Future technologies and implications for farm management

FUTURE DAIRY FARM SYSTEMS: A BIO-ECONOMIC ANALYSIS

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Abstract

The dairy industry is an important component of New Zealand economy particularly in terms of foreign exchange earnings, local communities and employment, contributing around 3.5% of NZ's total GDP annually. The future of the dairy industry can be influenced by consumer trends, the volatility of production, input and output prices, the environmental footprint, and stricter regulations on trade and animal welfare. In a previous study, a series of likely future scenarios had been developed conceptually through a rigorous analysis that involved farmers, researchers, industry participants and a multitude of stakeholders. However, the likely impact of these scenarios at a farm level has not yet been quantified. In an attempt to quantify the implications of these scenarios, this study developed a bio-economic analytical framework. This framework has been empirically applied on a case study dairy farm using FARMAX® whole-farm system software. Future scenarios simulated are "Consumer is King", "Governments Dictate", and "Regulation Rules". Determining the on-farm adjustments and then modelling the impact of these on the case study farm enabled in-depth analysis to occur. The feasibility of each and the economic implications of the changes differed between scenarios. For two of the scenarios, if they eventuate, further on-farm adjustments will be required.

Keywords: Farm systems, Modelling, Dairy farming, Future, Technology.

1. Introduction

Since the beginning, New Zealand (NZ) dairying has always been principally an export-oriented activity. Almost 95% of the milk produced in the country is exported accounting for 40% of global dairy trade. NZ is the world's largest exporter of dairy products and the 8th largest milk producer worldwide (IFCN, 2016). NZ's clean, green and environmentally friendly image in countries that have been shaken by food safety scares, contributed also to the success of the dairy industry as many products have been repositioned into high-value markets (Shadbolt and Martin, 2005). Additionally, NZ's farm systems had evolved rapidly as a consequence of a combination of improved animal genetics, precision farming, irrigation, changing pasture and feed systems and better farm management, leading to a global recognition of being low-cost producers of high quality milk (IFCN, 2016).

Nowadays, dairy farmers around the world are being faced with complex, dynamic and interrelated changes in the production context, connected to –among other things– climate change, increasing food demand, scarcity of natural resources, volatile input and output prices, rising energy costs and administrative regulations. In NZ, the rapid growth in milk production has had some unintended consequences: the environmental impact of higher stocking rates –especially on free draining soils and under irrigation, or in high rainfall areas–, is now being closely monitored and controlled (Shadbolt and Apparao, 2016). Furthermore, the inherent volatility of the dairy industry has always been an issue for NZ, because of the limited domestic market (less than 5% of New Zealand milk is consumed within the country) and extremely competitive traded market, which is subject to quite significant shifts in supply and demand volumes and prices.

On the social aspect, people are becoming less accepting of the negative impacts of dairy farming, despite the important economic and social contribution that dairying has to the nation (Clark et al., 2007). In recent times, this has led to an urban-rural divide in the community. In the past almost all New Zealanders had some contact with farming, however, the number of people with no involvement has been growing over time with urbanization, creating a social gap between 'townies' and farmers. Additionally, external entities like the government and social media have been putting pressure on the agricultural industry to change production focus from quantity to quality and sustainability. As a result, more attention has been put on highlighting agriculture's interaction with surroundings, such as the environment, production methods and food safety. Farmers find that they are having to modify some of their practices, keeping better records of animal treatments as well as informing the wider public about both new and old technologies (Martin et al., 2005). Along with this, the less political influence had reduced farmer's freedom to operate within some property rights. Social media's power has been growing, giving farming –and especially dairying– a hard time, communicating and informing –through media campaigns– what they believe standard practices of the dairy industry are attempting against animal welfare. Efforts are being put to mitigate this image:

industry organisations have been actively working in pushing back on negative reporting of dairy farming. DairyNZ, the industry organisation that represents all NZ dairy farmers, have been working proactively on a public perception programme to drive positive commentary in the media and to create opportunities for direct conversations with the public, focusing in sharing positive stories and encouraging farmers to share their stories about dairy, what is actually happening on-farm to protect waterways, and how farmers care for their animals through their management practices (DairyNZ, 2017).

