Journal of Applied Farm Economics

Volume 1 | Issue 2 Article 4

2017

Application of the Adjusted Weak Axiom of Profit Maximization to New Zealand Dairy Farming

Anne E. Dooley
Massey University, a.e.dooley@massey.ac.nz

Nicola M. Shadbolt
Massey University, n.m.shadbolt@massey.ac.nz

Koohyar Khatami
Massey University, s.khatami@massey.ac.nz

Loren W. Tauer
Cornell University, lwt1@cornell.edu

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Cover Page Footnote
This research was funded by New Zealand dairy farmers through DairyNZ and the Ministry for Primary Industries under the Dairy Primary Growth Partnership. The data for the research was provided by DairyBase.

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ABSTRACT

The weak axiom of profit maximization is a nonparametric, empirical approach that has been used in the United States to analyze dairy farmers' production and profit behavior under input and output price changes to determine whether farmers effectively respond to these changes. The expectation is that profit calculated using the current year's input and output combination will be greater than that calculated from the previous year's combination with current prices more often than due to chance. This approach was replicated using New Zealand dairy farm data (1,785 pairs of records over five years). Current year's profits were significantly greater in two of the years and less in two years and in total. New Zealand's pasture-based systems mean that this approach has limitations in evaluating farmers' input and output decisions in response to price changes. Factors such as climatic impacts on pasture availability (a volatile input not included in the data set), and hence purchased feed requirements, affected the results. Farmer responses to costs and prices were not readily differentiated from other factors that affected input decisions or output. Results were interpreted with respect to climate, production, and income and cost changes, both nationally and regionally, with some interesting observations on farmer responses to variability.

KEYWORDS

dairy farming, New Zealand, pasture-based systems, price responses, weak axiom of profit maximization

INTRODUCTION

Despite producing just 2–3% of global milk production, New Zealand is the largest international trader of milk products, exporting 96% of its dairy production (Shadbolt & Apparao, 2016). Consequently, the New Zealand dairy industry and its farmers are exposed to volatile international dairy prices and exchange rates as well as trade idiosyncrasies. In recent years, global dairy prices have become increasingly volatile, resulting in greater variability in farm gate milk prices.

According to production theory, the convex shape of the profit function for both output and input prices means that greater variation in prices will result in higher average profits over time if farmers optimally adjust the use of inputs in response to price changes (Chambers, 1988). The greater variation experienced by New Zealand dairy farmers should therefore lead to higher profits over time if they respond accordingly. Farmers have responded to prices (Hammond, 2016; Shadbolt, 2012; Shadbolt et al., 2016), but their responses are often interpreted as "lack of cost control" rather than as managed adjustments to farm inputs in response to price changes (DairyNZ, 2015). Similarly, Irish economists have identified the phenomenon of "sticky costs" whereby costs increase along with milk prices, with concerns that such costs will not easily be reduced when prices fall (Smyth et al., 2009).

Research to date on New Zealand dairy farmers (Shadbolt et al., 2016) identified a group of farmers who adjust inputs in line with price changes. This group had statistically higher operating profit margins, double those of their peers over a six-year period, with commensurate higher returns on assets and returns on equity. The higher operating profit margins of this group suggested that these farmers did optimally adjust the use of inputs in response to price changes each year (Chambers, 1988) and delivered higher average profits over time. These research findings suggested that more complex further analysis of New Zealand dairy farmer data to determine and better understand farmer behavior under price volatility would be productive.

The weak axiom of profit maximization (WAPM) is a nonparametric, empirical approach that has been used to analyze farmers' production and profit behavior under input and output price changes by testing the consistency of data with profit maximization to determine whether farmers were effectively responding to price changes (Debreu, 1951; Varian, 1984). WAPM techniques provide a computationally simple test of optimizing behavior by firms. The goal in WAPM approaches is to measure the extent to which farmers successfully adjust production in response to price changes such that the resultant profit will be more than the passive linear profit response that would occur with no input and production changes. The basic WAPM approach directly tests whether farmers maximize profits each year by calculating the profitability of all alternative feasible input and output bundles from the entire sample of farms under a given year-price vector and comparing these values with actual profits achieved in that year to find whether farmers choose production combinations that maximize farm profit (Zereyesus et al., 2009).

Farmers routinely make output and input decisions based on the prices of outputs and inputs. If the price of a product increases and a farmer makes no adjustment or change to the business as a result, then farm profit will increase by the amount of the price increase multiplied by the quantity of output produced. Similarly, if the price of an input decreases and no change to input use is made, profit will increase by the amount of the price decrease multiplied by the quantity of that input. However, when prices change, an informed farmer can make adjustments that would result in even greater profits by altering the quantities of outputs or inputs. If an improvement is possible, altering input use and outputs produced would be warranted to increase profit. A farmer is unlikely to make a change that does not result in at least the same profit possible under no change. These arguments hold if output price decreases or input prices increase, although in those cases profits would decrease. The theory behind WAPM approaches is described in Chambers (1988) and Nakane and Tauer (2009).

