Profit Margin Hedging in the New Zealand Dairy Farming Industry

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Abstract

This paper explores the effectiveness of Whole Milk Powder futures to protect the net profit margin of NZ dairy farms. The proposed strategy for farms suggests selling futures contracts when the current futures prices (adjusted for basis risk and commissions) are above the break-even prices. We use historical data from 2011 to 2017 and simulate a profit margin hedging strategy with a target price that covers total cash expenses of a representative farm. We find that the representative farm's payout of this strategy is statistically different to the continuous hedging and no hedging strategies, even after accounting for brokerage fees and basis risk. Additionally, we apply the strategy using actual farm-level data and demonstrate that, considering high transaction costs, the strategy helps to reduce discretionary cash variance by 35%, semivariance by 74% and decreases chances of financial distress by 18%. Moreover, we document that the strategy increases the mean of discretionary cash for individual farms by 36%, and that farms with a high level of leverage experience the biggest improvement. We estimate that if the strategy was adopted by all NZ dairy farms over a five year period, it could have generated NZD 0.49 billion yearly, on average.

Keywords: Profit Margin Hedging; Dairy Risk Management; Futures; Random Walk.

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1 Introduction

New Zealand (NZ) is the eighth largest milk-producing country in the world, exporting about 95% of its dairy production.[1] The dairy sector is the largest goods export sector of NZ, with an average annual export revenue of NZD 13.2 billion over the past five years to 2017 (Ballingall & Pambudi 2017). In 2017, Whole Milk Powder (WMP) accounted for 36% of total dairy export revenue, the highest proportion amongst all dairy products.[2] The dairy farming sector is the second most profitable farming sector in NZ (Ballingall & Pambudi 2017), however, recent milk payouts received by dairy farms have shown considerable variations. The dairy sector in NZ is free from government interventions, i.e. the government does not provide any price support mechanisms or subsidies and, hence, farms are exposed to shocks in global milk prices.[3] For most farms, the milk price per season is set by Fonterra, a farmer-owned cooperative, which controls about 80% of the NZ milk supply. The price of milk per season depends on five reference commodities which are WMP, Skim Milk Powder (SMP), and their by-products (butter, Anhydrous Milk Fat (AMF) and Buttermilk Powder (BMP)). Amongst those five commodities, WMP plays the most important role, as historically its contribution to the price of milk is about 62%.[4] In Figure 1, we show milk and WMP prices per season in NZD, where the WMP price is weighted by production during a season (Fonterra 2017). As can be seen from the graph, during the 2014-2015 season, the dairy sector experienced a downturn and the milk price dropped by 48%. The next season it further declined by 11% to 3.9 NZD per kg of milksolids. Consequently, this extreme volatility of milk prices led to a decline in operating profits of many dairy farms.[5] During the 2015-2016 season, total cash expenses exceeded the dairy cash income, resulting in negative profit margins for dairy producers (DairyNZ 2017). Such an inherently risky operating environment poses at least two problems. The first concerns the sustainability of farming businesses and the second is the inability of farms to service their debts. The Reserve Bank of NZ underlines the second problem in its financial stability report, stating that the dairy sector's indebtedness is one of the top three most important domestic risks to NZ's financial system (RBNZ 2018). Given the obvious importance of protecting the financial position of dairy farms, reducing milk price risk should be a key focus of financial institutions and farms.

Traditional literature on hedging (e.g. Stein 1961, Johnson 1960) sets its objective to minimize the variability of returns. For a producer of an agricultural commodity, this approach generally

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[1] `https://www.dcanz.com/about-the-nz-dairy-industry/`

[2] `https://www.mpi.govt.nz/news-and-resources/open-data-and-forecasting/situation-and-outlook-for-primary-industries-data/`

[3] The only programme in existence is called the Income Equalization Scheme which was designed to smooth out taxable income and hence reduce the tax obligations.

[4] `https://www.fonterra.com/nz/en/investors/farmgate-milk-prices/milk-price-methodology.html`

[5] According to NZ media, during this downturn mental health workers saw increased suicide rates, domestic violence, alcohol and drug use amongst farmers.

dictates routinely taking short positions in futures contracts to achieve a minimum-variance hedge ratio. However, Collins (1997) argues that hedging should be used to avoid bankruptcy, rather than to minimize the variability of returns. In the so called "profit margin hedging" strategy, a producer hedges for production only when a futures price is above expected variable and/or fixed costs, or more generally is above a target, which can deliver a predetermined fixed margin. Thus, the objective of profit margin hedging is to assure profitable production by locking in favourable prices in futures markets when they appear. While the protection against downside price risk for a future cash sale is the main concern of profit margin hedging, the debate on whether profit margin hedging can be used to enhance margins still goes on. Conceptually, in efficient markets future price changes are unpredictable and, thus, hedging in futures markets should not generate speculative profits. Nevertheless, some empirical evidence suggests that profit margin hedging can generate an increase in farms' average returns. Kenyon & Clay (1987), for instance, find that profit margin hedging for hog producers increases average returns and reduces return variance. Yoon & Brorsen (2005) argue that multiyear rollover hedging[6] can lead to increased expected returns if futures prices follow a mean reverting process. Kim, Brorsen & Anderson (2010) develop theoretical arguments that justify the profit margin hedging strategy over continuous hedging or selling at harvest. They show that when futures prices are mean reverting, profit margin hedging has a higher expected profit over alternative strategies.[7]

In this paper, we examine the performance of a profit margin hedging strategy for NZ dairy farms. We implement this strategy for six seasons covering 2011 to 2017. A target value of a milk payout which avoids a financial failure is called a break-even milk price (BEMP). BEMP defines what level of milk income is required to meet farm working expenses, taxes, interest and rent payments, and drawings. We develop a profit margin hedging strategy where the expected milk production is hedged whenever the price is above the BEMP. To construct this strategy, we use WMP futures contracts, which are the most liquid dairy derivatives traded on the NZ stock exchange (NZX). In the first part of our analysis, we apply the profit margin hedging strategy to a representative farm. Specifically, we compare the strategy's impact on risk and return of the farm's monthly revenue, relative to a no-hedging strategy of cash sales and to continuous hedging. In the second part of the analysis, we implement the strategy to a unique sample of real farm data, obtained from the DairyBase database, which contains NZ dairy farms financial and physical data. We measure the benefits of the profit margin hedging strategy by analysing the change in discretionary cash. Low discretionary cash signals liquidity/solvency problems, and we define an occurrence of a negative discretionary cash position as financial distress.

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[6] Multiyear rollover hedging is similar to profit margin hedging with the difference that the former considers the possibility to lock in favourable prices for multiple years, instead of a single period.

[7] Their derivation is based on a static one-period model without basis and yield risk.

Both parts of the analysis demonstrate significant benefits of profit margin hedging, and the results do not substantially change after the incorporation of basis risk. When we apply the profit margin hedging strategy to a representative farm, we find that, even after accounting for brokerage fees, the strategy increases the farm's average payout, and reduces its volatility and semivariance. Of the three strategies, profit margin hedging delivers the highest average farm payout, followed by continuous hedging, and not hedging. Paired differences tests confirm that the average price of the profit margin hedging strategy is significantly different from continuous hedging and not hedging. We also find that the profit margin hedging strategy delivers a greater decrease in semivariance relative to the continuous hedging scenario.

When we apply the strategy to a sample of real farm data, after accounting for a high brokerage fee, we find that the mean value of discretionary cash increases by 36%, volatility reduces by 35% and downside risk, measured by semivariance, reduces by 74%. We find that the largest improvement in discretionary cash, by 62%, occurs for the highly leveraged farms. Additionally, we show that profit margin hedging reduces the probability of financial distress during any year by more than half, from 35% to 16%. To estimate the economic effect of the profit margin hedging strategy, we scale profits generated by this strategy across the sample of farms to all NZ dairy farms. We estimate that the strategy could have generated an additional NZD 0.49 billion annually, about 3.7% of the yearly dairy export revenue. Our findings suggest that profit margin hedging can increase the sustainability of the farm businesses by decreasing the chances of their financial distress.

Our study has two important implications. First, our findings show that the WMP futures are not redundant and highlight the usefulness of the futures market to dairy producers. Second, the findings suggest that the futures market allows farms to lock in favourable prices and thus futures contracts could be used by farms or by financial and government institutions aiming at providing risk management services to farms. Our findings are an important reminder of the benefits of hedging.

This study is positioned within two streams of literature, cross hedging and selective hedging. Cross hedging means that we hedge exposure to milk price by not trading in milk price futures, but instead in WMP futures. Historically, the WMP price contributes to the price of milk with a weight of around 62%, which makes the correlation between milk price and WMP high, motivating us to explore cross hedging techniques.[8] In addition, it relates to the literature on selective hedging in the sense that an agent enters a futures position only when prices are favourable. We concentrate our study on hedging output prices only, while some studies develop risk management strategies for hedging both input and output prices (Peterson & Leuthold 1987,

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[8] The correlation between yearly returns in milk price and WMP price is 0.96.

Kim, Garcia & Leuthold 2009).

The remainder of this paper is organized as follows: Section 2 reviews the literature on dairy farm risk management, profit margin hedging, and explains the structure of the NZ dairy market. Section 3 starts by detailing how profit margin hedging is applied to NZ dairy farms and then proceeds with the empirical analysis. First, it examines the predictability of the WMP futures to determine whether profit margin hedging could be used to increase expected returns for dairy farms. Second, it presents the empirical results for an representative dairy farm. Third, it expands the strategy to the individual farms. We present concluding comments in Section 4.

2 Literature Review

2.1 Dairy Farm Risk Management

Previous research on dairy farm risk management has primarily focused on the US and mainly deals with managing the risk of output prices. However, some studies concentrate on hedging farms' input costs. Bosch & Johnson (1992) consider the variability in feed prices and crop yields as the main risk for net returns of dairy farms and find that hedging and crop insurance lower expected net returns but reduce risk. Maynard, Wolf & Gearhardt (2005) focus on output price variations and evaluate hedging effectiveness of futures and put options in minimizing downside price risk. They estimate minimum semivariance futures and options hedge ratios and find that, when futures are used, the semivariance of the net price received for milk is reduced by 24 - 59% depending on the region.

A few studies analyse the effects of various risk management strategies for dairy farms through the use of Monte Carlo simulations. Manfredo & Richards (2007) evaluate the effect of various risk management strategies on the financial performance of a representative US dairy cooperative and its members. They document that placing a hedge, when futures prices are greater than the variable costs of milk production, results in a reduction of semivariance of milk revenue by 27%, but increases the standard deviation by 8%. Neyhard, Tauer & Gloy (2013) incorporate an individual's debt position and analyse the performance of futures and options contracts as hedges for a dairy farm with three different levels of debt. They simulate both milk and feed prices, and implement different risk management techniques aimed at meeting all expense and debt obligations of the farm. They find that, in the case where both milk and feed are hedged with futures, the net farm income standard deviation decreases by 5.6%, 6.8% and 7.8% for low, average and high debt levels, respectively.

Another strand of literature aims to identify the factors that explain the adoption of risk management tools by farms. In an expected utility framework, Turvey & Baker (1989) show that the capital structure of a farm is an important variable determining the amount of commodity hedged. Empirical work by Wolf & Widmar (2014) supports this finding. Wolf & Widmar (2014) collect survey data of dairy farms in the US and estimate a multinomial logit model on forward pricing adoption of milk or feed. They find that managers of larger herds, with more education and higher solvency risk, are more likely to use both feed and milk forward pricing methods. Among the reasons that dairy farm managers provide for not using any forward pricing tools are lack of knowledge, reliance on cooperative to adopt forward pricing, costs, basis risk, and lack of time to manage finances.

In sum, the research on dairy farm risk management suggests that a reduction of volatility or semivariance of milk revenue can be achieved through the use of derivatives. However, in reality a lack of understanding of hedging techniques, among other reasons, prevents farms from an active use of forward pricing tools.

