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The intensification of the NZ Dairy Industry – Ferrari cows being run on two-stroke fuel on a road to nowhere?

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ABSTRACT

This paper applies an economic lens to the argument that dairy farmers should increase production via supplements, which has led to concerns regarding the environmental impact of intensification. This paper finds:

1. Intensification has led to farms producing at levels incompatible with profit maximisation
2. Claims that de-intensification will result in lower farm profitability are unconvincing
3. The current suite of assessment and planning tools are likely to be causing systemic overstocking
4. Failing to recognise the difference between marginal and average costs is likely to be leading to expensive mitigation measures that treat symptoms rather than address causes.

KEY WORDS

Average cost, Average revenue, Constant returns to scale, Diseconomies of scale, Economic loss, Economic profit, Economies of scale, Intensification, Lincoln University Dairy Farm (LUDF), Marginal cost, Marginal revenue, Subnormal/supernormal profit Theory of the Firm, Perfect competition,

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INTRODUCTION

From the turn of the 21st century, New Zealand dairy farmers have been advised to increase output through better utilisation of the biological capacity of their livestock and, if necessary, to use bought in feed to achieve this. Indeed, one of the catch phases has been that New Zealand farmers have 'Ferrari cows' that are being fed the equivalent of 'two-stroke' fuel. The result has been the intensification of dairy farming with a corresponding rise in concerns regarding the environmental consequences of this process – especially on water quality, greenhouse gas emissions (GHGs) and the migration of dairy farms into non-traditional dairy regions.

Noting the 'Ferrari cows' claim is essentially a biological argument regarding the removal of an energy constraint, this paper applies a series of elementary economic tools to examine the claim that reducing dairy externalities ('nasties' – e.g. nitrate leaching, GHG emissions) implies fewer cows (de-intensification) which means reduced farm profitability. The corollary is abatement costs are borne primarily by farmers.

This paper is structured around three questions, namely:

1. Is there an environmental/farm profitability trade off or is the claim a false dichotomy?
2. What are implications of long-run marginal cost on the dairy industry and profit maximisation at the farm level?
3. Are current mitigation techniques likely to result in least cost pollution abatement?

The paper finds:

1. Intensification is likely to have led to farms producing at a level that is incompatible with profit maximisation
2. Claims that de-intensification will result in lower farm profitability are unconvincing theoretically and empirically unsupported
3. The current suite of assessment tools are likely to be leading to systemic over production, which is likely to manifest itself as overstocking
4. A failure to recognise the difference between marginal and average costs is also likely to be leading to expensive environmental mitigation measures that treat symptoms rather than causes.

PART 1: IS THERE REALLY AN ENVIRONMENTAL/FARM PROFITABILITY TRADE OFF OR IS IT MERELY A FALSE DICHOTOMY?

New Zealand farmers have long prided themselves on being able to continually increase output; via productivity gains (e.g. higher meat production due to increased lambing percentages) or increased input use (e.g. the effect of aerial top dressing on hill country farming post World War Two) or both. Indeed, the orthodoxy for well over 100 years has been the need to lift output in order to raise revenues and thereby increase farm profitability.

A recent version of this orthodoxy has arisen in the dairy industry where it has been argued that farmers should move away from a purely pastoral-based system and increasingly use supplements such as palm kernel exfoliator (PKE) or maize silage. In addition to arguments such as better grass utilisation, one of the supposed benefits of using of supplements has been the ability to utilise the inherent genetic potential of dairy cows – in that a mature Holstein Friesian is able to produce up to 10,000 litres of milk per annum (approximately 870kg milksolids [MS]) but in a New Zealand context seldom produces even than half that (5,000 litres or 435kgMS). The result has been the cliché of farmers having 'Ferrari cows' but running them on 'two-stroke fuel'.

Since the turn of the current century farmers have increasingly heeded these arguments and intensified production – as well as extending the dairy footprint into non-traditional dairy farming regions such as Canterbury (and even the dry and semi-alpine McKenzie country). The corollary has been a dramatic increase in concerns regarding the environmental consequences of intensive (and extensive) dairy in terms of as water quality, water use, and greenhouse gas (GHG) emissions – with resulting calls for de-intensification.