The WAPM approach has been used by a number of researchers to determine how successfully farmers exhibit profit maximization or cost minimization behavior (Featherstone et al., 1995; Tauer, 1995; Zereyesus et al., 2009). A limitation of this method using data from a set of farmers in comparisons is the assumption that farms have homogenous production technology. However, each farm's unique location and farm characteristics mean that production technology is unlikely to be homogenous across farms, restricting the usefulness of comparing an individual farm's netput vectors[1] with all netput vectors.

To address this limitation, Nakane and Tauer (2009) suggested a variation of the WAPM technique, referred to as the adjusted WAPM. The critical difference in this adjusted WAPM approach compared to previous WAPM approaches is that it allows for the possibility that each farm's technology or output response to input use is unique to that farm, thus allowing for heterogeneity in technology among farms. That is, it is not assumed that production data from other farms are feasible. Instead, production data from two consecutive years for the same farm are used in calculating and comparing passive and actual profits.

In this adjusted WAPM technique, the previous year's netput vector quantities, representing a feasible production plan unique to that farm, are combined with the farm's input and output prices from the current year to calculate passive profit. This is the profit that would be realized if a farmer had made no changes in the use of inputs in response to current prices. This passive profit calculates "what profits would occur to a specific farm in a following year with prices of that following year if a farmer did not change his netput vector" (Nakane & Tauer, 2009, p. 7). This profit value is then compared to the actual profit achieved in the following year to determine whether changes in input use increased profits above those resulting from passive management. If actual profits exceed passive profits for farms in the data set at a frequency that is unlikely to be due to chance, it can be surmised that farmers are actively adjusting inputs in response to price signals. This adjusted WAPM method was used by Nakane and Tauer (2009) to determine whether New York dairy farmers were optimally adjusting their use of inputs in response to price changes. The results for this group of farmers suggested that they were not, although it is possible some farmers may have been.

The research presented in this paper adapts the adjusted WAPM method to investigate New Zealand dairy farmers' behavior in response to price changes. Nakane and Tauer (2009) used U.S. dairy farm data from systems where cows are housed and a relatively high proportion of feed inputs are externally sourced. In contrast, all New Zealand dairy farm systems are pasture-based, with all-year grazing and purchasing only 4–20% of feed as supplementary feed (DairyNZ, 2016). Weather variation can affect pasture production, and thus milk production and purchased feed required, so farmers are likely to also be responding to shifts in the production function rather than price signals in making input purchasing and production level decisions. Therefore, climate was also considered in interpreting the WAPM results because of its impact on milk production and input costs, particularly feed costs.

DATA AND METHODS

Data Used

Farm Data

The research data was provided by DairyBase, a New Zealand dairy industry database containing annual financial and production data from farms (Shadbolt, 2009). Participation in DairyBase is voluntary, and data is entered into the database by accredited providers. Reports and benchmarking comparisons are then made available to participating farmers. Confidential data sets are available for industry-good research on request. However, voluntary participation can lead to nonrandom sampling.

The adjusted WAPM approach was applied to DairyBase data from 817 New Zealand owner-operated dairy farms over a six-year period (2006/2007 to 2011/2012, May to June seasons). These farms had data for at least two consecutive years during that period: 348 farms only had data for one comparison (two years of consecutive data), and the remaining farms had data in more than one comparison (i.e., more than two years' data). There were a total of 1,785 consecutive pairs of data in the analysis data set over the five-year comparison. The number of paired comparisons was 424, 383, 369, 356 and 253 over comparison years 2007/2008 to 2011/2012, respectively.

New Zealand equivalents to income and expenditure items used by Nakane and Tauer (2009) in their adjusted WAPM analysis were identified in the DairyBase data (DairyBase, 2010). Appendix 1 shows the output and input data used in the analysis. Quantities and prices were not directly available in the DairyBase data for most income and expenditure items; instead, only the farm income or expenditure value was available (Appendix 1, items 2 to 35 in the table). For these variables, *passive profit* was calculated by using price indices to adjust the previous year's income or expenditure to current values to give the value of the quantity of inputs or outputs used in the previous year at the current year's prices. Price indices used are also shown in Appendix 1.

Milk Payment Prices

Cash milk solids (MS) payments received during a dairy farming production year (June to May) are a combination of advance payments for MS produced in that year plus retrospective payments for MS production from the previous year. A forecast farm gate MS price is announced by dairy processing companies at the beginning of the year for farmers to use to plan their cost structures. This price is revised over the season, and the final MS price for the year's production is finalized 16 months after the beginning of the year.

DairyBase data was available on net milk sales (Appendix 1), which is the cash received for MS (NZ$) during a given dairy farming year. The quantity of MS produced in the current production year was also available in the data. An average cash MS price per kilogram MS was calculated for each farm for each year by dividing the net milk sales value by MS produced. Values differed between farms and within a year because of adjustments for milk volume and concentration, milk quality, and premiums for winter or organic milk.