In contrast to the US, milk price risk management in NZ is a relatively new topic. In 2010, the NZX introduced WMP futures, followed by SMP and AMF futures, WMP options and butter futures in December 2014. In 2016, the NZX developed milk price futures and options contracts. Although NZ has an existing dairy derivative market, only one academic study has tested the effectiveness of dairy derivatives as hedgers (Koeman & Bialkowski 2015). They estimate the static minimum-variance hedge ratio through a regression model and control for the possibility of cointegration between spot and futures WMP prices. They use data from October 2010 to March 2013 and find that the optimal hedge ratio is equal to 0.6 and that the variability of a hedged portfolio can be reduced by 70%. Their paper is different from the current study in several aspects. Koeman & Bialkowski (2015) find the optimal hedge ratio as the slope coefficient in the regression of changes in spot prices on changes in futures prices. This classical approach evaluates the ability of WMP futures to minimize the variance of the hedged portfolio, where the effectiveness is measured by the R-squared. Their analysis is beneficial to producers of WMP. In contrast, we design a strategy specifically for dairy farms and measure a direct impact from hedging in WMP futures on farm revenue. We acknowledge that sustainability of farming business depends on the ability to receive milk payouts which are above break-even prices. We estimate how the WMP futures market can improve the level of cash that is available for drawings, debt repayments, capital development, and purchases. Additionally, we extend the analysis to actual farm-level data, where we incorporate individual farms' cash expenses and production data.

In this paper, we aim to expand our knowledge about the usefulness of WMP futures for NZ dairy farms when we apply a selective hedging technique, namely profit margin hedging. This strategy allows dairy farms to protect themselves from financial distress and opens a possibility to increased profits. Kim, Brorsen & Anderson (2010) have shown, theoretically, that, if futures prices follow a mean-reverting process, then a hedging rule of selling futures above the long-run mean leads to an increase in profits relative to continuous hedging and not hedging. We test this theory by examining the time-series properties of WMP futures to see whether we can expect increased profits in Subsection 3.2, but first we explain profit margin hedging in more detail.

2.2 Profit Margin Hedging

We start this subsection with an example that explains how profit margin hedging works. Suppose at time t a producer decides to hedge WMP to be sold at $t+1$ because there is a risk that the price could fall below the break-even WMP price. Assume that the break-even price is USD 3,000, there is no basis risk and no transaction costs. The hypothetical price of $t+1$ futures is plotted in Figure 2. Because the producer wants to sell WMP above USD 3,000, everyday he compares the $t+1$ futures price with the break-even price. On a given day the price of the futures contract is USD 3,030, the first time above the break-even price, and the producer sells one futures contract at USD 3,030. To offset the position the producer can buy the contract back, or wait till the expiration; we assume that he waits till the expiration. Since the contract is cash settled, she does not need to worry about delivery. At $t+1$, the price of the futures is USD 2,230, and thus the producer makes a profit of USD 800 on the futures contract. The WMP spot price is also equal to USD 2,230 (i.e. zero basis), and the net sell price is made up of the spot price and the gain on futures, totalling to USD 3,030. By adopting the profit margin hedging strategy, the producer has created price certainty ahead of time. She knows that she can meet her financial obligations. Next, we review specific approaches which were examined in the literature dedicated to profit margin hedging strategies for different agricultural commodities.

Martin & Hope (1984) define an approach where a proportion of the crop is hedged at a base target set at production costs, and the rest is hedged if the futures price moves up or down by the predetermined level relative to a base target. Wood, Shafer & Anderson (1989) explore profitable margins opportunities for cotton producers with an objective of locking in futures prices above total production costs. They find that cash sales at harvest generally provide lower profit margins than margins attained with futures contracts. Kenyon & Clay (1987) adapt a slightly different trigger of futures market activity for hog producers where a hedge is placed if the current futures price is above production costs plus a predetermined fixed margin. They document that, when hedging at low expected profit margins, the strategy does not yield an increased profit, but at several higher levels of expected profit margin, the strategy increases average profit and decreases its variance. Schroeder & Hayenga (1988) choose a similar approach for cattle feedlot producers and again find that hedging with futures can increase average returns and reduce variance compared to cash-market returns. Kim, Garcia & Leuthold (2009) use a local polynomial forecasting technique to predict cash prices and adopt hedging only when the forecasted cash profit margin is negative. They consider both a one-to-one and risk-minimizing hedge ratio. They show that such selective hedging dominates continuous and unhedged strategies in terms of mean and variance. Kim, Brorsen & Anderson (2010) implement a profit margin hedging strategy for wheat, corn and soybeans, respectively. They document that only in the case of soybeans, the strategy generates a significant increase in returns in comparison to continuous hedging and selling at harvest.

To summarize, there is no precise rule in profit margin hedging for choosing a target price and a hedge ratio. Some studies choose to cover only a part of production costs, some full production costs, and others extra positive profit margin. If futures prices are above a target, more commonly, producers sell futures contracts in a one-to-one ratio to spot market, but sometimes a risk-minimizing hedge is adopted.

2.3 The New Zealand Dairy Market

To further understand the dairy market in NZ, we will briefly explain the role of Fonterra, Global Dairy Trade (GDT) events and the NZX dairy derivatives market. The Fonterra co-operative was formed in 2001 from a merger of the country's two largest dairy co-operatives, Kiwi Co-operative Dairies and New Zealand Dairy Group, with the New Zealand Dairy Board. Upon its creation, Fonterra collected approximately 96% of NZ's milk production. As of today, Fonterra still has a dominant position in the dairy product markets and collects about 80% of milk production, 95% of which is exported in the form of dairy ingredients, which makes Fonterra the world's largest dairy exporter. Fonterra is owned by around 10,000 dairy farmers, whose proportion of ownership depends on the volume of milk they supply to Fonterra. Fonterra buys raw milk from its farmer shareholders at a rate per kilogram of milk solids, which is called the Farmgate Milk Price. The Farmgate Milk Price is calculated in accordance with the Farmgate Milk Price Manual. In broad terms, the Farmgate Milk Price is the theoretical price that Fonterra would derive if it converted all milk into the 'Reference Commodity Products', which are WMP, SMP and their by-products (butter, BMP, and AMF). This theoretical price is adjusted for costs, such as those which would be incurred to transport raw milk to Fonterra's NZ factories, produce these same commodities in an efficient way, freight them to the point of export from NZ and make a market return on investment. The prices for the 'Reference Commodity Products' are USD prices achieved by Fonterra on the twice-monthly GDT events platform, converted to NZD at Fonterra's actual average monthly foreign-exchange conversion rate. The GDT events trading platform was formed in 2008 to facilitate the global trading of dairy products. It connects sellers and buyers from over 80 countries, who during an online auction process discover reference prices for globally traded dairy ingredients. GDT offers six different forward contracts. Contract 1 is for shipment in one month, Contract 2 for shipment in two month and so forth.

The NZX launched its first dairy derivative - WMP futures - in 2010, shortly after the introduction of the GDT platform. WMP futures are cash settled to an average of the two winning prices for WMP, Contract 2, determined in GDT events in the same month. The futures trading terminates on the day before the second GDT event of the month. The NZX later added SMP, AMF and BMP futures and options. The most recent contracts are milk price futures and options, which are cash settled against Fonterra's farmgate milk price and were launched in 2016.

3 Profit Margin Hedging Strategy

3.1 Specifications of the Profit Margin Hedging Strategy for NZ Dairy Farms

In this section, we detail the steps in a profit margin hedging strategy, which are: an objective, decision rule to determine the time when a position in the futures market should be established, and the role of brokerage fees and basis risk. We also describe how we implement each of these steps for the case of a representative NZ dairy farm.

The objective of profit margin hedging is to lock in favourable prices when they occur in futures markets. We define prices as favourable if, after adjusting for basis risk and fees, they are higher than the target price which we set to the NZ break-even milk price (BEMP) reported in the Dairy NZ Economic Surveys (DairyNZ 2017). This approach in selecting a target price aims to guarantee the economic viability of the farm's business. BEMP indicates how much milk income is required to meet farm working expenses, interest, rent, tax and drawings. Table 1 reports BEMPs for the seasons 2011 - 2017 for owner-operated farms. The data shown in Table 1 are the averages for groups of farms that closely match the average regional herd size, hectares and milksolids production, as described in the New Zealand Dairy Statistics for a particular year (DairyNZ 2017). Because for hedging milk prices we use WMP futures, we need to convert BEMP to break-even WMP prices. To do so, we collect annual farmgate milk prices in NZD, weighted-average USD prices of WMP and average USD:NZD conversion rates from Fonterra's Farmgate Milk Price Statements for the seasons 2009-2017 (Fonterra 2017). We use these data to identify the relation between milk prices and WMP, and then use the estimated parameters to find break-even WMP prices. A linear regression of weighted-average NZD prices of WMP on farmgate milk prices yields the relation:

$$Milk_t^{NZD} = \underset{(-1.540)}{-0.733} + \underset{(14.544)}{1.578} WMP_t^{NZD}, \qquad R^2 = 0.97, \tag{1}$$

where t runs through eight seasons from 2009 to 2017 (the data frequency is annual) and t-statistics are presented in parentheses. We use the BEMPs reported in Table 1 as an input for the left-hand side of Equation (1) and solve it for break-even WMP prices in NZD. The last step is to convert NZD prices back to USD. Results are reported in Table 2. This method gives us an estimate of the break-even WMP price given the BEMP. Ideally, we would incorporate prices of the other four Reference Commodities (SMP, Butter, AMF and BMP). The WMP break-even price is calculated for the representative farm and indicates how much WMP income is required to meet farm working expenses, interest, rent, tax and drawings. It accounts for livestock and other dairy cash income received in the season. The WMP break-even price increases as farm working expenses, interest, rent, tax and drawings increase, and livestock and other cash income decrease.

In the simulations, we assume that a dairy farm receives payments each month. To fix a date, we choose the next day after the first GDT event each month, which usually happens to be the first Wednesday of each month. We assume that a farm enters into a short hedge for a contract which expires the same month as the payment is due. Additionally, we assume that there is a one month lag between milk collection and payment. For example, for milk collected in June, a farm would have received payment at the beginning of July (next day after the first GDT event in July), and she also would have been looking to hedge her June production by entering a short position in July WMP futures contracts.

The next point we want to address is a decision rule that triggers a transaction in futures and its timing. The net price received for milk sales is the value which consists of spot sales of milk, gain/loss in futures contracts minus transaction costs. The final price received by a farm equals the first Wednesday spot price of WMP plus any net gain or loss from the futures trade minus transaction costs. The net price received by a producer using short hedging is defined as:

$$NP = S_1 + F_0 - F_1 - C, \tag{2}$$

where S_1 is the WMP spot price, F_0 and F_1 are the opening and the closing futures price, and C is the futures transaction costs. We introduce a transaction cost at three different levels of 30, 50 and 70 USD per contract (round-trip transaction), which is comparable to the indicative fees charged by NZ brokerage firms.[9] The net price also can be expressed as $NP = F_0 + B_1 - C$, where B_1 is the closing basis ($B_1 = S_1 - F_1$). Because the closing basis is uncertain at the time the hedge is placed, a farm can only form expectations about the net price received. After defining the expected net price received, we can formulate the decision rule and its timing: a producer places a short hedge any time after the contract is available for trading, provided that the net price is at least as high as the target price. Because WMP futures for each calendar month are available 18 months into the future, dairy farms can hedge their production 18 months before monthly payments are received, if it is profitable to do so. Once hedges are placed they are not lifted until the cash sale of milk.