The response from farming circles can be summarised as follows:

1. *<u>Less</u>* environmental 'nasties' means –
2. *<u>Fewer</u>* cows, which implies –
3. *<u>Lower</u>* revenue – due to reduced milk production.

The implication is a trade-off between better environmental outcomes and farm profitability, with the 'costs' of environmental mitigation falling on farmers.

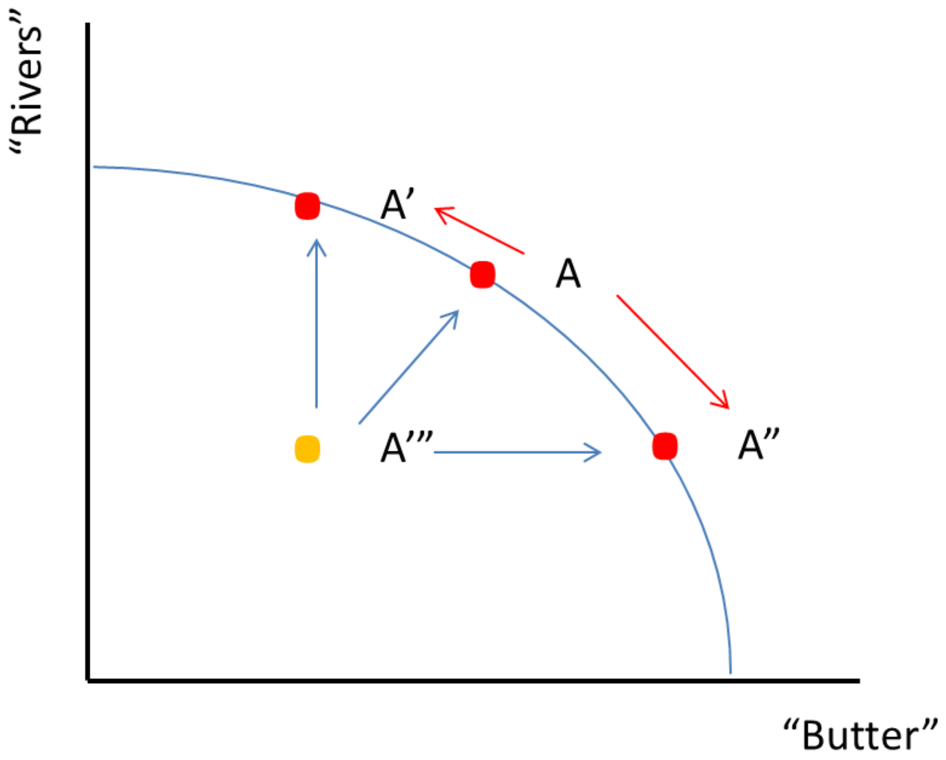
While this argument is intuitively appealing (and provides the type of emotional conflict beloved by the media and talkback radio hosts), without some form of analytical foundation it is merely unsubstantiated rhetoric masquerading as fact. In this sense, economics is well placed to provide such a foundation because issues such as scarcity and decision making under constraints are fundamental to the discipline.

Two sensible starting points are:

1. Examining trade-offs under different efficiency assumptions; and
2. Defining what is meant by a 'profit' and clarifying how it is achieved.

One of the first economic concepts taught is opportunity cost – which is the opportunity forgone due to the choice selected. The idea behind opportunity cost is that the same resources cannot be used twice so scarce resources should be employed in their highest value use. Traditionally, this was illustrated in the economics literature via a production-possibility frontier with 'society' supposedly making a trade-off between 'guns' and 'butter'; or that more of one meant less of the other. This can easily be adapted to 'rivers' (representing environmental goods) or 'butter' (representing the dairy industry) (see figure 1).

Figure 1: **PPF showing the trade-off between 'rivers' and 'butter'**



Assuming society is operating at a technical frontier, the production of both goods would be represented by a point such as A – so if society desired cleaner rivers then it could move to a point like A' (which implies less butter) or conversely, a point like A" (which means more butter, albeit at the cost of dirtier rivers).

When farming advocates argue that 'less nasties = fewer cows = lower revenue' they are implicitly assuming production consistent with point like A and a move to a position such as A'. However, such an assumption is itself based on a further assumption that the industry is operating at the technological frontier – and that is normally assumed to be a theoretical curiosity rather than a practical reality.