The analysis was also run using the forecast MS price and the final MS price for that season to allow consideration of the timing of price announcements on farmers' production decisions. Milk price values for the Fonterra Cooperative (New Zealand's largest dairy company) were used, with prices sourced from the Fonterra monthly newsletter, *Farm Link* (Fonterra, 2006–2011), and Fonterra's annual report (Fonterra, 2007–2012). The same yearly milk price values were used for all farms in that year.

Adjusted Weak Axiom of Profit Maximization Analysis

The WAPM analysis was adapted from that described in Nakane and Tauer (2009). Profit was calculated by deducting the expenditure items from the income items described in Appendix 1. Gross farm income, as described in Shadbolt and Gardner (2010) was used rather than cash revenue, since livestock value adjustments were included. In addition to farm working expenses, expenditure items included rent and noncash items such as labor adjustments for management and family labor, feed inventory adjustments and depreciation, and a 3% opportunity cost of capital (Hemme, 2015). So in effect, profit was operating profit less rent less cost of capital (Shadbolt & Gardner, 2010). Income tax payments, family drawings, capital expenditure, and debt repayments were not included as expenses.

Actual and passive profits were calculated for each farm-year comparison where there were two consecutive years of data available. *Actual profit* was calculated for a farm for each year where data was available for year 2 (2007/2008) to year 6 (2011/2012) as well as the corresponding previous year (years 1 to 5, respectively). *Passive profit* was calculated from the corresponding previous year for comparison. Items included in the profit calculation were the same for both *actual and passive profits* as described above; the difference was the quantity value used in these calculations.

Actual profit for each farm-year comparison was calculated as shown in Equation 1. The first term in parentheses is total receipts, and the second term is total expenses. For a description of the input and output items (k), see the table in Appendix 1. Year values (y) range from 2 to 6.

$$\pi = \left(\sum_{k=1}^{5} p_{ky}\, y_{ky}\right) - \left(\sum_{k=6}^{35} r_{ky}\, x_{ky} + OC_y\right) \qquad (1)$$

where:

p_{ky}: Output price for items (k) 1 to 5 in the second year (y) of the comparison;
y_{ky}: Output quantity price for items (k) 1 to 5 in the second year (y) of the comparison;
r_{ky}: Input cost for items (k) 6 to 35 in the second year (y) of the comparison;
x_{ky}: Input quantity for items (k) 6 to 35 in the second year (y) of the comparison; and
OC_y: Opportunity cost of capital in the second year (y) of the comparison (k=36).

Passive profit for each farm-year comparison was calculated as shown in Equation 2.

$$\bar{\pi} = \left(\sum_{k=1}^{5} p_{ky}\, y_{ky-1}\right) - \left(\sum_{k=6}^{35} r_{ky} x_{ky} + OC_{y-1}\right) \qquad (2)$$

where:

p_{ky}: Output price for items (k) 1 to 5 in the second year (y) of the comparison;
y_{ky-1}: Output quantity for items (k) 1 to 5 in the first year (y-1) of the comparison;
r_{ky}: Input cost for items (k) 6 to 35 in the second year (y) of the comparison;
x_{ky-1}: Input quantity for items (k) 6 to 35 the first year (y-1) of the comparison; and
OC_{y-1}: Opportunity cost of capital in the first year (y-1) of the comparison (k=36).

Since the quantity of MS produced and milk revenue received per farm were both available in the DairyBase data, a cash MS price value for each farm and year was calculable. Therefore, passive and actual milk revenues for each farm-year combination were calculated as shown in the formulas above using the MS quantities and the yearly cash MS prices per kilogram calculated for the two years. For the forecast MS price and final MS price analyses, these prices were multiplied by the farm MS production in the relevant years to calculate the actual and passive milk revenues.

Items other than milk revenue and opportunity cost were only available in the form of the total value ($r_{ky}x_{ky}$ value for expenses and $p_{ky}y_{ky}$ for income items). *Actual profit* was calculated using these total revenue or cost values in the formulas provided previously. However, in calculating *passive profit*, the equivalent of the $r_{ky}x_{ky-1}$ values for expenses and the $p_{ky}y_{ky-1}$ values for income items were required—that is, the value of the quantity of an input or output in the first year (y-1) at second-year (y) prices. Price indices from Statistics New Zealand (Appendix 1) were used to transform the known total income values ($p_{ky}y_{ky}$) for the first year (i.e., $p_{ky-1}y_{ky-1}$) to a $p_{ky}y_{ky-1}$ value for the nonmilk income items, as was the case for the calculation of the $r_{ky}x_{ky-1}$ cost value for expense items.

The price index vector change between two consecutive years for item k in year y was used to calculate passive income for year y, as shown in Equation 3:

$$\Delta i_{ky} = \frac{i_{ky}}{i_{ky-1}} \tag{3}$$

where:

i_{ky}: Price index for item k in the second year of the comparison and
i_{ky-1}: Price index for item k in the first year of the comparison.

