RESILIENCE, TO 'BOUNCE WITHOUT BREAKING', IN NEW ZEALAND DAIRY FARM BUSINESSES

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Abstract

New Zealand dairy farmers face an increasingly turbulent business environment which poses risks to their survival. To cope with a turbulent environment, dairy farmers need to have resilient farming systems that have the capacity to better deal with volatility. Although system resilience has been given increasing attention recently, limited research has been undertaken about resilience particularly in relation to New Zealand dairy farmers. The main purpose of this study was to develop an understanding of what resilience means for dairy farming and to determine how it might be measured. In the literature review it was identified that resilience can be described as buffer capacity, adaptability and transformability with increasing degrees of change required with each. The research for this paper focused on buffer capacity, the ability of a farming system to 'bounce without breaking', and carried out rigorous statistical analysis of the DairyBase® database to identify resilience surrogate measures. Of the three attributes of buffer capacity the PCA method identified that the dominant attribute was resistance (both technical and financial efficiency), the less dominant were precariousness (solvency) and latitude (liquidity) attributes. In conclusion, those farms that were more resilient when compared against the less resilient farm businesses, the farms that could 'bounce without breaking' were:

- *technically efficient – produced more milk per cow, hectare and labour unit*
- *financially efficient – generated more profit per unit of revenue, linked costs with prices, had higher Return on Assets*
- *cash liquid – generated more discretionary cash for investment/drawings*
- *managed debt servicing capacity*

The farms that were able to demonstrate both short-term optimization and long-term adaptability (Darnhofer et al, 2008) were those that were neither low input nor high input pasture based farms. They had farming systems that sat in the middle of the range (system 3) so were able to both respond to favourable and unfavourable conditions to improve or protect results respectively; they displayed the flexibility to bounce and not break. Further research is required to identify how some farm businesses are able to maintain resilience throughout quite volatile climatic and economic environments while others cannot. How do these farmers make sense of the information they receive and make sound decisions and what makes their systems more flexible than others?

Keywords: resilience, dairy farm systems, buffer capacity, efficiency

1. Introduction

New Zealand dairy farmers face not only climatic uncertainty but also an increasingly turbulent business environment (Mackle, 2010). Internal and external factors such as increased variability in milk prices, international trade policies, input price variability, policies on bio-fuels, increasing consumer awareness on sustainable food systems, government regulation on animal welfare, environmental regulations and consolidation of the dairy industry have brought about increased variability on the financial performance of the dairy farm business (Boehlje et al., 1995; Boehlje, 2004; Gray et al., 2008; Parsonson-Ensor and Saunders, 2011).

To cope with a turbulent environment, dairy farmers need to build the capacity of their businesses to be able to better deal with periods of poor performance (Kaine et al., 1993) and capture the opportunities that arise to perform better (Detre *et al*, 2006). This essentially refers to developing resilient farming systems. The concept of resilience when applied to agriculture (Milestad & Darnhofer, 2003; Kelly & Bywater, 2005; Crawford et al., 2007; Darnhofer et al, 2010) defines a resilient farming systems as having the ability to buffer and respond to change so resilience is considered a key attribute to help farmers deal with future challenges and shocks (Crawford et al., 2007). As with the ecosystem literature it also identifies resilience as not only persisting and maintaining farming systems through shocks but also adapting and adopting new systems when needed Darnhofer et al. (2010). Broadly speaking, a resilient farm should be able to withstand and/or bounce-back from sudden or acute shocks (such as a spike in input prices, a disease outbreak, etc.). What determines the fate of a business in turbulent market environment is how resilient the business is to turbulence.

The study is part of a wider research project on resilience, entrepreneurship and risk management carried out by the Centre of Excellence in Farm Business Management (www.onefarm.ac.nz), funded by DairyNZ, which is a research and extension organization funded by levies paid by New Zealand dairy farmers.

The overarching aim of this research was to examine the meaning of resilience for New Zealand dairy farmers. Specific objectives include:

- To define resilience for a dairy business farming business in a turbulent environment.
- To explore different measures of resilience in an attempt to identify suitable surrogates (indicators) for measuring resilience among dairy farmers.

Following a comprehensive review of the literature on ecosystems, organizational management and farm management (Rutsito, 2011), a three step quantitative approach was used to determine if resilience can be measured using a sample of dairy farmers from the DairyBase® database. The first step was a comparative analysis of dairy farm systems that determined that all NZ dairy farms were in fact delivering to the low cost of production (CoP) strategy for which they are renowned, some through low input and others high input, the numerator and denominator effect on CoP respectively (Shadbolt, 2012). In particular this step identified the operating profit margin as a key driver of financial success when analysing how systems coped under both high and low price shock scenarios.

The second step began with some in-depth statistical analysis and then grouped the farmers into quartiles with respect to performance and analysed the difference between those farmers that best captured upside risk (when prices lifted from one year to the next) and those that best avoided downside risk (when prices dropped from one year to the next) (Shadbolt, Rutsito, Gray, 2011). Of interest was the finding that none of the farmers who best captured up-side risk were in the group that best minimised down-side risk, this suggested that farms did not readily switch between systems as input and output prices changed. However regardless of the season, a positive or a negative shock, the best results were achieved from those farms that consistently managed their costs in line with their revenue, both groups had higher operating profit margins than their poorer performing counterparts.

The final step, the subject of this paper, was to extend the statistical analysis, this time with 5 years of data (06/07- 10/11) both by year and, where the farmer dataset allowed, across consecutive years, to determine a resilience index for each farm. The dominance of specific indicators in their ability to explain variability between farms and to connect such indicators back as surrogates for measuring resilience was also explored. The KPIs of those farms with higher scores were then compared against lower scoring farm businesses to identify any significant differences.