In contrast, a much more likely starting position is that of A'" – which is within the frontier. Critically, from a point such as A'" a Pareto efficient move to a position such as point A is possible where cleaner rivers *and* more production can simultaneously be achieved.

The point made is both critical and simple: unless it is assumed that the dairy industry is operating at the technological frontier then Pareto improvements are possible and rhetoric suggesting a binding environmental and financial trade-off is simplistic and misleading.

This idea can be extended by conceptualising 'dairy' as an industry and farms as profit seeking 'firms'. Central to an economic definition of profits is, once again, the concept of opportunity cost. In terms of a dairy farm 'firm', an economic view of on-farm profit therefore considers the opportunity cost of all the resources employed (e.g. land, labour and capital employed).

Firms were traditionally seen as profit maximisers; and profit maximisation occurs when the last dollar earned equals the last dollar spent; or more formally, when marginal revenue equals marginal cost (MR=MC). This is a 'normal' or 'economic' profit and is sufficient to keep resources (land, labour, capital) employed in their existing uses. In comparison, a profit greater than an economic profit is a super-normal profit whereas as a profit that is less is a sub-normal profit.

However, farmers tend to have a less challenging 'accounting' view, with 'profit' being the difference between total revenue and total costs. In 2009 the Ministry of Agriculture and Forestry (MAF – now the Ministry for Primary Industries [MPI]) published its annual *Farm Monitoring Report,*[4] which estimated that 52% of New Zealand dairy farms made a net **loss** and 63% had a negative farm surplus for reinvestment. MAF's report also showed that even the farms that made a surplus had levels of profitability that were relatively modest; especially given the asset values of the farms in question. Whilst it is

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4 Ministry of Agriculture and Forestry (2009) *Pastoral Sector Overview*, MAF Publications, Wellington

noted that 2008/2009 was an especially challenging season, a cursory review of previous and subsequent *Farm Monitoring Reports* show that these results are not unusual. Given that dairy farming appears as an industry typified by sub-normal profits (and quite likely, economic losses)[5] it would therefore seem foolhardy to suggest dairy is an industry operating at a technological frontier.

In short, the argument that 'less nasties = lower revenue' increasingly appears to be a false dichotomy and instead points towards the desperate need to understanding the cause (or causes) of what appears to be a systemic lack of farm profitability.

PART 2: WHAT ARE IMPLICATIONS OF LONG-RUN MARGINAL COST ON THE DAIRY INDUSTRY AND PROFIT MAXIMISATION AT THE FARM LEVEL?

Unlike wool, dairy products are perishable so it was not until the issue of storage was resolved (initially via refrigeration and more recently via dry powders) that the New Zealand dairy sector became a viable export industry. Apart from having a very small domestic population (New Zealand produces over 20 times more milk that can be consumed domestically) New Zealand's traditional comparative advantage was its cost structure – as a temperate country with plentiful rainfall permitted grass-based production without the need to house (and feed) animals during the winter. The result was that, despite the vagaries of commodity prices and commodity cycles, New Zealand dairy farmers were able to enjoy a sustained margin between international prices and cost of production.

Over the past decade, New Zealand dairy production has increased by over 60% - from approximately 1.1B kgMS per annum to approximately 1.8B kgMS today. As noted above, in addition to the intensification of production there has also been extensive growth into non-traditional dairy regions. The need to use supplements (which often require investment in feeding systems) and/or irrigation (which require investment in on-farm infrastructure plus on-going pumping costs) and/or to house animals during the winter months

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[5] The issue of the profitability of dairy farms – or the lack thereof – is the underlying issue behind two other debates – namely employment of overseas workers as farm workers (notability from the Philippines) and questions about level of company (and income) tax paid by farms (and farmers) (notably during the 2011 election campaign).

means the notion that the New Zealand dairy industry is increasing typified as an increasing cost industry is unlikely to be controversial.[6]

This also raises a reasonable question of whether the root cause of the profitability issue is essentially a marginal cost issue – notwithstanding the step-change in dairy commodity prices since 2007.

A focus on marginal cost, while a simple observation, it arguably an extremely powerful one – as economic theory tells us that an industry's long run supply curve is merely its long run marginal cost curve. This is illustrated in figure 2 (below).