If the price falls in the second year, Δi_{ky} is less than 1, and if it increases, the value of Δi_{ky} is greater than 1. Passive income for items k2 to k5 (Equation 4) and passive costs for items k6 to k35 (Equation 5) required for profit comparison for year y were calculated as follows:

$$(p_{ky}\, y_{ky\text{-}1}) = \Delta i_{ky} * (p_{ky-1}\, y_{ky-1}) \tag{4}$$

$$(r_{ky} x_{ky\text{-}1}) = \Delta i_{ky} * (r_{ky-1}\, x_{ky\text{-}1}) \tag{5}$$

Therefore, the *passive profit* in the analysis for each farm-year (y) comparison, allowing for the fact that price per unit and quantities were not available for most items, was calculated as shown in Equation 6:

$$\bar{\pi} = \left(\sum_{k=1}^{1} p_{ky}\, y_{ky-1} + \sum_{k=2}^{5} \Delta i_{ky} (p_{ky-1}\, y_{ky-1})\right) - \left(\sum_{k=6}^{35} \Delta i_{ky}\, (r_{ky-1}\, x_{ky-1}) + OC_{y-1}\right) \tag{6}$$

To identify whether farmers adjusted their netput vector in response to price changes that resulted in increased profit compared to making no changes, the difference between the *actual profit* and *passive profit* for each farm for each set of consecutive years was calculated as a *binomial variable*. If *actual profit* (π) ≥ *passive profit* ($\bar{\pi}$) a value of 1 was given, and if *actual profit* (π) < *passive profit* ($\bar{\pi}$) a value of 0 was given.

A normal distribution of 0s and 1s indicates that inputs are not, on average, adjusted in response to price signals. A significantly greater proportion of 1s or 0s suggests that farmers are adjusting their level of inputs between years in response to price signals or other factors that may affect input decisions. If farmers are adjusting their netput between years in response to price signals, there will be significantly more 1s than 0s. If there are significantly more 0s than 1s, this suggests that factors other than price are also influencing farmer decisions, since it is unlikely that they would alter inputs in response to price changes in order to reduce profit.

Differences in the *binomial variable* distributions between regions were also calculated, and results were compared with regional weather data (spring and summer/autumn rainfall, which affects supply of pasture for feed) and prices. Regional and national production and income and cost averages were calculated to identify farmer responses to price and climate variation.

RESULTS AND DISCUSSION

The weighted average cash MS price and Fonterra's forecast and final MS prices are shown in Table 1. The cash and final MS prices were similar (average 27 cents difference, range 10 to 52 cents) as expected, since most (usually 80%) of the cash income received is the advance payment portion of the final price for the current seasons' production. The difference between the forecast and final MS prices was more variable over the six years, with the final price ranging from \$1.80 less to \$2.13 more than the forecast price. The 2008/2009 final MS price was less than forecast, whereas the 2007/2008 and 2009/2010 prices were higher. Since it is assumed that farmers use the forecast MS price to help plan for the following year, some advance input decisions may not have resulted in optimal resource allocation because of incorrect information when decisions were being made (e.g., locking in feed contracts).

Table 1 also presents the *binomial variable* distribution over the five comparison years associated with the three MS prices. To determine whether the

Table 1. Percentage of 1s and 0s in each comparison year with associated cash, forecast and final MS prices (nominal values, NZ$)

Year	Cash Price		Forecast Price		Final Price	
2006/2007	$4.16		$4.05		$4.46	
2007/2008	$7.39		$5.53		$7.66	
2008/2009	$5.20		$7.00		$5.20	
2009/2010	$6.14		$4.55		$6.37	
2010/2011	$7.38		$6.90		$7.90	
2011/2012	$6.71		$7.05		$6.40	
	0	1	0	1	0	1
2007/2008	87.6%	13.4%	87.5%	12.5%	86.3%	13.7%
2008/2009	52.7%	47.3%	47.3%	52.7%	53.3%	46.7%
2009/2010	40.4%	59.6%	35.8%	64.2%	40.7%	59.3%
2010/2011	61.0%	39.0%	63.5%	36.5%	60.1%	39.9%
2011/2012	23.3%	76.7%	22.5%	77.5%	23.7%	76.3%
Total	**55.7%**	**44.3%**	**54.2%**	45.8%	55.7%	44.3%

number of 1s was statistically significant, counts were compared to a binomial distribution with the expected probability of a value of 1 being 0.5 (50% chance of a 1 or a 0) using both chi-squared and the expected normal distribution for a binomial model (z test). The null hypothesis (H_0) was that there was no difference between observed and expected frequencies, and H_1 was that there was a difference between frequencies. For all years except 2008/2009 the results were significantly different (1% level of significance), and the null hypothesis was rejected.

Final and cash MS price results were very similar as expected, and the forecast MS price results, particularly for 2008/2009 and 2009/2010, differed slightly (+ or – 6%) from these prices but not significantly so. For the cash and final MS prices, only two of the five comparison years (2009/2010 and 2011/2012) had more observations where *actual profit* was greater than *passive profit*. This pattern was similarly observed by Featherstone et al. (1995) and Tauer (1995) on U.S. farms. In contrast, in 2007/2008 and 2010/2011 and overall, the number of 1s was significantly less than the number of 0s. While research suggests that some New Zealand farmers do adjust inputs and outputs in their businesses between seasons (Shadbolt et al., 2016), these results suggest that factors in addition to prices influence netput decisions.