Lastly, we want to emphasize the role of basis risk. Basis risk is the risk of experiencing the realized closing basis different from the expected one. If a farm follows a decision rule described earlier and enters the position in the futures market, the expected profit margin (EPM), the realized profit margin (RPM) and their difference can be defined as follows:

$$\begin{aligned} EPM &= (F_0 + B_1^{exp} - C) - target \\ RPM &= (F_0 + B_1^{real} - C) - target \\ RPM - EMP &= B_1^{real} - B_1^{exp}, \end{aligned}$$

If RPM is greater or equal to zero, that means that a farm can cover all cash expenses (farm working expenses, interest and rent, tax and drawings) from milk sales and the objective of profit margin hedging is achieved. In the case where EPM is zero (net price just enough to cover cash expenses) and B_1^{real} is less than B_1^{exp}, then RPM is smaller than all cash expenses. Thus, in the case when the realized basis is lower than expected, the farm might receive less than the target price for the WMP sale, making profit margin hedging unable to secure a positive cash flow requirement.

The net price depends on the expected closing basis, and thus we need to make some assumptions about it. Kim, Brorsen & Anderson (2010) consider two scenarios of incorporating expected basis in hedging decisions. The first is to assume no basis risk, that is, to assume that the actual closing basis is known at the time of the decision. The second is to model an expected closing basis as a five-year moving average. Hatchett, Brorsen & Anderson (2010) conduct a study in which they try to find the best length of moving average to use. They find that different moving average lengths have similar forecast accuracy. However, if a structural break occurs, a previous year's basis should be used as a forecast. The main difference between our study and theirs is that they analyse commodities which are harvested once a year, while we need to

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[9] `https://www.omf.co.nz/legal/omf-disclosure-statement`

forecast a basis monthly. Because of the limited data available, we choose to forecast the basis as a moving average of past historical monthly values available up to the hedging decision time. Thus, in a perfect foresight basis scenario, a farm opens a trade in WMP futures if the sum of the futures price and the actual closing basis less brokerage fee is greater or equal to a target price. In the second scenario, instead of an actual closing basis, he uses an estimated closing basis.

After outlining the details of the profit margin hedging implementation, we will introduce various risk measures, which we use to assess hedging performance. We use the standard deviation and semivariance (standard deviation considers both positive and negative deviations from a mean as risk, while semivariance focuses on downside risk). Semivariance is the expected value of the squared negative deviations of possible outcomes from target returns. The semivariance is defined as

$$SV(X,T) = E\{min(X-T,0)^2\}, \tag{3}$$

where T is the target price and X is a random variable. In subsection 3.3, we will apply Equation (3) to realized NPs with the target as the WMP break-even price. In subsection 3.4, we use Equation (3) to calculate semivariance of discretionary cash below zero. We report semivariance as the square root of the semivariance measure defined by Equation 3. The square root is taken in order to express the semivariance in dollar units.

For each risk measure (RM), we follow Conlon & Cotter (2013) and define hedging effectiveness as:

$$HE_{RM} = 1 - \frac{RM(NP_h)}{RM(P_s)}, \tag{4}$$

where NP_h is the net price received by a producer if he chooses to hedge and P_s is the price received in the case of no-hedge.

As mentioned in the introduction, the primary objective of hedging is not to make money but to minimize risk. In an efficient market, new information is rapidly incorporated into futures prices. Because new information arrives randomly to the market, price changes should be unpredictable, leaving no possibility for speculative profits. Nevertheless, the question of whether profit margin hedging can increase expected returns is debatable. Kim, Brorsen & Anderson (2010) posit theoretical arguments that would justify profit margin hedging over continuous hedging or selling at harvest. They show that when futures prices are mean reverting, profit margin hedging has a higher expected profit over alternative strategies. In the next subsection, we resort to a standard test - variance ratio test - to examine mean reversion in WMP futures.

3.2 Mean reversion in WMP Futures

In our study, we use WMP futures contracts, which are based on the Fonterra product, Regular NZ, Contract 2, that is the GDT auction prices of a WMP contract with a delivery in two months. We obtain data from the Agri Data database, which is a part of the NZX Research Centre. The NZX launched WMP futures on October 8, 2010, and, therefore, we consider the sample period from October 8, 2010 to January 3, 2018. To test the random walk hypothesis, we use the second nearby contracts, which are the most active contracts[10] and use weekly observations referring to Wednesday. We consider Wednesdays' observations because GDT events usually happen on Tuesdays at 12:00 UTC, and information about a change in WMP prices is incorporated during the next trading session which is Wednesday in NZ. We define continuously compounded returns as $r_t \equiv log(P_t) - log(P_{t-1})$, and make sure that returns are always taken for a contract expiring in the same month. For example, on the 27th October 2010 the second nearby futures was the November contract, but in a week's time, on 3rd November 2010 the second nearby futures contract is the December contract. To calculate the return between 27th October and 3rd November, we take prices of the November contract only.

Panel A of Table 3 presents descriptive statistics of weekly returns on the WMP futures. Returns are negatively skewed and have excess kurtosis. Moreover, the Jarque-Bera test rejects normality at the 1% level. These findings are in line with prior research on futures prices of other agricultural commodities, which find that futures price changes are not well approximated by a log-normal distribution and often leptokurtic (see Hudson, Leuthold & Sarassoro 1987, Yang & Brorsen 1994, Khalifa, Miao & Ramchander 2011, among others). We use the Engle ARCH test to establish the presence of conditional heteroskedasticity in returns. The results indicate that we can reject the null hypothesis of no conditional heteroskedasticity and conclude that there are significant ARCH effects in the return series.

To establish the random walk nature of WMP futures prices we first check for serial correlation. Under the random walk hypothesis, returns of the time series must be uncorrelated at all leads and lags. Panel B of Table 3 reports autocorrelation and the Ljung-Box Q-statistic for weekly WMP futures returns. Results show the first, second and fifth order autocorrelation coefficients of 13%, 24% and -11%, which are significant at 5%. Moreover, the Ljung-Box Q-statistic with five (ten) lags has a value of 32.36 (45.67), which is significant at the 1% level. These findings indicate that we can reject the random walk hypothesis, which means that future price changes can be forecasted using the past price changes.

Next, we follow Lee, Gleason & Mathur (2000), Smith & Rogers (2006), Kim, Brorsen &

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[10] During our sample period, traded volume in the nearby contract is equal to 69,997 contracts, while the second nearby contract is 110,000 contracts.

Anderson (2010), among others and perform the Variance Ratio Test of Lo & MacKinlay (1988). The idea behind the test is that if the natural logarithm of a price series is a random walk, then the variance of q-period returns should equal q times the variance of one-period returns:

$$VR(q) = \frac{\sigma^2(q)}{q\sigma^2(1)}.$$

The sampling distribution of $VR(q)$ under the null hypothesis of uncorrelated return innovations in the presence of general heteroskedasticity is provided in Appendix A. Under the null hypothesis, the Z-statistic is asymptotically standard normal. We perform the variance ratio test for return horizons of 2, 4, 8 and 16 weeks. Table 4 shows the variance ratios and test statistics. Results show that the Z-statistic is significantly different from 1 at the 1% level for return horizons of 2, 4 and 8 weeks, meaning the rejection of the random walk hypothesis for the WMP futures prices. The reported Z-statistics are adjusted for heteroskedasticity, which means the rejections of the random walk hypothesis are not due to a changing variance.

The test of Lo & MacKinlay (1988) focuses on the hypothesis that an individual variance ratio for some q is one; however, the null hypothesis requires the variance ratio to be one for any q. The multivariate variance ratio test of Chow & Denning (1993) addresses this issue. The ZV-statistic takes the maximum value among different Z-statistics and asymptotically follows the studentized maximum modulus distribution. From Table 4, we deduce that the ZV-statistic is 3.74, rejecting of the null hypothesis $VR(q) = 1$ for all q at the 5% level (the studentized maximum modulus distribution with 20 degrees of freedom at the 5% level is 3.64). The results of the variance ratio test provide further evidence that the random walk hypothesis can be rejected for the WMP futures prices.

Given the results of predictability of WMP futures prices, based on Kim, Brorsen & Anderson (2010), we expect that profit margin hedging not only reduces risk of the low milk revenue, but also enhances average milk payout. In the next section, we first discuss some empirical studies which examine profit margin hedging strategy for different agricultural markets. Then, we explain how the strategy can be tailored to the needs of NZ dairy farms and present the findings of the simulations.

3.3 Results for the Representative Farm

In this section, we simplify the setting of the farm's operations and assume a situation where a representative farm sells one tonne of WMP monthly over six seasons 2011 - 2017, which totals 72 months. Because the underlying asset of a single WMP futures is one tonne of WMP, such simplification means that if a farm chooses to hedge, he sells one futures contract. As discussed in Subsection 3.1, for profit margin hedging we set a target price to WMP break-even prices realized during the years 2011-2017. For each season, the target is different and defined in Table 2. We model two scenarios to account for basis risk: we assume a perfect foresight on the closing basis (no basis risk) or make a forecast of the closing basis as the average realized basis available at the decision time. The strategy is selective in a sense that a farm only hedges when futures prices are favourable. This scenario only arises when the net price is greater or equal to the target.

We conduct simulations to compare the profit margin hedging strategy with continuous hedging and no hedging strategies. To make the continuous hedging strategy comparable to the profit margin hedging strategy, we set up a rule where a farm hedges the entire position in the cash market, i.e. one tonne of WMP. We choose the hedging horizon to be 15 months, because it is equal to the average hedging horizon in the profit margin hedging strategy, as shown in the next paragraph.

In Table 5, we show the effect of hedging on risk and return of the payout to a farm, measured in WMP prices (USD per one tonne). The results show the superiority of profit margin hedging versus continuous hedging. If fees are zero, continuous hedging leads to an increase in the mean payout by 7.3%, while profit margin hedging increases the mean by 14.1%. An effect on the standard deviation of the payout is similar, a reduction by 28.9% and 31%, but a reduction in semivariance clearly demonstrates the difference. While profit margin hedging sets its objective to select the WMP futures prices which can deliver the dairy revenue above the total cash expenses, continuous hedging dictates to mechanically enter the futures market without any consideration of the WMP futures price. Results show that continuous hedging reduces semivariance by 57%, while profit margin hedging completely eliminates the downside risk. In Table 6, we conduct a paired t-test to assess whether an increase in means of monthly WMP prices between each pair of strategies is statistically different from zero. In the continuous hedge vs. no hedge pair (Panel A), the t-ratio is between 1.7 and 1.2, meaning that the price difference is not statistically different from zero at the 5% level. At the same time, in the profit margin hedge vs. continuous hedge pair (Panel C), the profit margin hedging average price is statistically higher than the price of continuous price at any conventional significance level. Based on these findings, we conclude that profit margin hedging leads to a higher mean value of the payout and lower downside risk in comparison to continuous hedging. In the subsection 3.4, where we perform the analysis for a sample of farm-level data, we concentrate on profit margin hedging only, based on the findings for the representative farm data.

Now, we discuss the results of the profit margin hedging strategy in more detail. Simulations show that the decision rule was satisfied 72 out of 72 months, and the short position was opened on average 15.5 (15.3) months before the payout is due, in the case of no basis risk and basis risk scenarios, respectively. The results show that irrespective of how basis risk is modelled, profit margin hedging always increases returns and decreases risk. In the case of no basis risk and zero brokerage commission, the average price during 6 seasons is improved by 14.1%. The incorporation of brokerage commissions (USD 30, USD 50, USD 70) reduces the mean WMP price, but still results in an improved mean in comparison to the no hedge scenario. Implementation of profit margin hedging allows a substantial reduction in the volatility of prices, demonstrated by a decrease in the standard deviation of 31%. The coefficient of variation (CV) measures the ratio of standard deviation relative to returns. The strategy with the smallest CV is preferred. Results show that profit margin hedging provides the best risk-return trade-off. The semivariance, a measure of downside risk below the target, also strengthens the benefits of hedging. Because hedging was triggered for each month, in the case of no-basis risk the semivariance is reduced to zero, and when basis risk is taken into account, the semivariance is slightly above zero. To assess whether an increase in means of monthly WMP prices between two strategies is statistically different from zero, we conduct a paired t-test. From Table 6 Panel B, we can see that t-ratios range between 2.3 to 3, meaning that for each pair the price difference is statistically significant at conventional levels.