Figure 2: NZ Dairy Industry – Scale economies over time

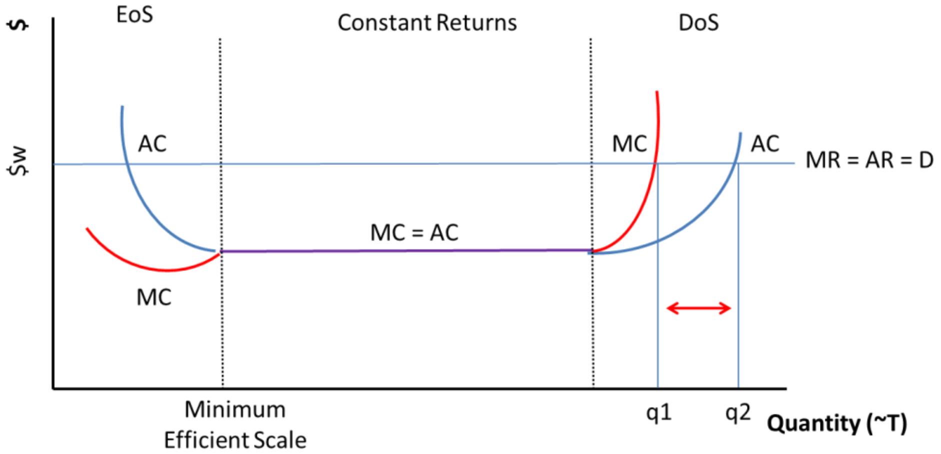

Figure 2 is divided into three panels. Firstly, on the far left, is the situation where average costs are higher than marginal costs. This is typical of an infant industry that is yet to reach critical mass – so increasing production is a necessity as it permits the industry to gain minimum efficient scale. Arguably, a key advantage the New Zealand dairy industry has enjoyed is land use rules that have permitted farm agglomeration. This means New Zealand farmers have long escaped the constraints of 'peasant' farming (where farmers literally know all their cows by name).

The second (or middle) panel is where an industry enjoys constant returns to scale; which is defined as being when average costs equal marginal costs. Intuitively, the expansion of dairying in the Waikato and Taranaki post World War Two are good examples of this – as improved roads, refrigerated tankers, and reticulated electricity meant that high quality land could easily be switched into dairy production.

6 In reality, this is simply a restatement of David Ricardo's observations from the early 19th century about the Law of Rent and diminishing marginal returns.

The third (or far right) panel shows an industry that is subject to some form of diminishing returns, which leads to increasing costs. Under these conditions, marginal costs are rising faster than average costs. This is a critical distinction because in the first two panels average cost was the only cost information the industry required.[7] However, once diseconomies of scale start to apply it is marginal cost that becomes the critical measure as it is marginal cost that is driving the industry's cost structure **and** its long run supply curve.

There is significant merit in teasing through the implications of this. Given the nature of the dairy industry (e.g. homogeneous commodity products, deep international markets, high levels of product knowledge, a fixed return to farmers on a milksolids basis irrespective of volume produced) an assumption of perfect competition is both a useful and legitimate simplification. A product price, $w ('dollars world') is set across the entire quantity produced. This implies that the world demand curve is also the industry's marginal revenue curve (which is also identical to its average revenue curve).

The critical issue, however, is the production point of the industry given a fixed exogenous world price. Given the dairy industry's long run supply curve should be its long run marginal cost curve; the industry should be producing at point q1. However, if the industry is continuing to employ information based on average cost, then it will be producing at point q2. The implication is if the industry is producing at a point consistent with average costs then it is systematically over producing compared to an industry producing in accordance with its marginal cost curve.

The implication is quite stark: rather than having a **profit** maximising industry with in-built limits one would have a **production** driven industry where those in-built limits are substantially weakened.

It is relatively easy to transition from an industry-level analysis to a 'firm' or 'farm' level analysis. This is represented in figure 3 below and the same price and perfect competition assumptions are applied.