New Zealand's pasture-based farming systems rely on forage production for the production of milk. The annual feed available from pasture is highly variable and largely the result of adequate rainfall and temperatures. This data is not provided in the database and thus is not included as an explicit input in the netput vector. Hence, variation in pasture production between years means that the netput vectors in any given year may not reflect the production technology used in other years. So, in the absence of a measure for the feed available from pasture in the database, the WAPM approach is limited, as it cannot make adjustments for stochastic output from good or poor production years that can occur in pastoral systems in New Zealand. Furthermore, results may also not be consistent with deterministic theory, given this stochastic technology and farmers who may not be risk neutral. While Varian (1985) introduced methods to measure and correct for stochasticity of the technology set, those procedures require more observations per farm than were available in our data set.

In interpreting the binomial data, both years need to be considered. *Actual profit* may be compared with a high *passive* revenue and *profit* based on high previous year production levels that are unattainable with current year pasture availability, or, alternatively, high or similar *passive profit*,

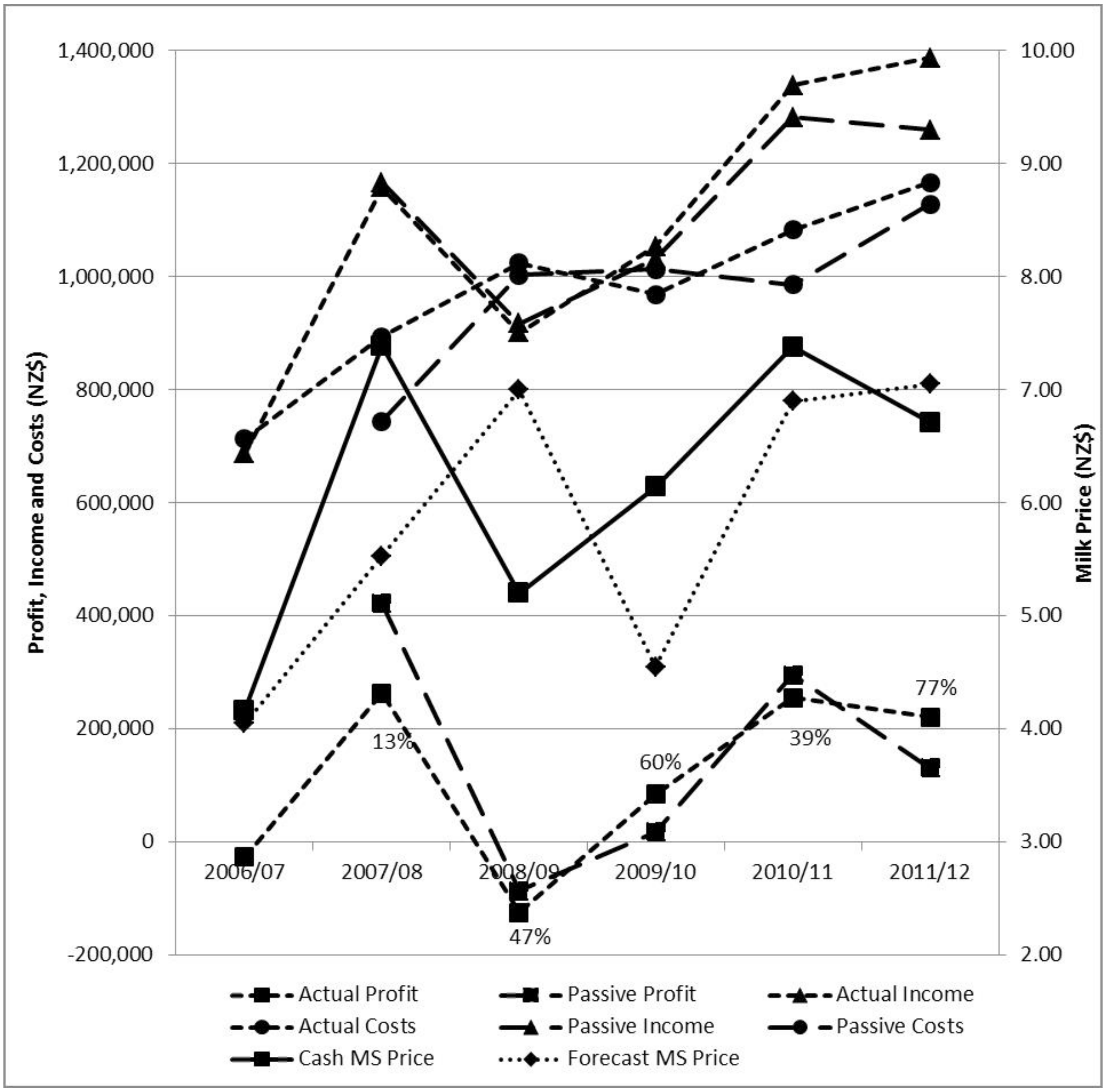

Figure 1. ***Passive and actual profit*** **based on Cash MS price, with associated income and costs**

Note: The percentage of 1s for the binomial variable is shown next to *actual profit* for each year. Cash MS and forecast MS prices are shown for comparison.

production, and revenue may be being achieved with fewer purchased inputs that would be possible in a current year (e.g., a drought year). The reverse may also occur.