In Table 7, we aggregate the resulting monthly payouts into average milk prices for each of the six seasons. We achieve this by averaging 12 payouts from July to June (we assume that milk collected in June is paid in July) for each season, converting the WMP USD averages to NZD and then converting it to the relevant milk price using Equation (1), which was used to convert BEMPs to break-even WMP prices. The main conclusion we draw is that profit margin hedging allows the representative farm to avert the turbulent times in the NZ dairy industry which occurred during seasons 2014-2015 and 2015-2016, when milk prices were lower than BEMPs. For example, the BEMP during the 2014-2015 season was NZD 5.77 per kgMS, which is higher than the milk cash price of NZD 4.46. However, in the no-basis risk, no fees scenario, the milk price with profit margin hedging is NZD 8.69. Thus, our findings demonstrate that profit margin hedging has the potential to support the financial viability of dairy business, without sacrificing average returns. The representative farm would have earned, on average, NZD 0.98 and 0.87 per kgMS in the case of no-basis risk, zero and high fees, respectively.

3.4 Results for Individual Dairy Farms

Individual farms may have BEMPs different from a representative farm as production costs, debt structure, and cash flow requirements vary across individual farms. The advantage of profit margin hedging is that it can be tailored to the specific needs of a farm, based on its unique cash flow requirements. In this section, we test our hedging strategy at the farm level. We begin by discussing the data, implementation of the strategy, followed by the results.

The DairyBase database was established by DairyNZ in 2005 and contains NZ dairy farms' financial and physical data. Participation is voluntary, meaning that farms may not report their information in all years. Our dataset contains owner-operator farm data from the Waikato and Marlborough-Canterbury regions for six seasons between 2011 and 2017. We choose these regions because they are the biggest regions of the North and South Islands of NZ, respectively, measured by the number of herds. For the 2016-2017 season, the Waikato region makes up 31.5% of all owner-operator farms and Marlborough-Canterbury makes up 11.4% (DairyNZ 2017). For the six season period, there are 608 farms that reported financial information for at least one of the seasons. However, only 50 farms consistently reported for all six seasons. If we remove the 2011-2012 season, we almost double the number to 92 farms. This observation motivates us to conduct further analysis using only data for the five seasons from 2012 to 2017. To assess how representative the selected farms are, we compare some profitability statistics and physical characteristics of the regional data from DairyNZ Economic Surveys to the averages of the sample. We find that the selected farms have slightly larger herds and milksolids production per cow; however, farm working expenses and operating profits are very close to regional averages. For the hedging analysis, profitability statistics are more important than physical characteristics, and thus, we conclude that the selected sample is a good representation of the regional data.

To implement the strategy, we need to define the break-even WMP prices and the quantity of produced milksolids for the cross-section of farms for each of the five seasons. We resort to ex-post analysis, that is, we find the break-even prices and output from realized data.[11] For example, to find the break-even WMP price and output for the season 2012-2013 for a specific farm, we use information reported by the farm for the 2012-2013 season. This approach allows us to concentrate only on price uncertainty, keeping output fixed. The DairyBase database reports total milksolids produced for a season, but does not specify the production for each month during the season. We assume that for each farm the distribution of milk production during a season is the same as the national average, provided by the Agri Data database.[12] To calculate monthly production for each farm, we extract monthly NZ milk production data from the Agri Data database for the seasons between 2012 and 2017 and find the fraction of each month's production relative to the total of the season. We then find averages for each month

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[11] We can infer the break-even prices only from the ex-post analysis for the following reasons: in case we set the break-even price for a new season, for example, to the same as in a previous season, but a farm decides to expand, for example, his farm working expenses, when, the discretionary cash in the new season is likely to be negative. For the profit margin hedging strategy to work, a farm needs to prepare a budget before the start of the season and control the spending according to the prepared budget.

[12] The Agri Data database is a part of the NZX Research Centre database.

across five seasons and use them to distribute individual farm milk production across a season.[13] We also assume that futures are completely divisible, that is, a farm can sell any number of futures contracts.

Similar to the analysis in the previous section, we consider scenarios with no, low, medium and high levels of brokerage fees: USD 0, USD 30, USD 50, and USD 70 per contract per round-trip transaction, respectively. The average annual milksolids production per farm is 216 tonnes, which translates into NZD 6,480, NZD 10,800 and NZD 15,120 annual brokerage expense for a farm. To assess the effect of hedging, we analyse the change in discretionary cash for each farm with and without a hedge. Discretionary cash is what is left after farm working expenses, rent, interest, and tax are paid and net income from non-dairy farming activities is added. Discretionary cash is available for drawings, debt repayments, capital development, and purchases. We define an occurrence of negative discretionary cash during a season as financial distress. To calculate the value of discretionary cash after the implementation of a profit margin hedge for a given farm, and for a given season, we add the profit/loss from profit margin hedging during the season to the discretionary cash realized during that season. WMP futures are priced in USD and, therefore, we need to convert a profit/loss to NZD. We use the annual average USD:NZD conversion rates from Fonterra's Farmgate Milk Price Statements.[14]

3.4.1 The Effect of Profit Margin Hedging

To assess the effect of profit margin hedging on the average discretionary cash over the 2012-2017 seasons, we start with a visual assessment of its distribution and compare it to the no hedge case. In Figures 3 and 4, we plot the empirical cumulative distribution functions (CDFs) as well as kernel density estimations for the average discretionary cash in NZD for the no hedge and profit margin hedging strategies, respectively. Four observations about the CDF plots deserve to be noted. First, the graphs show that the CDF for the no hedge lies to the left of the CDFs for profit margin hedging. This means that for each fixed value of discretionary cash, the probability to observe a value smaller than that is higher in the case without hedging. For example, the probability to observe discretionary cash below or equal to NZD 200,000 is equal to 55% under profit margin hedging and 72% for the no hedge case. Second, no hedge has more negative outcomes and less positive outcomes. Third, fees do not outweigh the benefits of

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[13] For example, to find the fraction for January, for each of the five seasons we divide NZ total production for January by NZ total production during that season. Then we find the fraction for January as the average of January's fractions across five seasons. We use the obtained fractions for each month to distribute the total production of each farm across months.

[14] As a robustness check, we use forex spot rates to convert profits/losses from monthly futures settlements. We obtained the exchange rates from Datastream. We find that this approach does not impair, but in fact improves the results. We attribute the finding to the fact that during 2014-2015 and 2015-2016 seasons, Fonterra's average exchange rate was 1% and 6% lower than the spot rates. While during 2012-2013, 2013-2014 and 2016-2017 seasons Fonterra locked better exchange rates than spot rates, 2014-2015 and 2015-2016 are the most important seasons, as the gains from hedging during these seasons were the biggest. Results are available upon request.

hedging. Fourth, basis risk does not substantially affect the results. Similar conclusions can be drawn from the density estimate graphs, which are presented in the bottom panels of Figures 3 and 4. First, with profit margin hedging, the distribution moves to the right, indicating an increase in the mean of discretionary cash. Second, the basis risk does not substantially change the results, and lastly, fees do not qualitatively change the conclusions about the benefits of hedging.

After this preliminary assessment of the differences between two alternatives, we perform a Kolmogorov-Smirnov (K-S) test to compare the two alternatives. In Table 8, we show the results for no hedge versus profit margin hedging with different levels of commissions. The null hypothesis of K-S is that the two data sets are drawn from the same distribution. The results show that, irrespective of fees and basis risk, we reject the null hypothesis that discretionary cash for no hedging strategy and profit margin hedging is from the same distribution. Therefore, we conclude that the observed shifts in distributions between the no hedge and profit margin hedging strategies in Figures 3 and 4 are statistically significant.

3.4.2 Effect of Profit Margin Hedging on Risk and Return of Discretionary Cash

As a next step we calculate the mean, volatility and semivariance of discretionary cash for each farm with and without profit margin hedging. Mean, variance and semivariance values are calculated for discretionary cash during five seasons and, thus, represent annual values. We present the results in Tables 9 and 10 where we group individual farms into quintiles based on the volatility (Panel A), semivariance (Panel B), and mean (Panel C) of discretionary cash without hedge. When we group individual farms into quintiles, we show the average of the individual farm's volatility, semivariance and mean of discretionary cash. As an example, in the first row and the first column of Panel A of Table 9 we show the average volatility of discretionary cash without hedge among farms with the smallest 20% volatility (i.e. low quintile) of discretionary cash without hedge. The average volatility of discretionary cash for the low quintile of individual farms is equal to NZD 109,309 per year. In the following rows we show how volatility of discretionary cash changes for the same group of farms if the profit margin hedging strategy is used. In the last column, we present the average volatility of discretionary cash for all individual farms grouped together.

We first discuss the results for the no basis risk scenario which are presented in Table 9. Panel A shows that the volatility of yearly discretionary cash is reduced by between 21% to 40%, with a mean value of 35% for the whole sample, ignoring fees. Volatilities of discretionary cash with hedge and different fees are very similar, as the fees expense is fairly constant for each season, and hence only slightly affects the volatility of discretionary cash. We conduct a paired *t*-test to find out if, on average, profit margin hedging leads to an improvement in volatility within each quintile and for the whole sample. We find that the average differences in means are statistically different from zero at the 5% level. Panel B of Table 9 presents the semivariance of discretionary cash. We measure semivariance relative to a threshold of zero. Discretionary cash below zero means that milk sales do not cover all farm working expenses, rent, interest, and taxes, and therefore the farm does not have any cash to make withdrawals, debt repayments or capital developments. We find that for the quintiles two to high the semivariance is reduced by 72% to 82%, with an average of 78%, and, only for the low group, we observe an increase in the semivariance. Intuitively, a profit margin hedge with a target price equal to break-even price, discretionary cash should always be positive. However, as our study uses a cross-hedge, the dynamics of the milk price are not fully explained by the WMP price and so there remains some risk of receiving a milk payout below BEMP. We find that commissions increase the semivariance and reduce the hedging effectiveness, on average by 2%, 3%, and 4% (moving from low to high fees). A paired *t*-test shows that the average differences in means of the semivariance between profit margin hedging and no hedging are statistically different from zero at the 5% level in all quintiles, except for the low quintile. Therefore, we conclude that the reduction in the semivariance of discretionary cash is significant at the 5% level. Panel C of Table 9 shows the effect of profit margin hedging on the mean of discretionary cash. We can see that without hedging the mean of discretionary cash for the low group is NZD -$28,953. After the hedge is in place, the mean goes up by 267% to NZD 48,298. Fees reduce the mean by roughly NZD 5,000, NZD 8,000 and NZD 10,000 (moving from low to high fees), respectively. For other quintiles, the mean increases by 81%, 53%, 38% and 24% (moving from second to high quintile) in the case of no fees, and by 64%, 40%, 29% and 17% in the case of high fees. It shows that the highest percentage increase in the mean occurs for the low group and effectiveness decreases as percentile group increases. These results show that profit margin hedging delivers the strongest benefits for the most vulnerable group of farms. The increase for the whole sample ranges between 36% and 47%, depending on the level of fees. A paired *t*-test shows that, on average, profit margin hedging leads to an increase in the mean of discretionary cash within each quintile and for the whole sample.

Table 10 presents the results when a farm does not know the value of the closing basis in advance and has to predict it. When we compare Tables 9 and 10, we find that a change in basis risk expectations does not change the results. In fact, the numbers are very similar, which means that the basis risk in WMP futures does not diminish the value of hedging. A paired *t*-test gives similar results to a no basis risk case, i.e. we find that the average difference between profit margin hedging mean, variance and semivariance of discretionary cash and no hedging mean, variance and semivariance of discretionary cash are statistically different from zero at the 5% level in all quintiles, except for the low quintile for semivariance of discretionary cash.