Table 1: A summary of the main characteristics of each future scenario

	Consumer is King Scenario	**Governments Dictate Scenario**	**Regulation Rules Scenario**
The World	Significant economic growth. Total global demand for dairy is robust. Supply of dairy has not been able to keep up with demands in many regions	Sustained deceleration in economic growth. Global demand for dairy highly constrained. Imports highly controlled	Global demand for dairy products is robust, but regulatory requirements constrain supply globally
New Zealand	Numerous market options for NZ dairy. Moved up in value chain producing high-value products.	Protectionist policies and political chaos. Back to undifferentiated commodity dairy products as consumers are price sensitive	Considerably greater transparency and compliance required, especially on environment and animal welfare
Farm systems	Flexible farm systems needed to adapt & deliver to changing international customer needs	Focus on producing at lowest cost. Fewer but larger farms. Increasing costs, low returns for farmers. Drop in land prices and capital value	Restrictions on stocking rates and feed sources. Ban on the slaughter of bobby calves and use of antibiotics
Milk price	Expected to be very high and variable. Most positive environment for NZ Dairy	Expected to be low and stable. Most restricted environment for NZ Dairy	Expected to be variable. Restricted but provides opportunity for NZ Dairy

Uncertainty is a fact of life in NZ dairying, as it is also a fact that future farms will differ from those of today (Shadbolt and Apparao, 2016). The Centre of Excellence in Farm Business Management (CEFBM), a joint venture between Massey and Lincoln Universities in New Zealand, began a project to research Dairy Farm Systems for the

Future. The purpose was to explore how to identify and design farm systems best suited to the changing environment and farmer circumstances. In this project, Shadbolt et al. (2015) emphasized on the importance of looking beyond the common view of the future to understand what are the underlying issues that are shaping the future of the dairy industry, as this will be critically important not only for the prosperity of the industry but also for New Zealanders in general, taking into account the significant contribution the industry represents to the economy of the country. The project initiated with the design of the future scenarios, which demanded a rigorous analysis in which farmers, researchers, industry participants and a multitude of stakeholders were involved. A set of "plausible scenarios about the future (10-20 years)" was articulated, contemplating a diverse range of factors and uncertainties that are set to shape volume, value, cost, complexity and volatility in the future of the dairy industry (Table 1). They were developed to support decision makers in exploring how the farm systems might have to change to stay competitive under different scenarios. The three future scenarios derived were: 'Consumer is the King' (CK), in which a wide range of dairy products are produced in direct response to consumer demand (a consumer-driven scenario), 'Governments Dictate' (GD), in which dairy products are produced for a world where political chaos exists, markets are shrinking and trade is dictated by governments scenarios (a highly-intervened and chaotic scenario), and 'Regulation Rules' (RR), in which regulatory requirements of dairy farm businesses are considerably greater (a highly-regulated scenario) (Dooley et al., 2018).

2. Objective

Though conceptualised future scenarios rendered a sensible insight about likely future, it is important for decision makers to know how a current dairy farm system would look like at a farm level if these future scenarios occur. Therefore, through the development of a bio-economical analytical framework, this study will determine the on-farm adjustments required under each scenario. These will then be modelled on a case study farm in an attempt to quantify the potential bio-economic implications of each likely future scenario at a farm level.

3. Method of analysis

A bio-economic analytical framework was developed for this study (Figure 1). This framework has been empirically applied on a single case study dairy farm using

FARMAX® whole-farm system software. FARMAX® is an evidence-based modelling and decision support tool developed in New Zealand for pastoral farmers and consultants. Using monthly estimates of pasture growth, farm and herd information, FARMAX® determines the production and economic outcomes of managerial decisions (Bryant et al., 2010).