The *passive and actual profits* based on cash MS price are presented in Figure 1 with their associated income and costs. Cash MS and forecast MS prices are also shown. *Actual and passive* income and *profits* tended to follow the cash MS price trend, reflecting the strong influence of MS price on profit. Average *actual and passive profits* were close for all years except 2007/2008. Actual costs increased when the forecast MS price increased and vice versa (2009/2010), although it cannot be definitively concluded from the *binomial variable* results that farmers effectively changed netputs in response to prices and costs because of the influence of other factors. In all years except 2009/2010 actual costs exceeded passive costs particularly in 2007/2008 and 2010/2011, which were also the highest profit years despite the fact that these years had the lowest number of 1s (13% and 39%, respectively). Differences between actual and passive costs tended to be greater than between actual and passive income except in 2011/2012 (see Figure 1); hence, cost differences had a greater impact than income differences on whether *actual profit* exceeded *passive profit*.

Average differences between *actual and passive* costs and income and *profit* were relatively small compared to the variability between years; however, only a small difference between profits was needed to significantly affect the *binomial variable* percentages (see Figure 1). The considerable variability between years in income, costs, and profits supports the view that factors that farmers cannot influence are having a greater influence on farm profits than farmers' netput adjustments in response to costs and prices. These factors may include milk markets (high milk prices had a large impact on profitability); input prices; climate affecting pasture availability, milk production levels, and input requirements; and a high proportion of fixed to variable costs limiting the relative impact of netput responses to prices.

Changes in national and regional averages for annual production, income, and the main cost items per farm (data not shown) suggested that farmers were responding to price signals. Comparing this information with MS prices and climate data showed that feed costs increased in drought years (2007/2008) and higher payout years (2007/2008, 2010/2011, and 2011/2012) in order to hold production in drought and/or increase production to benefit from high MS prices, respectively. Other discretionary variable costs also appeared to have changed in response to MS prices and income, with increases in years where MS prices are high or following years when there may be cash surpluses available (e.g., repairs and maintenance, fertilizer, and to some extent labor). There was also a trend for increasing production per farm per year over the five years at a slightly higher rate than farm size increase particularly in 2011/2012 (13% increase), which also had very favorable climatic conditions.

Table 2 shows the percentage of 1s for the binomial variable by region and year. The chi-squared test identified significant differences that existed across regions for all years (1% significance level). Climate differences affected results, as did other regional factors (e.g., 94% of Canterbury farms are irrigated compared to only 20% in total in the data set).

In 2007/2008, the average number of 1s overall was lowest at 13% (see Table 2). MS production per farm for 2007/2008 was similar to the 2006/2007 passive year at 147,498 kg MS and 147,301 kg MS per farm, respectively. Consequently, passive and actual milk revenues per farm were similar (NZ$1.09M) since they were both based on 2007/2008 MS prices. Livestock and other income was also over 40% higher, so actual income in 2007/2008 was slightly higher than passive income. However, the 2007/2008 production was achieved with considerably higher costs (30% more than 2006/2007), particularly purchased feed costs (64% higher) as a result of drought, and farmers responding to a high milk price. This increase in feed costs between years was the highest across all years (ranged from -10.6% to 17.4% difference per kg MS). Feed costs are one of the highest farm costs, so the 64% increase would have contributed to *passive profit* exceeding *actual profit* in 87% of farms. The opportunity cost of capital also increased 20% (reflecting increased land and livestock values) between 2006/2007 and 2007/2008, and repairs and maintenance as well as fertilizer costs increased 41%. Results suggest that the *passive profit* netput vector would not have been feasible for many farms in 2007/2008 (i.e., production unachievable with 2006/2007 inputs). Hence, the *binomial variable* value reflects the impact of the external environment rather than farmers' ability to successfully alter costs in response to prices.

In 2007/2008, the Northland and Marlborough-Canterbury regions considerably outperformed other regions and were the only regions that achieved over 20% of farms with more 1s than 0s (see Table 2). Northland (33% 1s) was the only region that was not exposed to drought that year (Fonterra, 2007–2012), and most dairy farms in Marlborough-Canterbury (48% 1s) have irrigation (94%) and thus can grow pasture for feed regardless of drought. This finding is also supported by the fact that irrigated farms in this 2007/2008 year had a higher proportion of 1s (38%) compared to nonirrigated farms (10%). However, in good climatic seasons such as 2011/2012, irrigated systems did not have a significant advantage over nonirrigated systems, which could be expected.