3.4.3 Economic Effect of Profit Margin Hedging

The previous analysis is based on data of 92 farms, which make up 1.09% of the milk production across all NZ. To assess the economic effect of profit margin hedging for the NZ economy, we want to know what the dollar value that the profit margin hedging strategy could have generated over the 2012-2017 seasons if it were adopted by all NZ dairy farms. Our approach is to scale up the profit/loss generated by hedging during each season for 92 farms where the scaling factor is the milk produced by the 92 farms relative to the total milk produced in NZ during each season. Specifically, for each season, we calculate the total profit/loss from the futures position across all farms in the sample and scale it to the profit/loss of all NZ farms by the proportion of milk production in the sample to the total milk production of NZ. Then, we take the average across all five seasons. We find that profit margin hedging could have generated NZD 0.49, NZD 0.54 or NZD 0.58 billion average per year (moving from high to low commission), with a perfect knowledge of the basis, or NZD 0.49, NZD 0.53, NZD 0.58 billion average per year without knowledge of the basis. Given that the average yearly dairy export revenue is NZD 13.2 billion, the average gain of NZD 0.49 billion translates to 3.74% (0.49/13.2) of the yearly dairy export revenue.

3.4.4 Effect of Leverage

Literature shows that capital structure plays an important role in explaining the adoption of futures by farms (e.g. Turvey & Baker 1989, Shapiro & Brorsen 1988, Wolf & Widmar 2014). Low-leveraged farms are less likely to hedge, as they are more financially secure. Based on this literature, we want to address two questions. The first is whether the level of leverage affects the level of volatility, semivariance and mean of discretionary cash. The second is whether we can establish a relation between leverage and hedging effectiveness.

To address the first question, we sort farms into quintiles by their leverage ratio and calculate the mean volatility, semivariance and mean of discretionary cash in each quintile group. We use a two-sample t-test between high and low quintiles to find whether the differences are significant. Tables 11 and 12 show that the difference in mean semivariance between the high-minus-low leverage ratio quintiles is NZD 113,434 (t-stat 6.42) and the difference in mean of discretionary cash is -NZD 112,941 (t-stat -2.29). We do not find that the difference in volatility is statistically significant. We find that after implementing the profit margin hedging strategy, the difference remains significant for the semivariance, but not for the mean. For the no fees hedge, an increase in the mean for the high leverage quintile is 66%, while for the low leverage it is 23%. This finding indicates that hedging reduces the gap between the mean of discretionary cash of different quintile groups.

As for the second question, we want to assess whether we can establish a relationship between the level of leverage and hedging effectiveness. From Panels A and C of Table 11, we conclude that farms with low debt to asset ratios benefit the least from hedging, as the reduction in volatility and increase in the mean of discretionary cash is the smallest in comparison to other quintiles. Another observation is that for the fourth and highest quintiles, the improvement in the mean of discretionary cash is the strongest. We conclude the same from Table 12, which groups data into quintiles of the debt to asset ratio in the case of profit margin hedging with basis risk. From Table 11, we find that highly leveraged farms in the fourth and highest quintiles (i.e. farms with the debt to asset ratio between 52% and 90%), have the biggest increase in the mean of discretionary cash by 92% and 66% (average of 79%) without fees, respectively, and by 73% and 51% (average of 62%) with high fees. Farms with low debt to asset ratios, i.e. below 31%, experience the smallest improvement in mean discretionary cash by 23% without fees and by 17% with high fees. These farms also experience the smallest reduction in volatility by about 22%. A paired t-test indicates that the improvements in the mean of volatility, semivariance and mean of discretionary cash are significant at the 5% level.

Based on our results, we conclude that the level of leverage is an important variable for farms, that adopt the hedging strategy. While we find that profit margin hedging decreases risk and increases return for farms at all levels of leverage, farms with low leverage are the least advantaged to hedge, while farms with high leverage benefit most from hedging.

3.4.5 Probability of Financial Distress

Table 13 presents a simple measure which allows us to evaluate the effect of profit margin hedging on the probability of financial distress during a given year. We define financial distress as the inability to cover farm working expenses, interest, rent and tax payments from dairy cash income. Quantitatively this is measured by the occurrence of negative discretionary cash. If a farm chooses not to hedge, 159 out of 460 observations (92 farms during 5 seasons) are characterized by negative discretionary cash, i.e. a proportion of 34.6%. If profit margin hedging is implemented, the number of observations with negative discretionary cash decreases by more than double, to 63, which is 13.7% of the total sample. Depending on the magnitude of fees, this proportion increases to 14.8, 15.4 and 16.3 for low, mid and high fees scenarios, respectively. The results do not substantially change after incorporating basis risk.

Overall, the results of this subsection demonstrate that our profit margin hedging strategy decreases risk and improves returns for a sample of NZ dairy farms. We also find that WMP futures do not bear high basis risk, and when we model different scenarios of basis risk we find qualitatively similar results.

4 Conclusion

In this study, we examine the effectiveness of profit margin hedging for NZ dairy farms. We demonstrate how the WMP futures can be used to protect farms from price risk. We base our results on historical data available for the period 2011 to 2017. We start by showing that prices of WMP futures do not follow a random walk. According to Kim, Brorsen & Anderson (2010) this result means that profit margin hedging can also be used as a tool to increase the average milk price.

In the first part of the analysis, we evaluate profit margin hedging from the perspective of a representative farm. We compare the risk and return of the average monthly payout expressed in WMP price between profit margin hedging, no hedging and continuous hedging strategies. We find that out of the three strategies, profit margin hedging delivers the highest average payout and lowest semivariance. We find that depending on fees and basis risk, the expected return is increased by between 12% to 14.1%, the variance is reduced between 30.5% to 31.0%, and that almost all downside risk is eliminated. We find that profit margin hedging shows especially reliable results in reducing the downside risk, thus helping us to maintain the financial viability of dairy farm operations.

In the second part of the analysis, we implement profit margin hedging, using actual data, for a sample of individual farms. The results show that in the case of no basis risk and zero fees, the mean value of annual discretionary cash for all farms is increased by 47%, volatility is reduced by 35% and downside risk, measured by semivariance, is reduced by 78%. Although the introduction of fees reduces the increase in returns and reduction in risk, profit margin hedging still offers a significant improvement over no hedging. We find that highly leveraged farms, which have debt-to-asset ratios above 52%, see the largest increase in mean discretionary cash by 79% without fees and by 62% with high fees. Additionally, we show that profit margin hedging reduces the probability of financial distress during a given year by more than half, from 35% to 16%. To estimate the economic effect of the profit margin hedging strategy, we scale up the profit generated by this strategy across the sample of farms to all NZ dairy farms. We estimate that the strategy could have generated NZD 0.49 billion yearly average over a five year period, which is 3.7% of the yearly dairy export revenue.

This study has several important implications. We document that WMP futures offer significant benefits for NZ dairy farms. We demonstrate that profit margin hedging enhances the sustainability of the farming business, by reducing uncertainty about future profit. Reduced certainty about profit can negatively impact investment and production planning decisions, restrict access to capital and threaten solvency. High indebtedness of the NZ dairy farm sector makes it vulnerable to low dairy prices, and the results of our study can be of interest for policy-makers who are concerned with financial stability.

A Variance Ratio Test

Let p_t denote the log price process and let a sample consist of $nq+1$ observations, where p_0 and p_{nk} are the first and the last observations and q is any integer greater than one. Lo & MacKinlay (1988) showed that the variance ratio statistic of q-period returns can be calculated as:

$$VR(q) = \frac{\sigma^2(q)}{\sigma^2},$$

where $\sigma^2(q)$ is an unbiased estimator of $1/q$ of the variance of the q-period returns and σ^2 is an unbiased estimator of the variance of the one-period returns and defined by:

$$\begin{aligned}
\sigma^2(q) &= \frac{1}{m}\sum_{k=q}^{nq}(p_k - p_{k-q} - q\mu)^2 \\
\sigma^2 &= \frac{1}{nq-1}\sum_{k=1}^{nq}(p_k - p_{k-1} - \mu)^2 \\
\mu &= \frac{1}{nq}(p_{nq} - p_0) \\
m &\equiv q(nq - q + 1)(1 - \frac{q}{nq}).
\end{aligned}$$

A test statistics $Z(q)$ is adjusted for heteroscedasticity in returns and defined by:

$$Z(q) = \frac{\sqrt{nq}(VR(q) - 1)}{\sqrt{\theta}} \overset{a}{\sim} N(0,1),$$

where θ is asymptotic variance of variance ratio $VR(q)$:

$$\begin{aligned}
\theta &\equiv 4\sum_{k=1}^{q-1}\left(1 - \frac{k}{q}\right)^2 \delta_k \\
\delta_k &= \frac{nq\sum_{j=k+1}^{nq}(p_j - p_{j-1} - \mu)^2(p_{j-k} - p_{j-k-1} - \mu)^2}{\left[\sum_{j=1}^{nq}(p_j - p_{j-1} - \mu)^2\right]^2}.
\end{aligned}$$

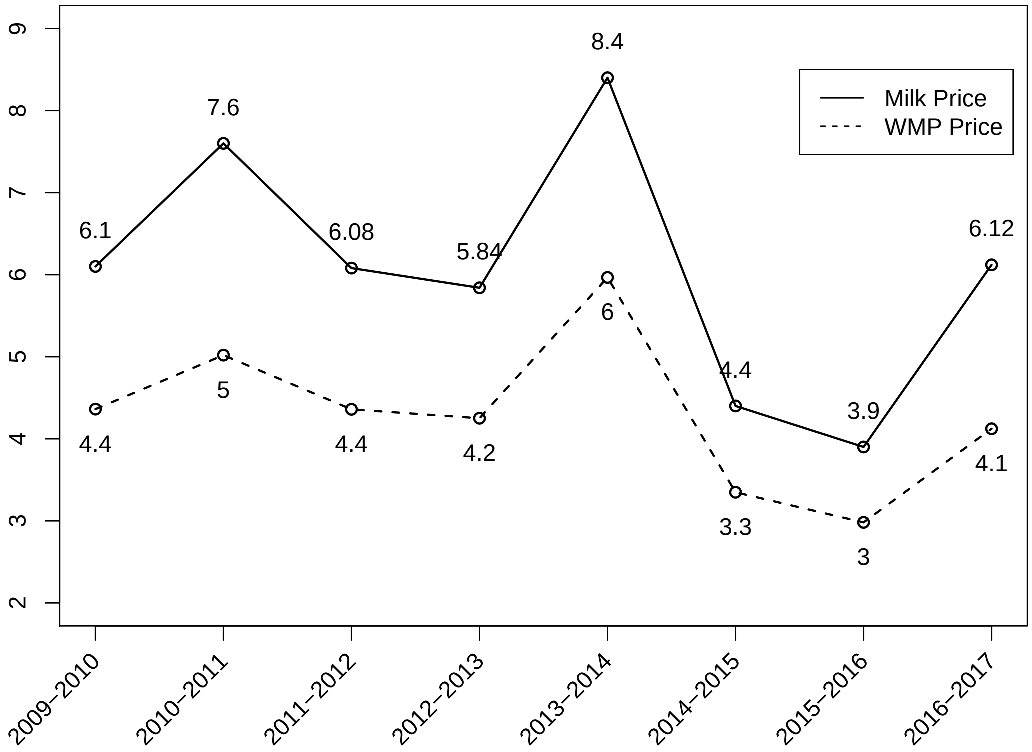
$Z(q)$ is asymptotically normally distributed with mean zero and standard deviation of one.