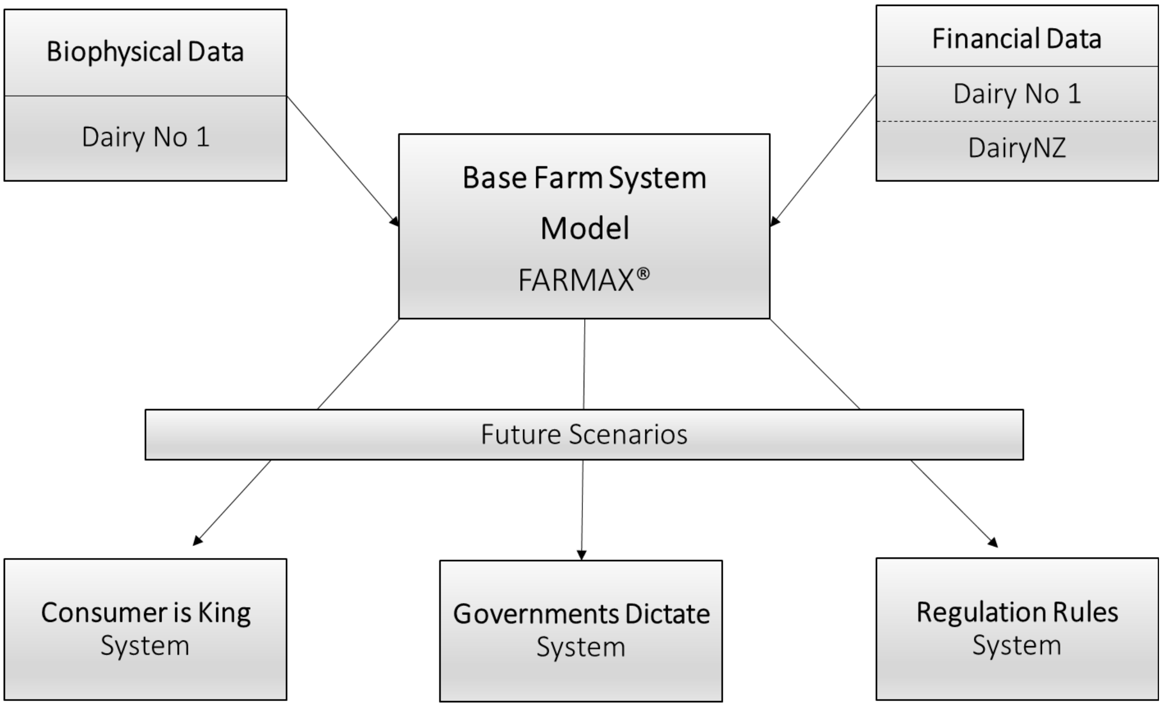

Figure 1: Modelling framework

Massey Dairy No 1 was used as a single case study farm in order to get in-depth insights. Financial and biophysical data from the 2016-17 season sourced from the farm was used to set up the Base Farm System Model on FARMAX®. Financial outputs were calibrated using DairyNZ Economic Survey data in an attempt to make the case study farm financial results more representative of a commercial dairy farm, as a few inconsistencies were found related to Dairy No 1 farm being part of a University and therefore having specific costs. Afterwards, a series of changes were introduced to the Base Farm System Model simulations based on the characteristics of each future scenarios. Simulated scenarios on new farming technologies and innovations were sourced from published literature and expert consultation. As discussed before, “CK System Model”, “GD System Model” and “RR System Model” were simulated. A summary of the characteristics of each farm system model at a farm level is outlined in Table *2*.

Table 2**:** Summary of the main characteristics of each Farm System Model

Characteristics	**Base System Model**	**CK System Model**	**GD System Model**	**RR System Model**
Main system change		All-year-round milking	Automatic milking system	All stock on farm
Cows (milk peak)	258	237	230	220
Stocking rate	2.2	2.0	2.8	1.8
Grazing off	Dry mob and young stock	Only young stock	Dry mob and young stock	No
Milking Frequency	Once-a-day	Once-a-day	Twice to thrice-a-day	Twice-a-day
Breed	Cross-bred	Jersey	Cross-bred	Cross-bred
Calving pattern	Spring	Split	Spring	Spring
Production system	System 1- 2	System 1 - 2	System 2 - 3	System 2 - 3
Milk price (per kgMS)	$5.92	$7.92	$3.92	$5.92

4. Results and Discussion

Overall, pasture-based systems were the basis of the three farm systems modelled, as higher feed costs were a common issue across all future scenarios analyzed. In addition, the decision for opting on entirely pasture-based systems was related to gain the confidence of consumers, every time more concerned and engaged in environmental, social, animal welfare and food safety aspects of dairying.