2. Literature review

The purpose of this section is to integrate knowledge gained from literature (Rutsito 2011; Shadbolt et al. 2011) about the definition of resilience in the context of dairy farming business. The section concludes with the conceptual framework for estimating resilience that was applied in this study. While some farm management scholars have used the term "'sustainability" to define resilience (Conway, 1985; Marten, 1988; Hansen & Jones, 1996; Kaine & Tozer, 2005) the perspective of Ott (2003) is that, instead, resilience is a key factor in achieving strong sustainability. Parsonson-Ensor & Saunders (2011) identify definitions at three levels – operational, ecological-economic and sustainability related – as well as a lack of any distinguished measurable variables for resilience.

The literature identified three key attributes of resilience – buffer capacity, adaptive capacity and transformability. A critical aspect of resilience from the ecosystem, organisational and farm management literature is the *capacity to absorb disturbance,* to *bounce back,* the buffer capacity that allows a system to persist (Conway 1991; Carpenter *et al.*, 2001; Sutcliffe and Vogus 2003; Walker *et al.*, 2004; Folke, 2006; Crawford *et al.*, 2007; Lien *et al.*, 2007; Darnhofer *et al.*, 2008). However, resilience is not merely about a system's robustness, it is also about the opportunities that arise from disturbance (Carpenter *et al.*, 2001; Folke, 2006) and the capacity of an organization to adapt to change (Hamel & Valikangas, 2003; McCann, 2004; Lengnick-Hall & Beck 2005). Darnhofer et al, (2010) describe this as farmers having the strategies to persist and maintain through shocks and adapt and adopt new states when they are needed. This element of resilience, adaptive capacity, is identified as a key element of resilience in farming systems (Crawford *et al.*, 2007; Ingrand *et al.*, 2007; Darnhofer *et al.*, 2008). Adaptive capacity is concerned with major disturbances that are rare, and less expected due to a major change in the underlying environment (Conway, 1993). As with buffer capacity, adaptive capacity can only work up to a point. When the disturbances imposed by highly dynamic environments push a farming system beyond what it can tolerate, transformation becomes the only option (Walker *et al.*, 2004). Transformability has been recognized as a key characteristic of resilient farming systems (Darnhofer *et al.*, 2008) who described it as the ability of a manager to find new ways of arranging resources when conditions make the current systems untenable.

The three attributes of resilience i.e. buffer capacity; adaptive capacity and transformability refer to varying degrees of change (Figure 1). Transformability represents the ultimate level of change. However, different farmers will cope differently with varying levels of change. Their response will vary depending on the level of change, their ability to respond and their perception or understanding of the risk involved.

A key finding of the study of resilience in the three bodies of literature, ecology, organisational management and farm management revealed the paradox between stability and resilience adaptability (Holling, 1996; Kaine & Tozer, 2005; Darnhofer et al, 2008). Stability or engineering resilience (Holling, 1996) focuses on optimization and efficiency whilst resilience adaptability is concerned with persistence of function of a system, which is dependent on its ability to adapt to changes in the environment (Gunderson & Holling, 2001). The resilience framework provides an understanding of the nature of change. This is fundamentally different from the assumption of a system near-equilibrium on which traditional farm management is based which has led to a one-sided emphasis on predictability and stability (Darnhofer *et al.*, 2008; Love *et al.*, 2008). During periods of stability**,** farmers use exploitation-led strategies by optimizing their farming systems and use buffer capacity to cope with variability. However, during periods of disturbance,

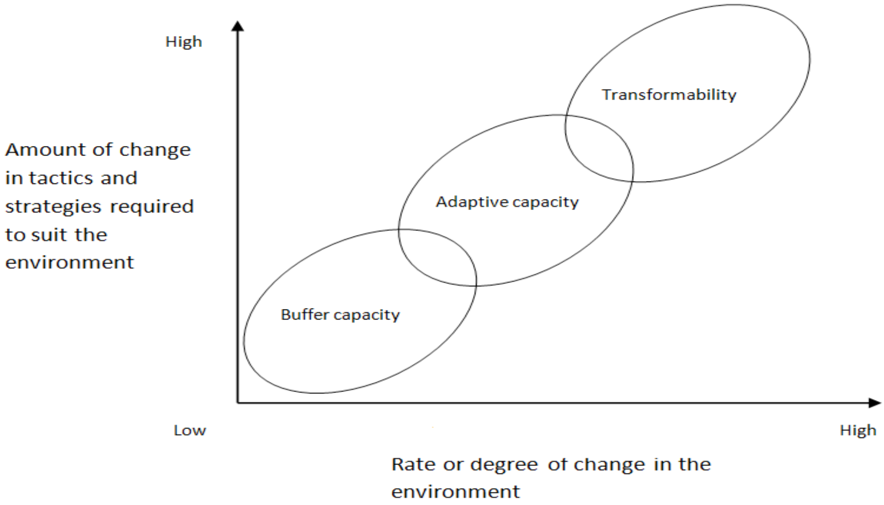

Figure 1. An illustration of the continuum of change, buffer capacity, adaptive capacity and transformability

when both threats and opportunities arise, an adaptive strategy needs to be pursued. To manage a farm for resilience, a portfolio of complementary strategies aimed at achieving both short-term optimization and long-term adaptability would be required (Darnhofer et al, 2008). Kaine & Tozer (2005) describes this as achieving the "*optimum balance between efficiency and resilience in achieving sustainability*'; thus describing the paradox between the two not as antagonistic but rather a fit that must be managed to deliver sustainability.

