the retrospective nature of farm gate price setting in NZ, and the government price supports in the United States. Therefore, this may explain the inability of dairy product futures returns to predict dairy processor earnings. Future research may wish to further clarify the relationship between spot prices and farm gate prices across different countries. Additionally, future studies may consider data across different time frames and using different statistical methods, or broaden the analysis by considering alternative agricultural commodities.

Data availability statement

The data that support the findings of this study are available from Thomson Reuters Tick History. Restrictions apply to the availability of these data, which were used under licence for this study.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Year-by-year regression including firm fixed effects results.