Table 3: Physical KPI summary

Category	Description	Base System Model	CK System Model	GD System Model	RR System Model
Production	MS total (kg)	92,289	97,638	136,385	66,100
	MS per ha (kg/ha)	771	816	1,139	577
	MS per cow (kg/cow)	358	438	413	314
Farm	Nitrogen Use (kg N/ha)	111	111	80	0
Feeding (per cow)	Pasture Offered (t DM/cow)	3.9	4.7	3.2	3.2
	Supplements Offered (t DM/cow)	1.2	1.3	1.6	2.0
	Off-farm Offered (t DM/cow)	0.2	0	0.2	0
	Total Feed Offered (t DM/cow)	5.3	6.0	5.0	5.2

Besides, the adoption of new technologies was modelled across all scenarios, which in some cases allowed for higher pasture growth rates (i.e. through Precision Irrigation technology or Genetically Modified cultivars). However, these 'high-tech' farms required highly trained and technology-savvy staff, increasing the cost of labour for all except the farm system model using Automatic Milking Systems (AMS). All season Once-A-Day milking frequency used in the base farm system was replicated in CK System Model, as research highlighted the benefits that this strategic management decision brings to the system in terms of animal and human welfare.

Assets values shown in

Table *4* were referenced from DairyNZ Economic Survey 2016-17. Land & Buildings values assumed were based on the Gross Farm Revenue (GFR) to result in a common Asset Turnover ratio across all the models.

Table 4: Assets values and financial ratios

Category	Base System Model	CK System Model	GD System Model	RR System Model
Land & Buildings	4,741,230	6,841,230	3,891,230	3,741,230
Plant, machinery and vehicles	202,013	232,013	898,679	232,013
Livestock	508,512	467,121	650,422	433,615
Shares	546,720	773,293	534,629	409,072
Total Assets Value	5,998,474	8,313,657	5,974,960	4,815,929
Gross Farm Revenue	603,873	840,497	603,785	487,903
Operating Expenses	453,574	493,498	668,656	478,103
Operating Profit	150,299	346,999	-64,871	9,800
Return on Assets (%)	2.5%	4.2%	-1.1%	0.2%
Asset Turnover (%)	10.1%	10.1%	10.1%	10.1%

CK System Model

The premise of the design of this farm system model was to make sure that the consumer was delivered whatever they requested while being a system that enables complete visibility and connectivity between the cow and the consumer. Firstly, in the search for a flexible farm system, this model was designed to supply fresh liquid milk all-year round. To do this, the herd was split into Spring and Autumn calving (70/30 respectively), which generated a feed deficit in the months where the pasture growth curve is low. Stocking rate was reduced by 0.2 cows per ha to help overcome this issue. The option to import feed onto the system was not considered as consumers in this likely future scenario will demand pasture-based systems. In addition, as the inclusion of precision irrigation technology at the farm caused a 5% increase of total pasture growth (kg DM/ha), an extra 0.8 t DM of pasture was offered per cow. This additional pasture offered helped to lift the production an extra 5,358 kg MS compared to the Base farm system. Milk revenue increased by $247,427 as a consequence of higher MS sold to the factory at a higher milk pay-out, plus the premium payment received for the milk supplied during winter ($3.15 kgMS). The choice of carrying an entire Jersey milking herd also benefit this system due to the breed's better tolerance and faster adaptability to OAD milking. Besides, the use of GPS collars contributed to a better understanding of cow behaviour, allowing to follow each cow movement individually which helped offering customized diets and detecting lameness on time (saving $9,955 in animal health costs). In addition, this technology has the potential to allow for higher connectivity between the consumer and the product they buy, however, this was not able to be modelled at a farm level.

A disadvantage found on this farm system model is that technology was not able to provide a solution in terms of the scarcity of labour. On the contrary, the lack of skilled staff available able to operate with the new smart technologies, adding to the fact that split-calving systems are more labour intensive, was translated into significantly high salaries offered, which increased total wages paid by $72,071 per annum.