3. Measurement of buffer capacity resilience

Attempts have been made to measure resilience in ecosystems (Carpenter et al., 2001; Cumming et al., 2005; Carpenter et al., 2005) however, because resilience is not a physical component of the system as such, but an emergent property, its direct measurement is difficult (Fletcher et al., 2006; Crawford *et al.*, 2007; Gray *et al.*, 2008). In view of this limitation, Carpenter *et al.*, (2005) proposed the use of surrogates as a means of indirectly inferring aspects of resilience. They distinguished however between those indicators that measure the current state of the system and resilience indicators that are 'ever changing variables' that inform on the capacity of the system to perform as it evolves.

Despite there being few studies into the use of surrogates in measuring resilience, the general farm management literature (Boehlje & Eidman, 1984; Shadbolt& Martin, 2005; Langermeire, 2010) has a variety of other indicators that have traditionally been used to measure the performance of farm businesses, which could be useful in measuring resilience. Parsonson-Ensor & Saunders (2011) propose a range of capital based sustainability indicators including human, natural, cultural and human-made capital with the suggestion that the best gauge of resilience would be 'non-declining capital stock' over time. The development of the DairyBase® database in New Zealand (Shadbolt et al, 2007) has provided farmers with both financial and non-financial measures to track their progress and benchmark against other farm businesses. In DairyBase® the business KPIs (Appendix A) identified by a team of experts include productivity, liquidity, profitability and solvency measures but cannot provide measures of human, natural and cultural capital stock. The research methodology required to explore human, natural and cultural capital would involve longitudinal studies of, at the very least, farmer skills and well-being, their networks, common norms and cultural values which would provide useful measures of adaptive capacity and, at the extreme, transformability. That was outside the scope and timeframe of this study in which the focus instead was on buffer capacity using available data relating to human-made capital, the farm, and its physical and financial performance over time.

The Walker *et al.* (2004) model for buffer capacity was adapted for this research. It is characterized by the four attributes of latitude, resistance and precariousness and panarchy. Panarchy, in a farm business, would include the interactions, both formal and informal, and networks that the business has with its supply chain partners and the wider community. The other three attributes focus within the farm system and include latitude, resistance and precariousness (Figure 2). The attributes are mutually exclusive but, ultimately, converge into the resilience status of the system.

Latitude in ecosystems refers to the amount of stretch which a system can allow without losing the ability to return to its original form (Walker et al., 2004). For this analysis of dairy farming businesses the surrogate adopted for latitude is liquidity (Appendix A). A farm with limited cash and sometimes unable to meet its commitments would imply narrow latitude and vulnerability to shocks, and vice versa.

Resistance measures how "resistant" the system is to shocks. For this analysis of dairy farming businesses the surrogate adopted for resistance is *efficiency*, which measures not only the simple input:output technical efficiency of the business but also the intensity with which that business uses its assets to generate gross farm income (Purdy & Langemeire, 1995) and realize profit. This implies that a highly efficient dairy farm would be relatively more resistant (i.e. higher buffer capacity) to shocks compared to a less efficient farm.

Precariousness describes how close the current system is to exceeding the threshold or tipping point and undergoing a permanent restructuring (Walker et al., 2004). Purdy and Langemeire (1995) state that solvency measures provide an indication of the farm's ability to continue operations as a viable business after financial adversity, which typically results in increased debt and reduced net worth. Therefore, for this analysis of dairy farming businesses the *solvency* surrogates were adopted for precariousness.

Based on the above definition of buffer capacity elements it is proposed that while the 3 surrogates of liquidity, efficiency and solvency could be taken as mutually exclusive they ultimately

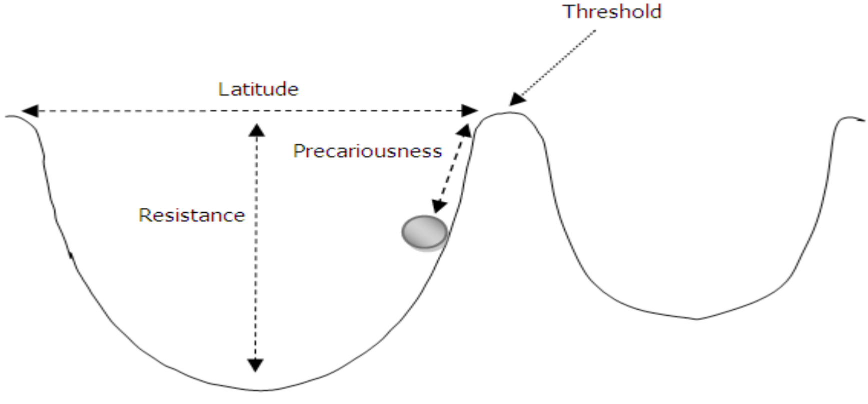

Figure 2. Two dimensional stability landscape based on Walker's model showing three aspects of resilience: Latitude, resistance and precariousness
Source: Walker et al., 2004

converge into an overall resilience status for the farm. In other words one farm business could have buffer capacity by having low debt and maintain a positive cashflow by having low personal drawings yet have poor productivity/profitability while another could have excellent profitability, high debt and a negative to breakeven cashflow position. The latter scenario when coupled with rapidly increasing land values provides the opportunity for significant equity growth and was a common phenomenon in NZ dairy farming in the years up until the financial crisis of 2009. It raised considerable commentary on the sustainability of such a strategy – farming for capital gain (Wills 2009; Ridden 2009; Wallace 2009) particularly as it often led to additional debt.