Chow & Denning (1993) derived the multivariate variance ratio test where the null hypothesis is that $VR(q_i)$ equals one for all $i = 1, ..., l$. The test statistic is defined by:

$$ZV = \max_{1 \le i \le l} |Z(q_i)|,$$

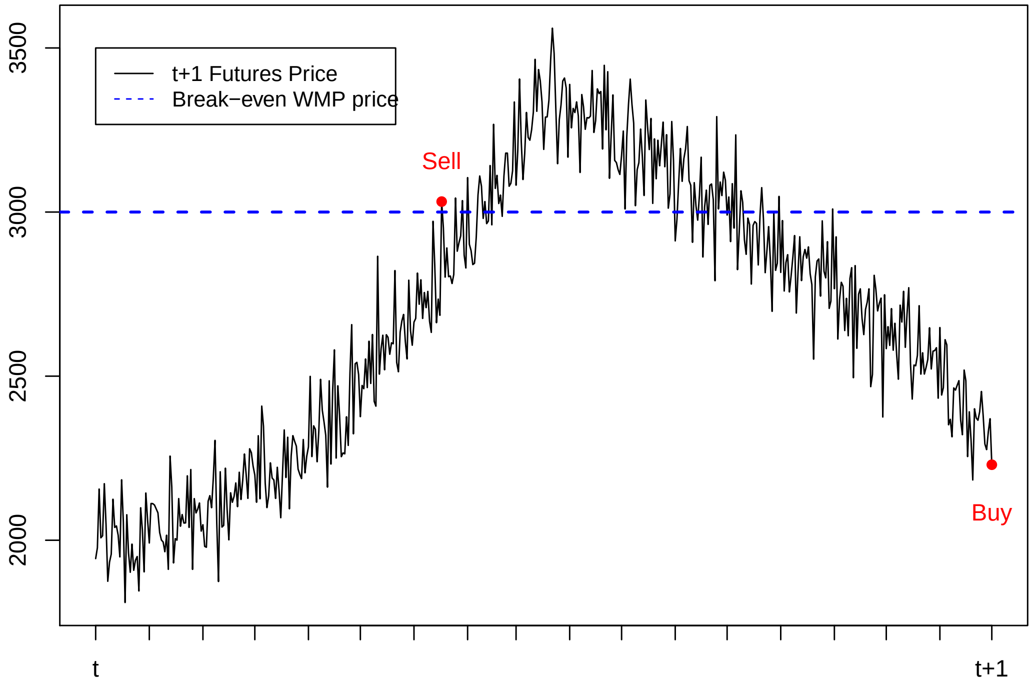
which asymptotically follows the studentized maximum modulus distribution under the random walk null hypothesis.

Figure 1: Milk and WMP prices per season in NZD \$/kg



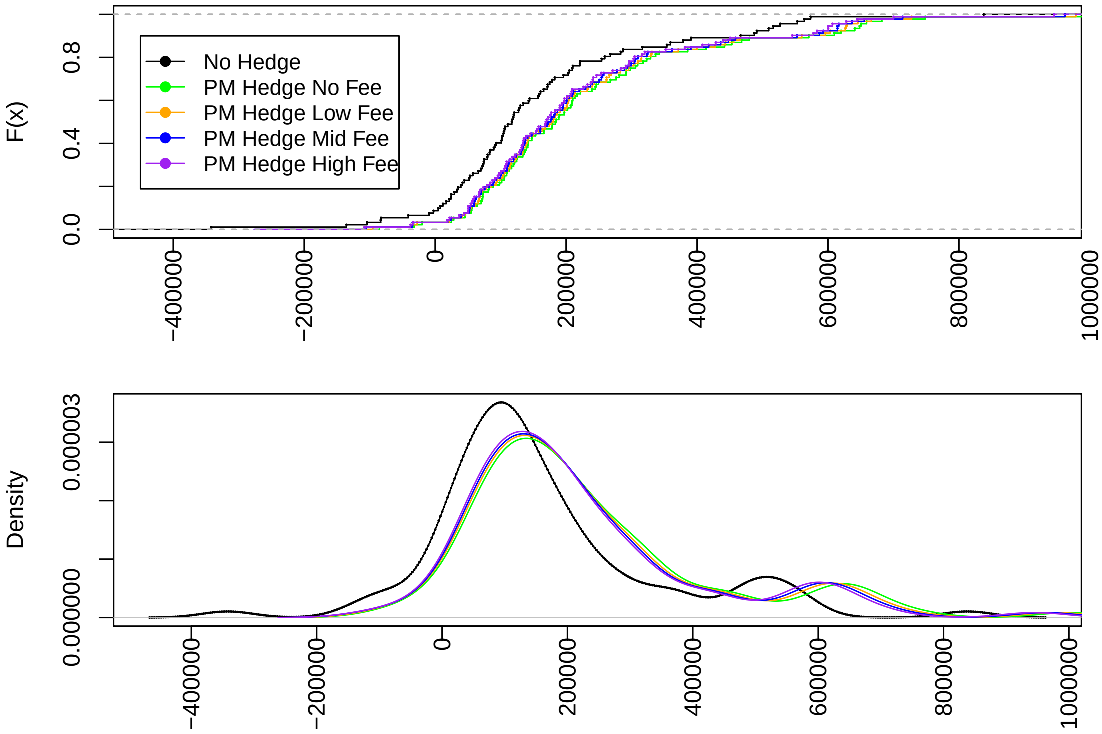
Note: Milk prices are Fonterra's prices per kilogram of milk solids and WMP price is the weighted average USD contract prices converted to NZD and divided by 1000.

Figure 2: Profit Margin Hedging Example



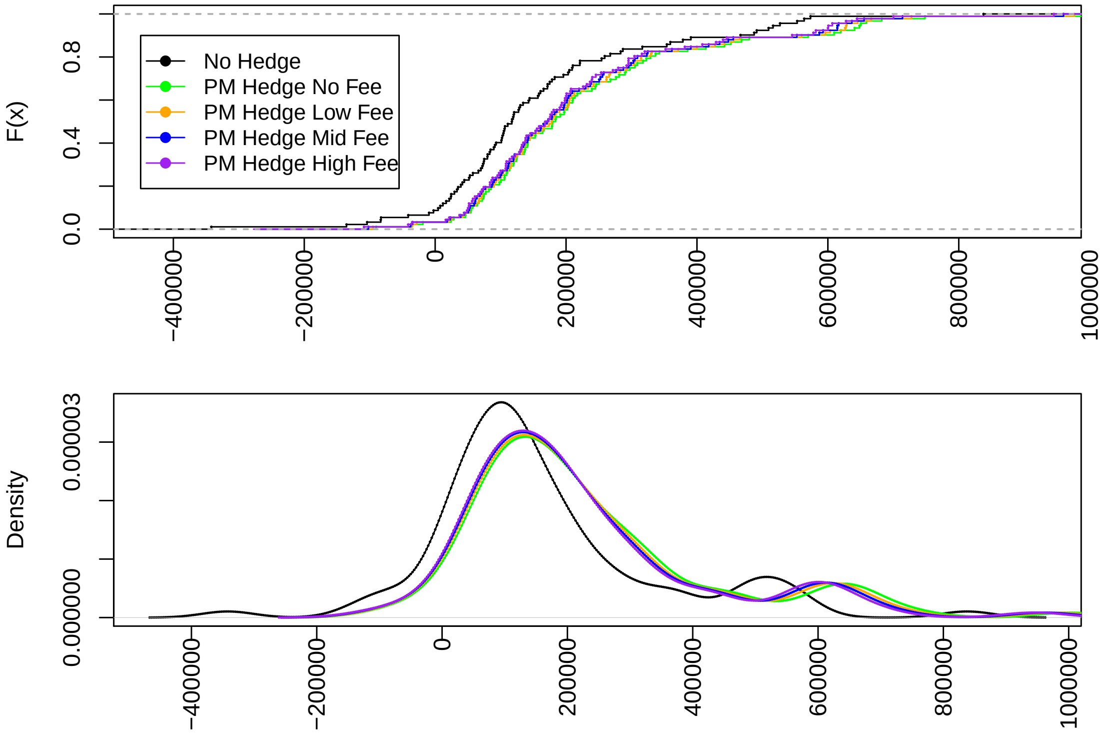
Note: The plot illustrates how a producer can hedge a production of WMP above the break-even price.

Figure 3: Kernel Density Estimation and Cumulative Distribution Function of Discretionary Cash without Basis Risk



Note: The x-axis of the plots shows the mean value of discretionary cash over 2012-2017 seasons in NZD. The y-axis of the bottom graph shows the probability $F(x) = P(Discretionary\ Cash\ \leq x)$.

Figure 4: Kernel Density Estimation and Cumulative Distribution Function of Discretionary Cash without Basis Risk



Note: The x-axis of the plots shows the mean value of discretionary cash over 2012-2017 seasons in NZD. The y-axis of the bottom graph shows the probability $F(x) = P(Discretionary\ Cash\ \leq x)$.

Table 1: New Zealand Break-even Milk Price (NZ$ per kg MS)

	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
Farm working expenses	3.95	4.13	4.33	4.07	3.64	3.73
Interest and rent	1.31	1.39	1.29	1.36	1.36	1.35
Tax	0.32	0.25	0.38	0.21	0.05	0.1
Drawings	0.57	0.65	0.77	0.69	0.49	0.51
Total cash expenses	6.14	6.42	6.77	6.33	5.53	5.7
Livestock & other dairy cash	0.4	0.44	0.42	0.56	0.6	0.53
Break-even milk price	5.74	5.98	6.35	5.77	4.93	5.17

Note: This table reports total cash expenses and break-even milk price for the representative farm between 2011 and 2017.

Table 2: Break-even WMP Prices

Season	Break-Even Milk Price NZD/kg MS	Break-Even WMP Price USD/kg MS
2011-2012	5.74	3.160
2012-2013	5.98	3.397
2013-2014	6.35	3.629
2014-2015	5.77	3.248
2015-2016	4.93	2.541
2016-2017	5.17	2.590

Note: This table reports the break-even WMP price given the break-even milk price. WMP prices are obtained from the equation $Milk_t^{NZD} = -0.733 + 1.578WMP_t^{NZD}$ and then converted to USD.

Table 3: WMP Futures: Summary Statistics and Autocorrelation for Weekly Returns

Panel A: Summary Statistics						
Sample Size	Mean	SD	Skewness	Kurtosis	Jarque-Bera	Engle ARCH
372	-0.003	0.047	-0.04	8.37	447.44***	29.02***
Panel B: Autocorrelation						
ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	LBQ_5	LBQ_{10}
0.13**	0.24***	0.01	0.06	-0.11**	32.36***	45.67***

Note: This table presents summary statistics, autocorrelation coefficients and Ljung-Box Q-test for WMP weekly returns. ***, ** indicates significance at the 1% and 5% levels, respectively.

Table 4: Variance Ratio Test for Futures Prices

Return Horizon (q-weeks)	$VR(q)$	Z-statistic
2	1.14	2.50***
4	1.45	3.74***
8	1.52	2.62***
16	1.14	0.46

Note: Under the random walk null hypothesis the variance ratio $VR(q)$ is one and Z-statistics have a standard normal distribution. *** indicates significance at the 1% level.