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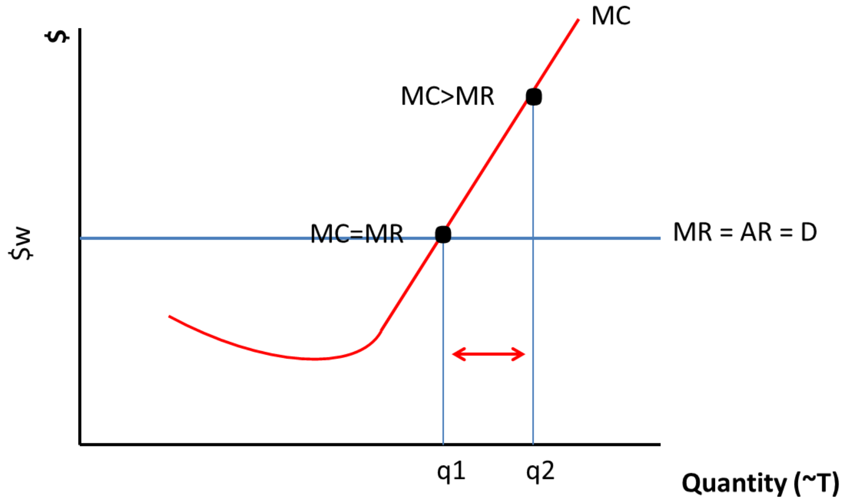
7 This also provides a theoretical foundation to argument that the key to increasing profitability is increasing revenue through increasing production. However, the advent of diminishing returns implies that as a nation, New Zealand is no longer an abundant and low cost producer of agricultural products.

Fig 3: Dairy Farm profit maximisation



As noted above, profit maximisation occurs when marginal cost equals marginal revenue. However, if the industry is typified as being output maximising then individual 'firms' must be producing at a point where marginal cost is greater than marginal revenue. This is represented in figure 3 as the difference between output at q1 rather than q2.

Under such circumstances, reducing output from q2 to q1 would be consistent with a move from output maximisation to profit maximisation. The corollary is that de-intensification will lead to increased profitability as marginal costs fall faster than any marginal revenue forgone.

In summary, in addition to being able to explain the dairy industry's lack of economic profitability, an analysis based on marginal costs shows that for any given level of per cow production marginal production produces excess externalities ('nasties') from uneconomic marginal cows.[8]

Having provided an analytical foundation, it is possible to test the theory against reality – which is the 'gold standard' of any scientific analysis. This is especially relevant because a hypothesis about a non-profit maximising industry quickly raises the spectre of the '$10 note on the sidewalk' analogy – where if it was a possible to make a financial gain then someone will have noticed it and 'picked it up' (or in other words, markets clear as economic agents [farmers] are not systemically stupid).

The challenge, therefore, is explaining what appears to be permanent dis-equilibrium. Whilst not attempting to be a complete answer, two

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[8] Or, in other words, the marginal social cost of dairy production is greater than its marginal social benefit.

explanations are offered complete with the results of economic modelling of the Lincoln University Dairy Farm (LUDF) employed to provide the empirical insights.

Misinformation?

The first explanation is likely to be highly controversial: the spectre of systemic misinformation to farmers. Whilst worthy of a detailed analysis, none of the mainstream dairy industry farming simulation models (e.g. the Whole Farm Model, Farmax, DairyMax, Udder) and performance measures (e.g. information derived from Dairy Base or Red Sky, benchmarks such as milksolids per hectare, average profit per hectare, gross farm returns, production at x percentile, etc.) are economic models or measures as **none** employ marginal analysis. As a result, **none** can profit maximise at a farm level and **all** are likely to lead to a production decision where marginal costs are greater than marginal revenue.

The corollary is that if the observation that the New Zealand dairy industry is facing diseconomies of scale and intensification typified by increasing marginal costs is correct, then the very information that dairy farmers are using to inform production and management decisions will be, at best, sub-optimal and, at worst, just plain wrong.

Farmer motives

The argument above is, however, still unsatisfying to an economist as no firm should not be able to retain resources (let alone expand and attract more) in a world where profit maximisation is unlikely and poor profitability is the norm. This leads directly to the second explanation: perhaps an assumption of farmers being like other entrepreneurs and acting as profit maximisers is misplaced?

One alternative explanation is that dairy farmers are wealth maximisers (or more prosaically, long term asset accumulators). Intuitively, this is appealing as it accords with the promise that a dairying couple can, over time, 'build a stake' in the industry with the eventual goal being farm ownership.