It is surmised that 2 out of 3 attributes being favourable will deliver buffer capacity but if the farms are 2-3 out of 3 unfavourable they will fail to be resilient.

4. Methodology

One attribute of resilience, buffer capacity, that consists of latitude, resistance and precariousness was measured using quantitative surrogates; liquidity, efficiency and solvency respectively. This began with a statistical principal component analysis (PCA), explained in more detail in Appendix B, of the DairyBase® database, over 5 years (2006/07 – 2010/11) to test the assumption that the underlying 'common information' in the database might be determined by resilience - the underlying common phenomenon being measured. On the basis that this assumption was correct the analysis did then identify and rank farm businesses using those key performance indicators (KPIs) that accounted for the most variability between farms. It identified the KPIs of most relevance in comparative analysis and used them to rank the farm businesses into high:low 'resilience' groups.

The results of the PCA were used to develop constructs to test the data with respect to surrogates for resilience – are these 3 surrogates (latitude – liquidity, resistance – efficiency, precariousness – solvency), essentially groups of KPIs, defined and different from each other? Does one attribute dominate the others and within each attribute do some variables dominate others in terms of variance and commonality amongst the farm businesses that they explain?

In the data set from DairyBase® there are 625 observations in the 2006/07, 628 in the 2007/08, 497 in the 2008/09, 567 in the 2009/10 and 297 in the 2010/11 year. Only 40 farmers have consistent data for each of these 5 years. The PCA analysis identified the KPIs that differentiated the farm businesses most and they were ranked on that basis. The subsequent t-test of all KPIs then determined the measures that were significantly different between the high index farms and the low index farms. This identified other elements of buffer capacity in addition to the dominant elements providing a further test of the resilience of these businesses.

5. Results & discussion

From the PCA analysis it was concluded that the dominant construct, or buffer capacity attribute, is efficiency (resistance) with neither liquidity (latitude) nor solvency (precariousness) dominating in any year[1]. Of interest is the swing between technical and financial efficiency KPIs with financial efficiency dominating overall in the 5 year set of data from 40 farms. The dominant variables of operating profit margin (OPM) and milk production per hectare (kgMS/ha), financial and technical efficiency measures respectively, both meet the definition of surrogates as 'ever

[1] For more in-depth details of the methodology and the results refer to the Resilience of New Zealand Dairy Farm Businesses research report on www.onefarm.ac.nz

changing variables' (Carpenter *et al.*, 2005) able to inform on the capacity of the system to perform as it evolves. It is therefore not always relevant to compare these indicators with previous years (with different climatic and economic environments) but it is very useful to compare them with other businesses within the same year. In essence these indicators reflect the cumulative outcome of decisions made throughout the year and the ability of the business to flex and adapt to within season volatility.

By contrast the indicator operating expenses per hectare was unable to be a consistent surrogate, it flip flopped with the price of milk. When milk prices were low it was negatively correlated with returns and when they were high it had a positive correlation as farmers spent money to capture the higher returns. Similarly the solvency indicator, debt:asset ratio also flip flopped as a resilience surrogate. As described by Shadbolt et al (2011) in step two of this research when farm businesses best captured upside shocks they did it through debt leverage; in contrast those that best mitigated against downside risks had minimal debt leverage.

Further analysis of the group of 40 farms that had data in all of the 5 years (Table 1) identified that the higher index farms achieved statistically better liquidity (discretionary cash per hectare) and better financial efficiency through lower costs per kgMS and per hectare, higher operating profit margin, operating profit/kgMS, return on assets and return on equity than the lower index group.

Table 1. Average performance of two farm groups over 5 years (2006/07-2010/11)

Item	Higher index group (N=19)	Lower index group (N=21)
Latitude (liquidity)		
Discretionary cash/ha	2,018.27	1,074.97
Resistance (financial efficiency)		
FWE/Kg MS	2.94	3.93
Operating expenses/ha	4,131.72	5,096.16
Operating expenses/Kg MS	3.83	4.89
Operating profit (EFS)/Kg MS	2.75	1.60
Operating profit margin (%)	40.21	22.82
Operating return on dairy assets (%)	7.33	3.68
Total Return on Assets (%)	9.76	5.31
Return on Equity (%)	6.32	0.56

In the first two steps of the research it was noted that different farming systems coped better in some circumstances than others but it was not possible to know if individual farms switched from system to system when conditions changed. The outcome of both short-term optimization and long-term adaptability (Darnhofer et al, 2008) can only be measured from a time series of data. How the forty farms adjusted to market and environmental conditions over the 5 years and maintained or lost resilience status was therefore a useful observation (Table 2).

In the two low milk price years of 2006/07 and 2008/09 the more resilient farm businesses were operating the lower input systems 1 to 3 while in the higher milk price years a higher percentage of resilient farms were operating in the higher input systems 3 and 4.