Table 5: Alternative Hedging Strategies, Prices are in US$/MT

Risk/Return Characteristics of monthly WMP Prices					Effectiveness of Hedging			
Panel A: No Basis Risk								
Strategy	Mean	St Dev	Semivariance	CV	Mean	St Dev	Semivariance	CV
No Hedge	3,250	1,032	410	0.32				
Continuous Hedge No Fee	3,488	734	176	0.21	7.3%	28.9%	57.0%	33.7%
Continuous Hedge Low Fee	3,458	734	190	0.21	6.4%	28.9%	53.7%	33.2%
Continuous Hedge Mid Fee	3,438	734	199	0.21	5.8%	28.9%	51.5%	32.8%
Continuous Hedge High Fee	3,418	734	208	0.21	5.2%	28.9%	49.2%	32.4%
PM Hedge No Fee	3,708	712	0	0.19	14.1%	31.0%	100.0%	39.5%
PM Hedge Low Fee	3,686	713	0	0.19	13.4%	30.9%	100.0%	39.1%
PM Hedge Mid Fee	3,668	713	0	0.19	12.9%	30.9%	100.0%	38.8%
PM Hedge High Fee	3,659	712	0	0.19	12.6%	31.0%	100.0%	38.7%
Panel B: Basis Risk								
Strategy	Mean	St Dev	Semivariance	CV	Mean	St Dev	Semivariance	CV
No Hedge	3,250	1,032	410	0.32				
Continuous Hedge No Fee	3,473	796	176	0.23	6.9%	22.8%	57.0%	27.8%
Continuous Hedge Low Fee	3,443	796	190	0.23	5.9%	22.8%	53.7%	27.1%
Continuous Hedge Mid Fee	3,423	796	199	0.23	5.3%	22.8%	51.5%	26.7%
Continuous Hedge High Fee	3,403	796	208	0.23	4.7%	22.8%	49.2%	26.3%
PM Hedge No Fee	3,709	717	8	0.19	14.1%	30.5%	98.0%	39.1%
PM Hedge Low Fee	3,679	717	14	0.19	13.2%	30.5%	96.5%	38.6%
PM Hedge Mid Fee	3,659	717	19	0.20	12.6%	30.5%	95.4%	38.3%
PM Hedge High Fee	3,639	717	24	0.20	12.0%	30.5%	94.2%	37.9%

Note: This table presents the mean, standard deviation and semivariance of monthly WMP prices for no hedge, continuous hedge and profit margin hedging strategies. Panel A reports the results without basis risk and Panel B with basis risk.

Table 6: Paired Differences t-Ratios of Average Prices

No Basis Risk					Basis Risk				
Panel A: Continuous Hedge vs. No Hedge									
	No Fee	Low Fee	Mid Fee	High Fee		No Fee	Low Fee	Mid Fee	High Fee
Mean	238	208	188	168	Mean	238	208	188	168
SD	1222	1222	1222	1222	SD	1222	1222	1222	1222
t-ratio	1.7	1.4	1.3	1.2	t-ratio	1.7	1.4	1.3	1.2
Panel B: Profit Margin Hedge vs. No Hedge									
Mean	458	436	418	409	Mean	459	429	409	389
SD	1294	1284	1282	1273	SD	1290	1290	1290	1290
t-ratio	3.0***	2.9***	2.8***	2.7***	t-ratio	3.0***	2.8***	2.7***	2.3***
Panel C: Profit Margin vs. Continuous Hedge									
Mean	221	228	230	242	Mean	222	222	222	222
SD	353	363	362	360	SD	354	354	354	354
t-ratio	5.3***	5.3***	5.4***	5.7***	t-ratio	5.3***	5.3***	5.3***	5.3***

Note: This table presents paired differences of the expected price between continuous hedge and no hedge, profit margin hedging and no hedge, profit margin and continuous hedge for three different levels of fees. Under the null hypothesis t-statistic follows t-distribution with 71 degrees of freedom. The *** indicates significance at the 1% level.

Table 7: Milk Price Per Season

Season	BEMP	Cash Sale	Hedge No Fee	Hedge Low Fee	Hedge Mid Fee	Hedge High Fee
Panel A: No Basis Risk						
2011-2012	5.74	6.08	6.61	6.55	6.51	6.47
2012-2013	5.98	6.88	6.79	6.73	6.70	6.66
2013-2014	6.35	8.36	6.48	6.51	6.48	6.56
2014-2015	5.77	4.46	8.69	8.63	8.59	8.55
2015-2016	4.93	3.99	7.42	7.36	7.31	7.27
2016-2017	5.17	5.99	5.64	5.57	5.52	5.49
Average	5.66	5.96	6.94	6.89	6.85	6.83
Panel B: Basis Risk						
2011-2012	5.74	6.08	6.61	6.55	6.51	6.47
2012-2013	5.98	6.88	6.78	6.72	6.68	6.64
2013-2014	6.35	8.36	6.53	6.48	6.44	6.40
2014-2015	5.77	4.46	8.69	8.63	8.59	8.55
2015-2016	4.93	3.99	7.42	7.36	7.31	7.27
2016-2017	5.17	5.99	5.60	5.53	5.49	5.44
Average	5.66	5.96	6.94	6.88	6.84	6.79

Note: This table presents the estimated price of milk per season with and without profit margin hedging. The price of milk is calculated as an average WMP price per season and then converted to milk price using Equation (1).

Table 8: Kolmogorov-Smirnov Test for Discretionary Cash with and without Profit Margin Hedging

	No hedge vs. hedge no fee	No hedge vs. hedge low fee	No hedge vs. hedge mid fee	No hedge vs. hedge high fee
Panel A: No Basis Risk				
K-S statistic	0.239***	0.228***	0.228***	0.217***
p-value	0.010	0.016	0.016	0.026
Panel B: Basis Risk				
K-S statistic	0.239***	0.228***	0.217***	0.217***
p-value	0.010	0.016	0.026	0.026

Note: This table presents the results of the Kolmogorov-Smirnov test which measures the difference between two cumulative distribution functions. The null hypothesis is that two samples are drawn from the same distribution. *** indicates significance at the 1% level.

Table 9: Hedging Effectiveness for Individual Farms in the No Basis Risk Scenario

Quintiles	Low	2	3	4	High	All	Low	2	3	4	High	All
Panel A:	Volatility of Discretionary Cash						Reduction in Volatility of Discretionary Cash					
No hedge	109,309	180,562	255,860	410,700	678,701	328,482						
Hedge no fee	86,362	135,074	194,525	244,391	403,944	213,561	21%**	25%***	24%***	40%***	40%***	35%***
Hedge low fee	85,818	134,620	193,803	243,709	402,909	212,872	21%**	25%***	24%***	41%***	41%***	35%***
Hedge mid fee	85,614	133,993	193,284	243,366	402,300	212,412	22%**	26%***	24%***	41%***	41%***	35%***
Hedge high fee	85,415	133,570	192,442	242,379	401,942	211,857	22%**	26%***	25%***	41%***	41%***	36%***
Panel B:	Semivariance of Discretionary Cash						Reduction in Semivariance of Discretionary Cash					
No hedge	745	27,739	80,066	135,241	316,757	113,124						
Hedge no fee	2,474	7,726	14,968	24,073	76,406	25,209	-232%	72%***	81%***	82%***	76%***	78%***
Hedge low fee	2,631	7,726	16,221	24,491	81,314	26,814	-253%	72%***	80%***	82%***	74%***	76%***
Hedge mid fee	2,736	8,559	16,726	25,172	85,272	28,048	-267%	69%***	79%***	81%***	73%***	75%***
Hedge high fee	2,785	9,650	17,492	25,841	88,076	29,131	-274%	65%***	78%***	81%***	72%***	74%***
Panel C:	Mean of Discretionary Cash						Increase in Mean of Discretionary Cash					
No hedge	- 28,953	71,274	116,562	188,264	443,343	159,165						
Hedge no fee	48,298	128,875	178,067	259,654	550,718	234,566	267%***	81%***	53%***	38%***	24%***	47%***
Hedge low fee	43,640	124,296	171,479	252,082	536,296	226,959	251%***	74%***	47%***	34%***	21%***	43%***
Hedge mid fee	40,646	120,442	167,796	247,478	526,718	221,987	240%***	69%***	44%***	31%***	19%***	39%***
Hedge high fee	38,355	116,930	163,134	243,027	517,152	217,068	232%***	64%***	40%***	29%***	17%***	36%***

Note: This table presents the effect of hedging on individual farms in the no basis risk scenario. We group farms into quintiles of annual volatility, semivariance and mean of discretionary cash for unhedged position. We use a paired t-test to compare the difference in means of volatility, semivariance and mean of discretionary cash between no hedge and profit margin hedging strategies. **, *** indicates significance at the 5% and 1% levels, respectively.

Table 10: Hedging Effectiveness for Individual Farms in the Basis Risk Scenario

Quintiles	Low	2	3	4	High	All	Low	2	3	4	High	All
Panel A:	Volatility of Discretionary Cash						Reduction in Volatility of Discretionary Cash					
No hedge	109,309	180,562	255,860	410,700	678,701	328,482						
Hedge no fee	86,745	134,938	194,599	245,513	404,170	213,895	21%**	25%***	24%***	40%***	40%***	35%***
Hedge low fee	86,041	134,491	192,713	243,972	403,901	212,936	21%**	26%***	25%***	41%***	40%***	35%***
Hedge mid fee	85,550	133,941	192,237	243,616	403,462	212,473	22%**	26%***	25%***	41%***	41%***	35%***
Hedge high fee	85,477	133,619	192,201	242,770	402,349	211,993	22%**	26%***	25%***	41%***	41%***	35%***
Panel B:	Semivariance of Discretionary Cash						Reduction in Semivariance of Discretionary Cash					
No hedge	745	27,739	80,066	135,241	316,757	113,124						
Hedge no fee	2,474	7,902	15,582	23,536	77,835	25,515	-232%	72%***	81%***	83%***	75% ***	77%***
Hedge low fee	2,631	7,902	16,109	23,185	81,816	26,674	-253%	72%***	80%***	83%***	74%***	76%***
Hedge mid fee	2,736	8,568	16,748	22,799	85,849	27,709	-267%	69%***	79%***	83%***	73%***	76%***
Hedge high fee	2,841	9,479	17,946	24,006	89,050	29,040	-281%	66%***	78%***	82%***	72%***	74%***
Panel C:	Mean of Discretionary Cash						Increase in Mean of Discretionary Cash					
No hedge	- 28,953	71,274	116,562	188,264	443,343	159,165						
Hedge no fee	48,262	127,609	177,336	259,662	550,587	234,142	267%***	79%***	52%***	38%***	24%***	47%***
Hedge low fee	44,081	124,150	170,933	251,764	536,120	226,816	252%***	74%***	47%***	34%***	21%***	43%***
Hedge mid fee	40,965	121,041	166,471	246,894	526,369	221,725	241%***	70%***	43%***	31%***	19%***	39%***
Hedge high fee	37,890	117,464	163,539	241,599	516,814	216,807	231%***	65%***	40%***	28%***	17%***	36%***

Note: This table presents the effect of hedging on individual farms in the scenario with basis risk. We group farms into quintiles of annual volatility, semivariance and mean of discretionary cash flow for unhedged position. We use a paired t-test to compare the difference in means of volatility, semivariance and mean of discretionary cash between no hedge and profit margin hedging strategies. **, *** indicates significance at the 5% and 1% levels, respectively.