Overall, the CK System Model delivered the highest total Operating Profit (Table 5). This is a promising scenario and it has a lot of scope for New Zealand pasture-based systems. However, meeting the specificity in consumer's demand under this scenario will require important investments in value-chain development.

Table 5: Financial KPI summary

	Base System Model	**CK System Model**	**GD System Model**	**RR System Model**
Total Gross Farm Revenue ($/kgMS)	6.54	8.61	4.43	7.33
Total Farm Working Expenses ($/kgMS)	4.54	4.69	3.96	5.75
Operating Expenses ($)	453,574	493,498	668,656	478,103
Total Operating Profit ($)	150,299	346,999	- 64,871	9,800
Operating Profit Margin	25%	41%	- 11%	2%
Return On Assets	2.5%	4.2%	- 1.1%	0.2%
Operating Profit ($/ha)	1,256	2,899	- 542	82

GD System Model

On this scenario, there was a need for high levels of bulk milk to be produced at any expense. An Automatic Milking System (AMS) was incorporated into the model, allowing to increase the milking frequency (twice- to thrice-a-day). Additionally, more milking cows were carried on farm to lift milk production levels. Altogether, an extra 44,096 kg MS were harvested compared to the Base situation. The higher stocking rate (0.3 cows/ha) and higher cow energy demand were supported with genetically modified cultivars that allowed for higher total pasture production. Even though AMS has the benefit of monitoring each cow individually while they are being milked on the robot, animal health costs increased by $16,280 as overall there is less attention on cow welfare on this likely future scenario. The main savings on expenses occurred on wages, as a consequence of the use of robots instead of people. However, these technologies implied a significant increase in the depreciation cost, as well as in repair & maintenance costs that almost offset the savings that robotics brought to the system.

As in this future scenario global crisis affected economic growth, constraining the demand for dairy products and affecting consumer's disposable income due to increases in their cost of living, a milk pay-out of $3.82 per kgMS was assumed. Additionally, an overflow of milk supply globally contributed to this low pay-out, being the main driver of the poor result of the GD System Model (Table 5).

In conclusion, adaptation will have to happen in this system, as it delivered the lowest Operating Profit Margin and Return On Assets (Figure 3). Even though assumptions were made on land prices (which fell as a consequence of being related to GFR), further changes will be needed to become economic. A possibility is through scale: as current farm size and structure is not allowing metrics to work, this dairy farm could potentially merge with others. Additionally, if technology becomes more affordable in the future, AMS could potentially become a solution to reduce costs of labour, which is the single highest cost after feed expenses in a dairy farm in NZ.

RR System Model

This model required a system where all stock is kept on farm, as a biosecurity regulation prohibit the transport of cattle within farms due to cattle related diseases. Besides, the slaughter of calves at a young age is also banned on this scenario. Considering this, the RR System Model was designed to raise bobby calves on-farm until they are 11 months old to be then sold to the beef industry. This extra livestock sale increases the GFR by

$21,309. In addition, Grazing costs are avoided ($41,014) from keeping all cattle on the farm. Altogether, these results helped this model to partially overcome the reduction of milk supplied to the factory (23,189 kgMS), due to having less milking cows on farm (-38 cows). Also, the restriction imposed on the use of fertilisers and irrigation brought important savings to the farm ($53,444), with the additional benefit in the reduction of nitrogen leaching. However, a ban imposed on the use of antibiotics impacted negatively on animal health costs, increasing them an extra $7,535. Breeding costs also increased due to the use of Angus straws for the 'beefies' and wages rise because of the extra labour needed to run all stock on-farm the whole season.

In order to reduce dependence on external sources of energy, this model included solar technologies on farm which convert energy from the sun into electricity. The use of solar panels allowed this model to save money on the electricity bill ($7,000), plus other advantages from this technology such as the fact of having no running costs after installation, and the potential expansion of the solar network by adding more panels.

Even though this system model delivered the second highest GFR (Figure 2), high Operating Expenses lead to very low margins and, thus, will need further refinement. Finding a market niche for the potential new class of beef product –derived from rearing bobby calves that would ordinarily be sent to slaughter– may become a solution in the future for this system to deliver a more consistent result.