Table 2. Distribution of the 40 farms by farm systems across the 5 years: from system 1 (self-contained low input pasture based system) to system 5 (high input, 30% introduced feed, pasture based system)

Farm and farmer charac-teristics	2006-07		2007-08		2008-09		2009-10		2010-11	
	more resilient (24)	less resilient (16)	more resilient (19)	less resilient (21)	more resilient (27)	less resilient (13)	more resilient (17)	less resilient (23)	more resilient (18)	less resilient (22)
Production system	% frequency									
1	12.50	6.25	0.00	19.05	18.52	7.69	5.88	17.39	5.56	18.18
2	37.50	43.75	21.05	52.38	29.63	15.38	11.76	43.48	11.11	36.36
3	50.00	25.00	47.37	28.57	33.33	53.85	47.06	39.13	44.44	40.91
4	0.00	12.50	21.05	0.00	11.11	23.08	29.41	0.00	38.89	4.55
5	0.00	12.50	10.53	0.00	7.41	0.00	5.88	0.00	0.00	0.00

Also of interest is whether farm businesses were able to maintain their position in the more resilient group (short-term optimizers) over time (long-term adaptability). From Figure 3 it can be seen that 27.5% of the 40 farms maintained their more resilience (MR) status from start to finish, 15% made progress from being low resilience (LR) farms to more resilient while 17.5% remained low resilience farms throughout the five years and 27.5% got worse by starting as more resilient but were classified as low resilience at the end.

Illustrating the breakdown by farming system of the three groups with the most farms (LR:LR:LR, MR:MR:LR; MR:MR:MR) reveals some interesting results (Figure 4). The group that was consistently less resilient appear to follow no particular pattern. The group that was consistently more resilient (MR:MR:MR) however were dominated by system 3 farms (82, 64 and 64% in 06/07, 08/09, 10/11 respectively). The percentage of MR farms in system 4 increased from 0 to 18% in 08/09 and 10/11 so the combination of system 3 & 4 farms was 82% throughout.

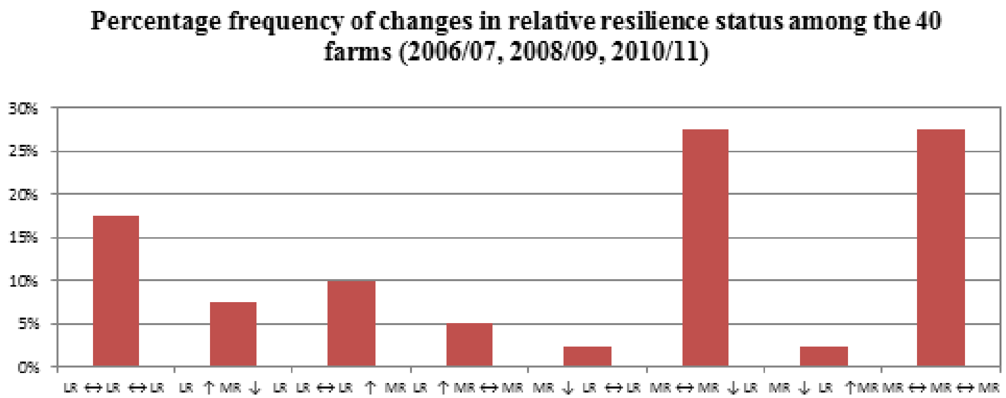

Figure 3. Transition of farm's resilience status between the 3 years of 2006/07, 2008/09 and 2010/11

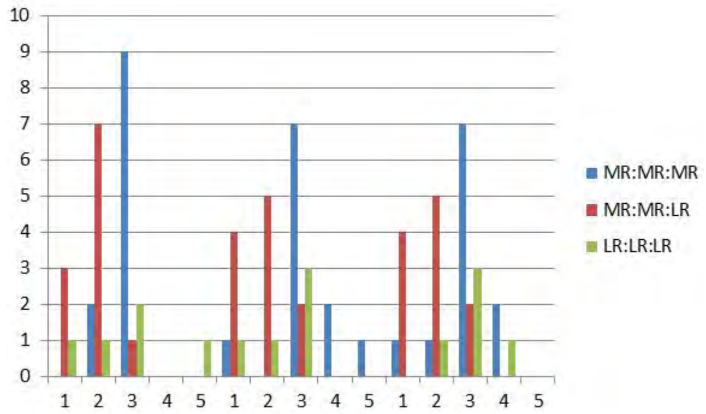

Figure 4. Number of farms in each farming system (1-5) for the three years of 06/07, 08/09 & 10/11 in each of three farms resilience trends (MR:MR:MR; MR:MR:LR; LR:LR:LR)

By contrast the farms that were more resilient in both 06/07 and 08/09 but dropped to less resilient in 10/11 were dominated by system 1 & 2 farms (91, 82 and 82% respectively). These farms are similar to those identified in step two of the research as the farms that managed to mitigate downside risk but were less likely to capture upside risk. The 10/11 year was a high milk price year and these farms were less able to capture the benefits of those higher prices.

6. Conclusions

The PCA enabled the dominance of specific indicators to be determined in their ability to explain variability between farms and to connect such indicators back as surrogates for the attributes of the theoretical model for buffer capacity. The analysis identified and ranked those key performance indicators (KPIs) that accounted for the most variability between farms thereby identifying the KPIs of most relevance in comparative analysis. While the PCA method enabled an index or score to be obtained for each farm the common phenomenon being explored, resilience has three attributes. Of interest is the dominance of the resistance (both technical and financial efficiency) attribute, the less dominant position of the precariousness (solvency) and the latitude (liquidity) attribute. However while solvency and liquidity were weak at differentiating between farms at the highest principal component level they did appear at the lower levels and the subsequent t-test also identified several KPIs in solvency and liquidity for high index farm businesses.

In conclusion, those farms that were more resilient when compared against the less resilient farm businesses, the farms that could 'bounce without breaking' were:

- technically efficient – produces more milk per kgMS, hectare and labour unit,
- financially efficient – generated more profit per unit of output, managed expenditure in line with prices (OPM), had higher Return on Assets,
- cash liquid – generates more discretionary cash for investment/drawings,
- managed debt servicing capacity,

with milk production per hectare and operating profit margin the dominant KPIs.