The average number of 1s increased to 47% in 2008/2009 but varied across regions (see Table 2). Many regions had adverse weather conditions this year as well, and there will have been carryover impacts from the previous year's drought. Despite the lower milk price, average production

Table 2. Percentage of 1s by region and comparison year

Year	Northland	Waikato	Bay of Plenty	Taranaki	Lower North Island
2007/2008	33%*	3%**	9%*	2%**	7%**
2008/2009	30%**	64%**	48%	69%**	73%**
2009/2010	38%**	56%	54%	51%	57%
2010/2011	54%	53%**	45%	34%	24%
2011/2012	77%	83%	86%	73%	90%*
All years	**43%**	**46%**	**45%**	**44%**	**47%**

Year	**West Coast & Tasman**	**Marlborough & Canterbury**	**Otago & Southland**		**New Zealand**
2007/2008	20%	48%**	13%		**13%**
2008/2009	18%**	14%**	33%		**47%**
2009/2010	81%**	79%*	72%		**60%**
2010/2011	18%**	33%	17%**		**39%**
2011/2012	75%	75%	38%*		**77%**
All years	**42%**	**48%**	**34%**		**44%**

Note: The Marascuilo procedure was used to identify regions that differed significantly from at least one other region in that year (*=5%, **=1% level of significance), although the pairs of regions that differed are not specifically identified.

increased 9%, but costs remained high (increased on average 12% per farm but only 3% per kg MS because of production increases): feed costs were up an extra 11% and 2%, respectively. The high forecast MS price but low cash MS price realized may have affected farmers spending decisions, with some contracted purchases put in place at the beginning of the season or earlier. Passive and actual costs and income were similar, with costs higher than the previous year, and income was lower because of the low milk price, resulting in similar profits (see Figure 1). Hence, the average *binomial variable* percentage (47% 1s) was close to normal, although there was considerable regional variation (14% to 73%; see Table 2). Marlborough-Canterbury region had double their normal winter rainfall with some areas damaged by flood, with a 27% per farm increase in feed costs and a 20% increase in feed costs per kg MS and a small increase in production (4%), achieving the lowest proportion of 1s that year (14%; see Table 2). This was the lowest proportion of 1s across all regions in the last four comparison years. In contrast, some North Island regions did well compared to the previous year, resulting in a high proportion of 1s.

The 2009/2010 year showed the reverse trend for all MS prices (low forecast, higher cash price; see Table 1) and slightly higher production and lower costs compared to the previous year. Spending was 7% lower on average on a per kg MS basis than 2008/2009, suggesting that farmers responded to low prices by reducing spending. Spending on feed, which had increased each year, dropped 11% per kg MS (8% per farm), and spending on other variable costs dropped as well, with total costs being 5% lower per farm. Sixty percent of farmers had higher *actual profit* than *passive profit* based on the previous year's netput, although this varied regionally (38% to 81% 1s), with the Lower North Island and South Island outperforming the top of the North Island (see Table 2), particularly Northland, which was affected by drought.

The highest proportion of 1s occurred in 2011/2012 (77% on average by regions ranging from 73% to 90% except for Otago-Southland at only 38%), which was a year with a favorable climate although only average for Otago-Southland after a poorer year. Milk production increased 13% from 2010/2011, resulting in a notably higher actual income (see Figure 1) as expected, considering that MS revenue accounts for the majority of the income and that the price for actual and passive income is the same. Extra MS production compensated for a drop in MS price (see Table 1), so actual income increased slightly (see Figure 1). Although total costs were higher (8.5% per farm, 9% for feed), higher production meant costs that per kg MS were relatively lower (4% less, similar for feed). While actual costs per farm exceeded passive costs, this was compensated for by the increased income, so average *actual profit* exceeded *passive profit* and led to the high percentage of 1s in 2011/2012 (77% average; see Table 2). However, profits were lower than the previous year due to relatively higher costs compared to income (see Figure 1). In contrast, Otago-Southland's costs relative to the previous year were higher than the other regions (14% per farm, 22% for feed), and their production increase was slightly lower (11%), contributing to higher costs per kg MS (10% more kg MS for feed) and resulting in their proportion of 1s remaining low (38%) although increasing from the previous year (17%).

CONCLUSIONS

The adjusted WAPM method was proposed to evaluate whether New Zealand dairy farmers adjust netputs in response to costs and prices, with U.S. results suggesting that their dairy farmers do not (Nakane and Tauer 2009). While previous New Zealand research showed that dairy farmers on average do respond to prices and costs (Shadbolt, 2012) and that a group of farmers adjusted inputs in line with price changes (Shadbolt et al., 2016), it was concluded in the absence of pasture availability data that this WAPM approach has limitations in evaluating New Zealand dairy farmers' decisions on production inputs and outputs (netputs) in response to price changes because of their pasture-based systems. Factors other than price influence farmer decisions, such as climatic impacts on pasture availability and hence milk production and purchased feed requirements. Thus, farmer responses to costs and prices were not readily differentiated from other influencing factors in the WAPM results. Pasture availability is variable between and within seasons, with farmers having limited control over this, and this input is not explicitly accounted for in the netputs. Hence, stochastic technology and lack of data limit the application of WAPM methods in pasture-based systems. The DairyBase data set now includes calculations of the quantity of pasture eaten for a subset of farms that could be included in the netputs for future WAPM analyses once sufficient records are available.