Besides, economies of scale through the fusion with another dairy farm could also become an alternative solution for the metrics to work in this model, as this can help to reduce the relative cost of feed because of the efficiencies of scale.

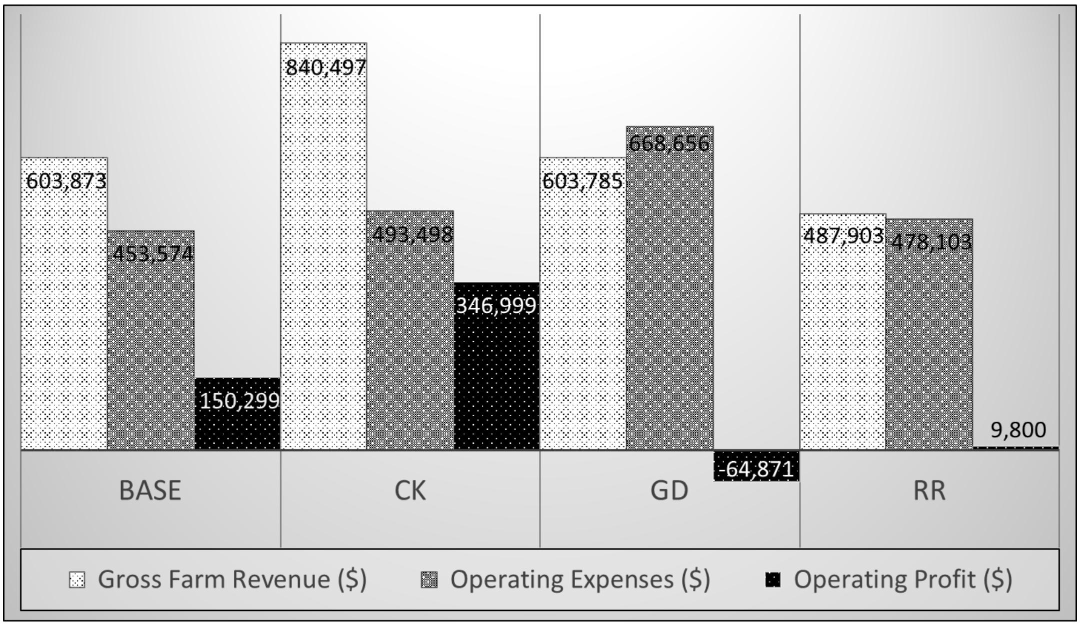

Figure 2: Total Gross Farm Revenue, Operating Expenses and Operating Profit for all models