The farms that were able to demonstrate both short-term optimization and long-term adaptability (Darnhofer et al, 2008) and achieved "*optimum balance between efficiency and resilience in achieving sustainability*' (Kaine & Tozer, 2005) were those that were neither low input nor high input pasture based farms. They had farming systems that sat in the middle of the range (system 3) so were able to both respond to favourable and unfavourable conditions to improve and protect results respectively; they displayed the flexibility required to maintain resilience.

Further research is required to identify how some farm businesses are able to maintain resilience throughout quite volatile climatic and economic environments while others cannot. How do these farmers make sense of the information they receive and make sound decisions and what makes their systems more flexible than others? Beyond buffer capacity what is the degree of disturbance farm businesses need to adapt to new systems or to transform into completely new businesses. These questions cannot be answered with quantitative analysis but require in-depth qualitative research to complement the results delivered to date.

7. References

Boehlje M.D., Eidman V.R., 1984. Farm Management. Wiley, New York

Boehlje M., 2004. Financial risk and capital structure. Retrieved 20th September, 2010, from www.agecon.purdue.edu/extension/sbpcp/resources/whatrisks.pdf

Boehlje M., Akridge J., Downey D., 1995. Restructuring agribusiness for the 21st century. *Agribusiness, 11*(6), 493-500.

Carpenter S., Walker B., Anderies J., Abel N., 2001. From metaphor to measurement: resilience of what to what? Ecosystems, 4(8), 765-781. 68

Carpenter S., Westley F., Turner M., 2005. Surrogates for resilience of social–ecological systems. Ecosystems, 8(8), 941-944.

Conway G., 1985. Agroecosystem analysis. Agricultural Administration, 20(1), 31-55.

Conway G., 1991. Sustainability in agricultural development: trade-offs between productivity, stability and equitability. Journal for Farming Systems Research-Extension, 4(2):1-14.

Conway G., 1993. Sustainable agriculture: The trade-offs with productivity, stability and equitability. In Barbies, E. (Ed.), Economics and ecology, new frontiers and sustainable development. London: Chapman & Hall.

Crawford A., McCall D., Mason W., Paine M., 2007, 18th - 20th September 2007. Industry adaptation - challenges when building resilient farming systems. Paper presented at the Meeting the Challenges for Pasture-Based Dairying, Melbourne.

Cumming G., Barnes G., Perz S., Schmink M., Sieving K., Southworth J. et al., 2005. An exploratory framework for the empirical measurement of resilience. Ecosystems, 8(8), 975-987.

Dairybase, 2011. Report Description Handbook. February 2010. Accessed online September 2011 at http://www.dairybase.co.nz/file/fileid/21532

Darnhofer I., Bellon S., Dedieu B., Milestad R., 2008, 6-10 July. *Adaptive farming systems: A position paper.* Paper presented at the 8th European IFSA Symposium, Clermont - Ferrand (France).

Darnhofer I., Fairweather J., Moller H., 2010. Assessing a farm's sustainability: insights from resilience thinking. International Journal of Agricultural Sustainability 8(3).

Detre J., Briggeman B., Boehlje M., Gray A.W., 2006. "Scorecarding and heat mapping: tools and concepts for assessing strategic uncertainty" International food and agribusiness management review 9(1):71-92

Fletcher C., Craig M., Hilbert D., 2006. Operationalizing resilience in Australian and New Zealand agroecosystems.

Folke C., 2006. Resilience: The emergence of a perspective for social-ecological systems analyses. Global Environmental Change, 16(3), 253-267.

Gray D., Dooley E., Shadbolt N., 2008. Risk and Dairy Farm Management in New Zealand : a review of literature. Palmerston North: agresearch Massey University.

Gunderson L., Holling C.S., (eds)., 2001. Panarchy: understanding transformations in human and natural systems. Washington (DC): Island Press.

Hamel G., Valikangas L., 2003. The quest for resilience. Harvard Business Review, 81(9), 52-65.

Hansen J., Jones J., 1996. A systems framework for characterizing farm sustainability. *Agricultural Systems*, 51(2), 185-201.

Harris D., 1997. `Principal Components Analysis of Cointegrated Time Series', Econometric Theory, 13, 529-557.

Holling C., 1996. Engineering resilience versus ecological resilience. Engineering within ecological constraints, 31-43.

Ingrand S., Bardey H., Brossier J., 2007. Flexibility of Suckler Cattle Farms in the Face of Uncertainty within the Beef Industry: A Proposed Definition and an Illustration. The Journal of Agricultural Education and Extension, 13(1), 39-48.

Kaine G.W., Tozer P.R., 2005. Stability, resilience and sustainability in pasture-based grazing systems. Agricultural Systems, 83(1), 27-48.

Kelly T., Bywater A., 2005. Farm Systems. Chapter in Farm Management in New Zealand editors Shadbolt N.M. & Martin S.M. Oxford University Press.

Langemeier M.R., 2010. Persistence in Financial Performance. *Journal of International Farm Management, 5*(2), 1-15.

Lengnick-Hall C., Beck T., 2005. Adaptive fit versus robust transformation: How organizations respond to environmental change. Journal of Management, 31(5), 738.

Lien G., Hardaker J.B., Flaten O., 2007. Risk and economic sustainability of crop farming systems. Agricultural Systems, 94, pp. 541-552.