Farmers' price responses in pasture-based systems could be explored further with other techniques such as regression analysis incorporating regional and/or climate impacts and other system impacts (e.g., irrigation). Further work could also be conducted to identify the impact of a range of factors on farmers' netput responses and whether regional, system, farm, or farmer attributes influence these. For example, is the decision to purchase feed, or alternatively sell or dry off cows, influenced more by MS price or by climatic factors and to what extent? Research exploring production responses and what costs are adjusted between seasons to what extent and why could be useful. Similarly useful would be research into the influence on information availability and the timing of the decisions (e.g., input costs and availability, MS prices) and the impact of these decisions, both short and long term.

The data set used had a mix of different farms each year, and a data set with a relatively consistent set of farms across years could result in more reliable results in comparing responses (e.g., cost changes). However, looking at a mixed farm data set, it does appear that costs change in response to factors such as prices and climate. Furthermore, it needs to be recognized that farmers recording in this voluntary database could be more focussed than most on their financial and business performance.

NOTE

1. A production activity is represented as a netput vector or vector of netputs. A netput vector consists of the input and output quantities for a production activity. Positive quantities signify outputs, and negative quantities signify inputs.

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Appendix 1. DairyBase data used in the analysis and the associated index.

	DairyBase Variable	Source of Price Indices
Income Items		
1	Net milk sales	
2	Net dairy livestock sales, and change in nondairy livestock values	Producer price index outputs—sheep, beef cattle, and grain farming
3	Change in dairy livestock values	FEPI—livestock purchases
4	Other dairy revenue	FEPI—miscellaneous
5	Nondairy cash income	Producer price index outputs—average of sheep, beef cattle and grain farming, and forestry
Expenditure Items		
6	Wages	FEPI—salaries and wages
7	Labor adjustment–unpaid	
8	Labor adjustment–management	
9	Animal health	FEPI—animal health and breeding
10	Breeding and herd improvement	
11	Farm dairy expenses	FEPI—dairy shed expenses
12	Electricity (farm dairy + water supply)	FEPI—electricity
13	Supplements purchased, made and cropped, and feed inventory adjustment	FEPI—grazing, cultivation, harvest and purchase of animal feed
14	Calf feed	
15	Young stock and dry stock grazing	
16	Winter cow grazing	
17	Runoff lease and runoff adjustment	FEPI–rent and hire
18	Fertilizer	FEPI–fertilizer, lime, and seed
19	Nitrogen	
20	Irrigation	FEPI—electricity
21	Regrassing	FEPI—grazing, cultivation, harvest, and purchase of animal feed
22	Weed and pest	FEPI—weed and pest control
23	Vehicle expenses	FEPI—repairs, maintenance, and motor vehicle repairs
24	Fuel	FEPI—fuel
25	Repairs & maintenance - land and buildings	FEPI—repairs, maintenance, and motor vehicle repairs
26	Repairs &maintenance - plant and equipment	
27	Freight and general	FEPI—average of freight, and miscellaneous
28	Administration	FEPI—administration
29	Insurance	FEPI—insurance
30	ACC	FEPI—salaries and wages
31	Rates	FEPI—local and central government rates
32	Lease or rent (excluding runoff)	FEPI—rent and hire

Appendix 1. DairyBase data used in the analysis and the associated index (*continued*)

	DairyBase Variable	Source of Price Indices
33	Depreciation	Capital Goods Price Index–agricultural machinery
34	Nondairy operating expenses	FEPI–all inputs excluding livestock
35	Extraordinary expenses	FEPI—all inputs excluding livestock
36	Opening and closing asset values (used to calculate the opportunity cost of capital)	

Note: FEPI = Farm Expenses Price Index (Dairy Farming).

- The "Producer Price Index—Outputs" (Statistics New Zealand, 2016a) for "Sheep, Beef Cattle and Grain Farming" and for "Forestry" were used for nondairy income and livestock sales. Most sales will be cull cow sales to works or calves to beef farmers.
- The "FEPI for Dairy Farming" (Statistics New Zealand, 2016b) for the relevant category was used for the majority of income and costs.
- The "FEPI for Livestock Purchases" was used for the change in dairy livestock values since this probably better reflects the market value of dairy livestock (i.e., replacement value) than the Producer Price Index livestock indices.
- The "Capital Goods Price Index for Agricultural or Forestry Machinery or Parts" (Statistics New Zealand, 2016c) was used for depreciation since plant and machinery are the most significant depreciable items.
- Indices provided were quarterly, and the average of the four quarters over the farming year was used, assuming a June 1 to May 31 year.
- The opportunity cost of capital (OCC) for each farm-year combination was calculated at 3% of total fixed asset value (average of opening and closing) as per the International Farm Comparison Network approach (Hemme, 2015). Asset values were affected by sales, purchases, and changes in capital values. There were some large differences between opening and closing values, resulting in some large differences in the OCC between years largely due to capital gains or losses rather than business profits.