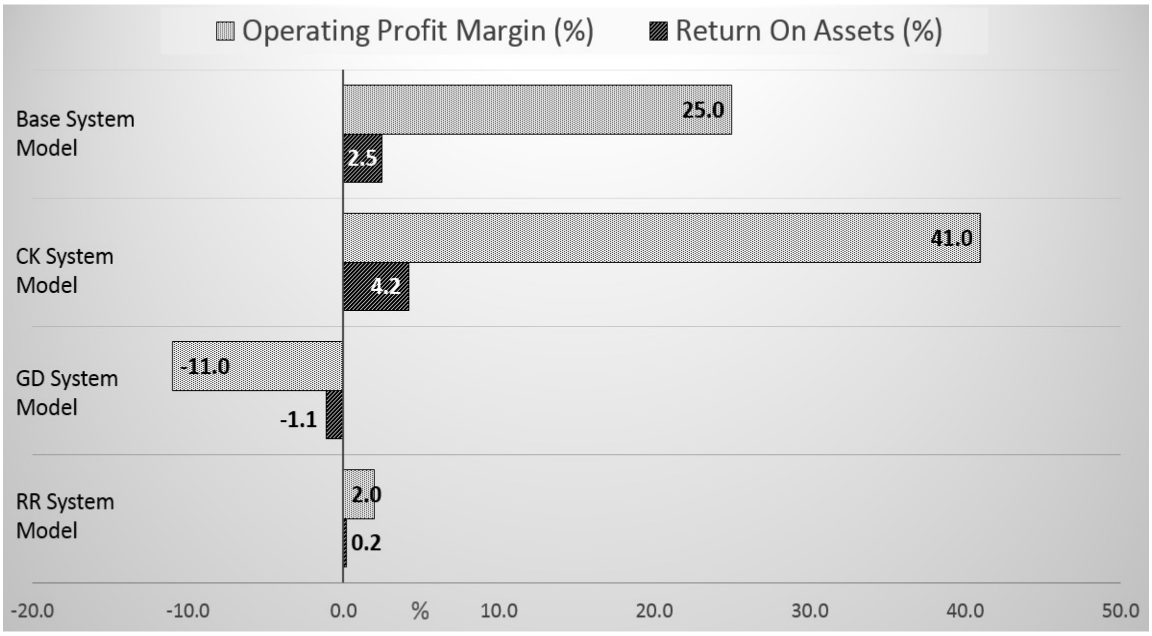

Figure 3: Operating Profit Margin and Return on Assets for the systems modelled

4. Conclusion & Future research

Modelling a case study farm and bioeconomic simulations enabled in-depth analyses and the impact of likely future scenarios to be quantified. FARMAX® whole-farm system platform helped in modelling the physical changes needed to simulate the likely future scenarios at a farm level. Irrespective of the likely futures analysed in this study, a constant –both in the scenario analysis itself and then in this subsequent on-farm analysis– is that technology will be critical to the adjustments that are required at a farm level. Concurrent with the strong need for smart systems, the assumption was made that all farms will continue to be pasture-based, as this has been New Zealand dairy farming's competitive advantage since inception. As specificity of consumer requirements mostly happens beyond the farm –and farm level bio-economic models cannot address questions faced by society that transcend agriculture– some really clear and defined value chain development must occur, which could, for the New Zealand dairy industry, mean fragmentation of current chains and structures.

Further studies could adopt this approach to apply the possible, plausible scenarios to other farming systems and extend the analysis to explore the impact of the breadth of likely climate and economic variability.

5. References

BRYANT, J. R., OGLE, G., MARSHALL, P. R., GLASSEY, C. B., LANCASTER, J. A. S., GARCÍA, S. C. & HOLMES, C. W. 2010. Description and evaluation of the Farmax dairy pro decision support model. New Zealand Journal of Agricultural Research, 53, 23-28.

CLARK, D. A., THORROLD, B. S., CARADUS, J. R., MONAGHAN, R. M. & SHARP, P. 2007. Issues and options for future dairy farming in New Zealand. New Zealand Journal of Agricultural Research, 50, 203-221.

DAIRYNZ. 2017. Annual Report 2016/17 [Online]. Available: https://www.dairynz.co.nz/media/5788170/dairynz-annual-report-2017.pdf [Accessed].

DOOLEY, A., APPARAO, D., MCCARTHY, I. & SHADBOLT, N. 2018. Envisaging Future Dairy Farm Systems: A scenario analysis approach. *International Journal of Agricultural Management,* 7.

IFCN 2016. *IFCN Dairy Report 2016: For a better understanding of the dairy world*, International Farm Comparison Network, Kiel, Germany.

MARTIN, S., ZWART, T., GARDNER, J. & PARKER, W. 2005. Introduction. *In:* MARTIN, S. & SHADBOLT, N. (eds.) *Farm Management in New Zealand.* Hong Kong: Oxford University Press.

SHADBOLT, N. & APPARAO, D. 2016. Factors Influencing the Dairy Trade from New Zealand. *International Food and Agribusiness Management Review,* 19(B)**,** 241-255.

SHADBOLT, N., APPARAO, D., HUNTER, S., BICKNELL, K. & DOOLEY, A. 2015. Scenario analysis to determine possible, plausible futures for the New Zealand dairy industry. *New Zealand Journal of Agricultural Research,* 60**,** 349.

SHADBOLT, N. M. & MARTIN, S. K. 2005. *Farm management in New Zealand*, Melbourne, Vic. ; Auckland [N.Z.] : Oxford University Press, 2005.