Love et al, 2008. cited by Parsonson-Ensor C., Saunders C. (2011)

Mackle T.R., 2010. " New Zealand dairy farming on the global stage" in the Abstracts of IDF world Dairy Summit 2010, accessed online November 2012 at http://www.wds2010.com/program/Abstract/02-DairyPolicies.pdf

Marten G.G., 1988. Productivity, stability, sustainability, equitability and autonomy as properties for agroecosystem assessment. *Agricultural Systems, 26*(4), 291-316.

McCann J., 2004. Organizational Effectiveness: Changing Concepts for Changing Environments. Human Resource Planning, 27(1), 42-51.

Milestad R., Darnhofer I., 2003. "Building farm resilience: The prospects and challenges of organic farming." Journal of sustainable agriculture 22(3): 81-97.

Ott, 2003 cited by Parsonson-Ensor C., Saunders C. (2011)

Parsonson-Ensor C., Saunders C., 2011. Resilience of farming Systems during periods of hardship. ARGOS Research report: Number 11/03. www.argos.org.nz

Purdy B.M., Langemeier M.R., 1995, Measuring Farm Financial Performance, Kansas State University Agricultural Extension Service, Manhattan, Kansas.

Ridden C., 2009. In: Analyst warns of dairy debt tsunami. The New Zealand farmers Weekly, January 19, 2009. pg. 40

Rutsito B., 2011. Masters thesis in progress 'Resilience of Dairy Farms in Turbulent Environments' Massey University

Shadbolt N.M., Newman M., Lines I., 2007. Dairy farm business analysis: current approaches and a way forward" in the proceedings of the 16th International Farm Management Association Congress. S. O'Reilly, M, Keane and P. Enright (eds), University College Cork, Cork, Ireland, 15-20 July 2007.

Shadbolt N.M., Rutsito B., Gray D., 2011. "Resilience of New Zealand dairy farms in a turbulent environment: Definition and measurement", in the proceedings of the International Food & Agribusiness Management Association, 21st Annual World Symposium, Frankfurt, Germany, June 20-21, 2011

Shadbolt N., 2012. *Competitive strategy analysis of New Zealand pastoral farming systems.* International Journal of Agricultural Management Volume 1, issue 3; 19-27

Sutcliffe K., Vogus T., 2003. Organizing for resilience. Positive organizational scholarship: Foundations of a new discipline, 94–110.

Truxillo C., 2003. Multivariate Statistical Methods: Practical Research Applications Course Notes. Cary,

Walker B., Holling C., Carpenter S., Kinzig A., 2004. 'Resilience, adaptability and transformability in social-ecological systems', Ecology and Society 9(2):81-83.

Wallace N., 2009. Bank warning over dairy debt. Published on Otago Daily Times Online news 13/11/2009.

Wills B., 2009. "Painful price falls expected as farm sales slow", The Dominion Post, 17th February

Appendix A. Description of the DairyBase KPIs

KPIs	Description
Resistance (Technical Efficiency)	
Stocking Rate (cows/ha)	Peak Cows Milked divided by Milking area
Kg Milksolids/ha (KgMS/ha)	Milksolids Kilogrammes divided by Milking area
Kg Milksolids/cow (Kg MS/cow)	Milksolids Kg divided by Peak Cows Milked
Cows/FTE	Peak Cows Milked divided by Total Full Time Equivalent labour units (FTEs)
Kg MS/FTE	Total Milksolids Kg produced divided by Total FTEs
Net Cash Income per ha ($/ha)	Net Cash income from milk sales; net (sales-purchases) dairy livestock sales and other dairy farm related revenue. This value is divided by milking area
Latitude (Liquidity)	
Discretionary cash per ($/ha)	This is the cash available from dairy, non-dairy and off-farm operations to meet capital purchases, debt repayments, drawings, and extraordinary expenses (discretionary items). The calculation is Cash Operating Surplus less rent, interest and tax plus net non-dairy cash income, change in income equalisation and net off-farm income. This value is divided by milking area
Cash Surplus/Deficit per ha ($/ha)	The cash surplus from dairy, non-dairy and off-farm operations over the year. The calculation is total discretionary cash plus introduced funds less net capital purchases, net change in debt, drawings and extraordinary expenses. This value is divided by milking area
Drawings per ha ($/ha)	This includes all owners' household cash expenditure eg living expenses, holidays, donations, life insurance and private portion of farm cash expenditure. Any off-farm wages and Salaries earned are netted off drawings. This value is divided by milking area
Precariousness (Solvency)	
Interest and Rent/Total Revenue:	Interest and Rent (excluding run-off rent) paid as a percentage of Total Revenue: Total GFR + Net off-farm income where GFR = net cash income plus value of the change in dairy livestock numbers.
Interest and Rent/Kg MS ($/kgMS)	Interest and Rent (excluding run-off rent) paid divided by Milk solids Kg.
Debt to Assets % (%)	Closing Total Liabilities as a percentage of Closing Total Assets. This measures the proportion of the business value that is borrowed by the owners.
Resistance (Financial Efficiency)	
FWE/Kg MS	Farm Working Expenses divided by Milksolids Kg
Operating expenses per ha ($/ha)	Total Dairy Operating Expenses: (FWE plus depreciation, feed inventory adjustment, value of unpaid family labour, owned run-off adjustment) divided by Milking area.
Operating expenses/Kg MS ($/KgMS)	Total Dairy Operating Expenses divided by Milksolids Kg.
Operating Profit Kg MS ($/KgMS)	Dairy Gross Farm Revenue per Kg MS less Total Dairy Operating Expenses per Kg MS.
Operating profit margin (%)	Dairy Operating Profit (Dairy GFR less Operating Expenses) as a percentage of Dairy GFR.
Asset turnover (%)	Dairy Gross Farm Revenue as a percentage of Opening Dairy Assets.
Operating return on dairy assets (%)	(Dairy Operating Profit plus owned run-off adjustment less rent) as a percentage of Opening Dairy Assets.
Total Return on Assets (%)	(Total Operating Profit plus owned run-off adjustment less rent plus change in capital value) divided by Opening Total Assets. The TRoA is the profit generated by the assets employed plus capital gains or losses. It measures the overall financial performance of the business.
Return on Equity (%)	(Total Operating Profit plus owned run-off adjustment plus net off-farm income less rent less interest) as a percentage of Opening Equity. The RoE measures the return on the funds of the owner but does not include the change in capital value