Table 11: Effect of Hedging on Discretionary Cash for Individual Farms Grouped by Leverage without Basis Risk

Quintiles	Low	2	3	4	High	All	High - Low	t-stat	Low	2	3	4	High	All
Debt to Asset	31%	41%	52%	64%	90%	47%			31%	41%	52%	64%	90%	47%
Panel A:	Volatility of Discretionary Cash								Reduction in Volatility of Discretionary Cash					
No hedge	217,762	324,713	302,947	487,880	315,956	328,482	98,194	1.73						
Hedge no fee	169,658	178,898	216,106	270,959	233,516	213,561	63,857	1.32	22%***	45%***	29%***	44%***	26%***	35%***
Hedge low fee	169,110	178,352	215,799	269,880	232,555	212,872	63,445	1.31	22%***	45%***	29%***	45%***	26%***	35%***
Hedge mid fee	168,939	177,717	215,305	269,488	231,943	212,412	63,003	1.30	22%***	45%***	29%***	45%***	27%***	35%***
Hedge high fee	168,679	177,242	214,962	268,277	231,436	211,857	62,757	1.29	23%***	45%***	29%***	45%***	27%***	36%***
Panel B:	Semivariance of Discretionary Cash								Reduction in Semivariance of Discretionary Cash					
No hedge	10,525	105,606	103,565	227,062	123,959	113,124	113,434***	6.42						
Hedge no fee	2,009	15,508	24,718	54,658	30,168	25,209	28,158**	2.53	81%**	85%***	76%***	76%***	76%***	78%***
Hedge low fee	2,148	16,310	26,217	58,916	31,581	26,814	29,433**	2.56	80%**	85%***	75%***	74%***	75%***	76%***
Hedge mid fee	2,145	17,057	26,857	62,590	32,765	28,048	30,620**	2.61	80%**	84%***	74%***	72%***	74%***	75%***
Hedge high fee	2,239	17,805	27,879	64,816	34,133	29,131	31,893**	2.67	79%**	83%***	73%***	71%***	72%***	74%***
Panel C:	Mean of Discretionary Cash								Increase in Mean of Discretionary Cash					
No hedge	228,204	170,924	155,504	124,535	115,263	159,165	-112,941**	- 2.29						
Hedge no fee	281,252	237,935	222,602	239,509	191,339	234,566	-89,912	- 1.53	23%***	39%***	43%***	92%***	66%***	47%***
Hedge low fee	275,489	230,758	215,498	228,820	183,924	226,959	-91,565	- 1.61	21%***	35%***	39%***	84%***	60%***	43%***
Hedge mid fee	271,456	226,326	210,996	221,797	179,001	221,987	-92,454	- 1.64	19%***	32%***	36%***	78%***	55%***	39%***
Hedge high fee	267,453	221,852	206,364	215,429	173,846	217,068	-93,606	- 1.69	17%***	30%***	33%***	73%***	51%***	36%***

Note: This table presents the effect of hedging on individual farms in the scenario with no basis risk. We group farms into quintiles of average leverage ratio. We use a paired t-test to compare the difference in means of volatility, semivariance and mean of discretionary cash between no hedge and profit margin hedging strategies. We use a two-sample t-test to compare the difference in means of volatility, semivariance and mean of discretionary cash between high and low quintile of leverage ratio. **, *** indicates significance at the 5% and 1% levels, respectively.

Table 12: Effect of Hedging on Discretionary Cash for Individual Farms Grouped by Leverage with the Basis Risk

Quintiles	Low	2	3	4	High	All	High - Low	t-stat	Low	2	3	4	High	All
Debt to Asset	31%	41%	52%	64%	90%	47%			31%	41%	52%	64%	90%	47%
Panel A:	Volatility of Discretionary Cash Flow								Reduction in Volatility of Discretionary Cash					
No hedge	217,762	324,713	302,947	487,880	315,956	328,482	98,194	1.73						
Hedge no fee	169,851	179,358	216,306	271,999	233,325	213,895	63,474	1.31	22%***	45%***	29%***	44%***	26%***	35%***
Hedge low fee	169,325	178,468	215,722	270,254	232,258	212,936	62,933	1.30	22%***	45%***	29%***	45%***	26%***	35%***
Hedge mid fee	169,003	178,272	215,426	269,536	231,487	212,473	62,484	1.29	22%***	45%***	29%***	45%***	27%***	35%***
Hedge high fee	168,784	177,654	215,427	268,386	231,054	211,993	62,270	1.28	22%***	45%***	29%***	45%***	27%***	35%***
Panel B:	Semivariance of Discretionary Cash Flow								Reduction in Semivariance of Discretionary Cash					
No hedge	10,525	105,606	103,565	227,062	123,959	113,124	113,434***	6.42						
Hedge no fee	2,026	15,452	25,520	56,090	29,565	25,515	27,539**	2.47	81%**	85%***	75%***	75%***	76%***	77%***
Hedge low fee	2,161	16,357	26,068	59,001	30,909	26,674	28,748**	2.48	79%**	85%***	75%***	74%***	75%***	76%***
Hedge mid fee	2,259	17,108	26,893	61,587	31,878	27,709	29,618**	2.50	79%**	84%***	74%***	73%***	74%***	76%***
Hedge high fee	2,359	17,892	27,967	64,769	33,450	29,040	31,091**	2.58	78%**	83%***	73%***	71%***	73%***	74%***
Panel C:	Mean of Discretionary Cash Flow								Increase in Mean of Discretionary Cash					
No hedge	228,204	170,924	155,504	124,535	115,263	159,165	-112,941**	-2.29						
Hedge no fee	281,076	237,609	221,868	238,619	191,309	234,142	- 89,767	-1.52	23%***	39%***	43%***	92%***	66%***	47%***
Hedge low fee	275,097	230,385	215,907	228,239	184,140	226,816	- 90,957	-1.60	21%***	35%***	39%***	83%***	60%***	43%***
Hedge mid fee	271,496	225,705	210,851	220,935	179,231	221,725	- 92,265	-1.64	19%***	32%***	36%***	77%***	55%***	39%***
Hedge high fee	267,359	221,278	205,991	214,704	174,256	216,807	- 93,103	-1.68	17%***	29%***	32%***	72%***	51%***	36%***

Note: This table presents the effect of hedging on individual farms in the scenario with basis risk. We group farms into quintiles of average leverage ratio. We use a paired t-test to compare the difference in means of volatility, semivariance and mean of discretionary cash between no hedge and profit margin hedging strategies. We use a two-sample t-test to compare the difference in means of volatility, semivariance and mean of discretionary cash between high and low quintile of leverage ratio. **, *** indicates significance at the 5% and 1% levels, respectively.

Table 13: Frequency of Negative Discretionary Cash Occurrence

	No Basis Risk	Basis Risk
No hedge	34.6%	34.6%
Hedge no fee	13.7%	13.9%
Hedge low fee	14.8%	14.8%
Hedge mid fee	15.4%	15.4%
Hedge high fee	16.3%	16.5%

Note: This table presents the frequency of negative discretionary cash among 92 farms during five seasons 2012-2017, totalling to 460 observations.

References

Ballingall, J. & Pambudi, D. (2017), Dairy trade's economic contribution to New Zealand, Technical report, NZIER, `https://nzier.org.nz/publication/dairy-trades-economic-contribution-to-new-zealand`.

Bosch, D. J. & Johnson, C. J. (1992), 'An evaluation of risk management strategies for dairy farms', *Journal of Agricultural and Applied Economics* **24**(2), 173–182.

Chow, K. V. & Denning, K. C. (1993), 'A simple multiple variance ratio test', *Journal of Econometrics* **58**(3), 385–401.

Collins, R. A. (1997), 'Toward a positive economic theory of hedging', *American Journal of Agricultural Economics* **79**(2), 488–499.

Conlon, T. & Cotter, J. (2013), 'Downside risk and the energy hedger's horizon', *Energy Economics* **36**, 371–379.

DairyNZ (2017), Dairynz economic survey 2015-16, Technical report, DairyNZ, `https://www.dairynz.co.nz/media/5787208/dairynz-economic-survey-2015-16.pdf`.

Fonterra (2017), Farmgate milk price statement, Technical report, Fonterra Co-operative Group Limited, `https://www.nzx.com/files/attachments/266472.pdf`.

Hatchett, R. B., Brorsen, B. W. & Anderson, K. B. (2010), 'Optimal length of moving average to forecast futures basis', *Journal of Agricultural and Resource Economics* **35**(1), 18–33.

Hudson, M. A., Leuthold, R. M. & Sarassoro, G. F. (1987), 'Commodity futures price changes: Recent evidence for wheat, soybeans and live cattle', *Journal of Futures Markets* **7**(3), 287–301.

Johnson, L. L. (1960), 'The theory of hedging and speculation in commodity futures', *The Review of Economic Studies* **27**(3), 139–151.

Kenyon, D. & Clay, J. (1987), 'Analysis of profit margin hedging strategies for hog producers', *Journal of Futures markets* **7**(2), 183–202.

Khalifa, A. A., Miao, H. & Ramchander, S. (2011), 'Return distributions and volatility forecasting in metal futures markets: Evidence from gold, silver, and copper', *Journal of Futures Markets* **31**(1), 55–80.

Kim, H. S., Brorsen, B. W. & Anderson, K. B. (2010), 'Profit margin hedging', *American Journal of Agricultural Economics* **92**(3), 638–653.

Kim, M., Garcia, P. & Leuthold, R. M. (2009), 'Managing price risks using and local polynomial kernel forecasts', *Applied Economics* **41**(23), 3015–3026.

Koeman, J. & Bialkowski, J. P. (2015), Cross-hedging on the milk-derived product market. Working paper.

Lee, C. I., Gleason, K. C. & Mathur, I. (2000), 'Efficiency tests in the French derivatives market', *Journal of Banking & Finance* **24**(5), 787–807.

Lo, A. W. & MacKinlay, A. C. (1988), 'Stock market prices do not follow random walks: Evidence from a simple specification test', *The Review of Financial Studies* **1**(1), 41–66.

Manfredo, M. R. & Richards, T. J. (2007), 'Cooperative risk management, rationale, and effectiveness: the case of dairy cooperatives', *Agricultural Finance Review* **67**(2), 311–339.

Martin, L. J. & Hope, D. (1984), 'Risk and returns from alternative marketing strategies for corn producers', *Journal of Futures Markets* **4**(4), 513–530.

Maynard, L. J., Wolf, C. & Gearhardt, M. (2005), 'Can futures and options markets hold the milk price safety net? policy conflicts and market failures in dairy hedging', *Review of Agricultural Economics* **27**(2), 273–286.

Neyhard, J., Tauer, L. & Gloy, B. (2013), 'Analysis of price risk management strategies in dairy farming using whole-farm simulations', *Journal of Agricultural and Applied Economics* **45**(2), 313–327.

Peterson, P. E. & Leuthold, R. M. (1987), 'A portfolio approach to optimal hedging for a commercial cattle feedlot', *Journal of Futures Markets* **7**(4), 443–457.

RBNZ (2018), Financial stability report, Technical report, Reserve Bank of New Zealand, `https://www.rbnz.govt.nz/financial-stability/financial-stability-report`.

Schroeder, T. C. & Hayenga, M. L. (1988), 'Comparison of selective hedging and options strategies in cattle feedlot risk management', *Journal of Futures Markets* **8**(2), 141–156.

Shapiro, B. & Brorsen, B. W. (1988), 'Factors affecting farmers' hedging decisions', *North Central Journal of Agricultural Economics* **10**(2), 145–153.

Smith, G. & Rogers, G. (2006), 'Variance ratio tests of the random walk hypothesis for south african stock futures', *South African Journal of Economics* **74**(3), 410–421.

Stein, J. L. (1961), 'The simultaneous determination of spot and futures prices', *The American Economic Review* **51**(5), 1012–1025.

Turvey, C. G. & Baker, T. G. (1989), 'Optimal hedging under alternative capital structures and risk aversion', *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie* **37**(1), 135–143.

Wolf, C. A. & Widmar, N. J. O. (2014), 'Adoption of milk and feed forward pricing methods by dairy farmers', *Journal of Agricultural and Applied Economics* **46**(4), 527.

Wood, W. C., Shafer, C. E. & Anderson, C. G. (1989), 'Frequency and duration of profitable hedging margins for texas cotton producers, 1980–1986', *Journal of Futures Markets* **9**(6), 519–528.

Yang, S.-R. & Brorsen, B. W. (1994), 'Daily futures price changes and non-linear dynamics', *Structural Change and Economic Dynamics* **5**(1), 111–132.

Yoon, B.-S. & Brorsen, B. W. (2005), 'Can multiyear rollover hedging increase mean returns?', *Journal of Agricultural and Applied Economics* **37**(1), 65–78.