Appendix B. Analytical approach – Principal Component Analysis (PCA)

PCA is a technique for extracting from a set of observed variables (KJPIs) those few orthogonal linear combinations of the KPIs that capture the common information most successfully. Principal components are uncorrelated and orthogonal (Truxillo, 2003). Meaning a principal component is a linear combination of weighted observed variables (KPIs). PCA is used to measure indirectly from the observed factors a set of few principal factors also called unobservable variables or latent/underlying construct. The latent construct are measured indirectly by determining its influence to responses on measured variables (Harris, 1997). Intuitively the first principal component of a set of variables is the linear index of all the variables that captures the largest amount of information that is common to all of the variables. For instance, as we have a set of KPIs; x_{kj} represents the value of KPIs k for each farmer *j*. PCA is implemented by normalising each x_{kj} by its mean and standard deviation such that:

$$x_{kj}^* = \frac{(x_{kj} - \bar{x}_k)}{s_k} \tag{1}$$

where is the normalised KPIs, and are the mean and standard deviation of KPIs across farmers. The selected KPIs (variables) are expressed as linear combinations of a set of underlying components for each farmer j such that:

$$\begin{aligned} x_{kj}^* &= v_{11}A_{1j} + v_{11}A_{2j} + \ldots + v_{1k}A_{kj} \\ &\vdots \qquad\qquad \forall_j = 1, \ldots, j \\ x_{k1j}^* &= v_{k1}A_{1j} + v_{k2}A_{2j} + \ldots + v_{kk}A_{kj} \end{aligned} \tag{2}$$

where the *As* are the components and the *v's* are the coefficients on each component for each variable (and do not vary across farmers). The solution for the problem is indeterminate because only the left-hand side of each line is observed. To overcome this indeterminacy, PCA finds the linear combination of the variables with maximum variance, usually the first principal component A_{1j} and then a second linear combination of the variables, orthogonal to the first, with maximal remaining variance, and so on. Technically the procedure solves the equations:

$$v_n(R - \gamma I) = 0 \tag{3}$$

For λ_n and v_n, where *R* is the matrix correlations between the scaled variables (*x's*) and *v'n* is the vector of coefficients on the nth component for each variable. Solving the equation yields the eigenvalues of *R*, λ_n and their associated eigenvectors, v_n. The final set of estimates is produced by scaling the v_n so the sum of their squares sums to the total variance.

The 'scoring factors' from the model are recovered by inverting the system implied by equation (2), and yield a set of estimates for each of the *k* principal components:

$$\begin{aligned} A_{k1j} &= f_{11}x_{1j} + f_{12}x_{2j} + \cdots + f_{1k}A_{kj} \\ &\vdots \qquad\qquad \forall_j = 1, \ldots, j \\ A_{k1j} &= f_{k1}x_{1j} + f_{k2}x_{2j} + \cdots + f_{kk}A_{kj} \end{aligned} \tag{4}$$

The fist principal component, expressed in terms of the original (un-normalised) variables, is therefore an index for each farmer based on the expression:

$$A_{1j} = f_{11}x_{11}^* + f_{12}x_{12}^* + \cdots + f_{1k}x_{kk}^* \tag{5}$$

The assigned weights are then used to estimate an overall "resilience index" as applying the following formula:

$$R_j = \sum_i^k \frac{[b_i((x_{kj} - \bar{x}_k)]}{s_k} \tag{6}$$

Where R_j is the standardized resilience index for farmer *j; b_i* represents the weights (scores) assigned to the KPIs *k*; other variables as defined above. A negative *Rj* means that relative to the other farmers' measure of resilience, the farmer is not resilient and a positive *Rj* signifies that the farmer is relatively resilient. A zero value, which is also the sample mean index, implies the farm is neither more resilient nor less resilient relative to the farmers sampled.

The critical assumption of the method is that the underling common information is determined by the underlying phenomenon that the index is trying to measure (in this case resilience) which unfortunately cannot be statistically verified since it depends on the correct identification of the relevant variables or indicators, and is therefore largely a matter of judgment. In this study we used physical and financial indicators as surrogates for resilience. The construct of resilience measured here was based on extensive literature as presented above. One of the advantages of PCA apart from being able to estimate objective weights is it estimates the contribution of each variable to the underlying common phenomenon, the construct (in this study, resilience and it's components), and thus enables the ranking of indicators according to their importance in determining a farmer's level of resilience relative to others.

On the basis that the assumption on PCA identified ‘common information’ is correct the analysis could then identify and rank those key performance indicators (KPIs) that account for the most variability between farms thereby identifying the KPIs of most relevance in comparative analysis. While the PCA method enabled an index or score to be obtained for each farm the common phenomenon being explored, resilience has three attributes so also of interest is if all three are expressed in the PCA and whether any one is more dominant.