The corollary is that if farmers are focused on accumulating assets then a 'satisficing' position of having sufficient cash flows to pay drawings and to service debt is likely to suffice. Critically, this can also explain why more resources are flowing into the dairy industry: farmers are willing to borrow (and banks willing to lend) in order to accumulate assets (and potentially realise [untaxed] capital gains, especially if converting a dry stock farm into a dairy farm, as this is akin to property development).[9]

In short, a combination of systemic misinformation combined with farmer motives can go a fair way towards explaining why a $10 note may be left on the pavement after all.

The Lincoln University Dairy Farm

The suggestions regarding misinformation and motives remain interesting curiosities without empirical evidence. This is where the LUDF is useful.

The LUDF is a 160 hectare irrigated farm milking approximately four cows per hectare. The farm is focused on grass based milk production that is supplemented by small amounts of bought in silage with the majority of the cows wintered off (i.e. a 'System 2' farm in terms of the Dairy NZ dairy farm classification system). Critically, benchmarking of the farm's profitability indicates that on the basis of operating surplus per hectare, the LUDF is already in the top 2-5% of New Zealand dairy farms.

In 2011/12 a system change was introduced on the LUDF in the attempt to increase profitability without increasing the farm's total environmental footprint. The changes were driven by modelling undertaken by Grazing Systems Limited (GSL). In terms of this paper, the key point to note is that unlike the suite of mainstream models GSL is an economic model based on linear programming techniques. One of the advantages of a linear programme it is able to simulate different allocations of inputs – subject to predetermined constraints – and then select the profit maximising combination of inputs (or picking the point where marginal costs equal marginal revenue) subject to whatever constraint is imposed.

The result is a testable experiment: where the model makes certain predictions based on specified changes and those predictions are then tested against empirical reality and either confirmed or rejected – and in this case they were confirmed.

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9 The speed and scale of the growth of dairy debt has been staggering: in a little over a decade it has more than tripled (from about $10B in 2002 to $32B in 2014) whilst dairy output has grown by about 64%. Put differently, the marginal milk production has an effective debt loading of over $31 kgMS (compared to an average debt loading of less than $18 kgMS), and at an interest rate of about 6% debt servicing alone would present over a third of the forecast total dairy payout for the 2014/15 season. This does raise serious questions about financial sustainability, but that is outside the scope of this paper.

For example, in terms of production, the system change in 2011/12 increased production by 12.5% and profitability by 15% whilst reducing the herd size by 5.2%.[10] In other words, even on a farm operating at the 95th percentile, it was shown that:

1. Reducing cow numbers from 667 to 632 – a 5.2% reduction; but
2. Increasing milksolids per cow (from 398 kgMS per cow to 465 kgMS per cow – an increase of 67 kgMS per cow or 16.8%); meant
3. Increased profitability by 15% (on a farm that was already considered a top performer).

These changes are entirely consistent with the starting point of a farm operating at a point where marginal costs are greater than marginal revenue – which is precisely what was expected. However, there was a subtle nuance in that the expected over production or output maximisation was exhibited primarily as overstocking rather than excess milk production.

Indeed, total milk production **increased**.

The environmental footprint story is somewhat more complex – as analysis was limited to the milking platform only. That said, given fewer cows it is reasonable to assume an environmental foot print that is – at worst – no worse than the status quo (and most likely better).

Critically, these results were achieved without further intensification (the farm remained a System 2 farm – albeit a more efficient one). Indeed, GSL modelling also shows that while it is possible to **further** increase per cow production via supplements it is not economically profitable to do so without a significant lift in the milk price (to over $9 kgMS).

The material above illustrates two very important points:

1. **Stocking rates**: Even on a relatively low intensity and seemingly well run System 2 farm, the starting point was one of over-stocking – a factor that is likely to worsen as intensity increases and attention switches to more poorly run farms.

   Critically, excess stocking rates is entirely consistent with a farm operating where MC>MR; and

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[10] Pellow, R. *et al.* (2013) *Assessing the impact of input choices within Overseer (v6) on the modelled N losses to water for Lincoln University Dairy Farm (LUDF) Unpublished paper pg. 1 (see:* http://www.massey.ac.nz/~flrc/workshops/13/Manuscripts/Paper_Pellow_2013.pdf)

2. **Tipping points**: While the biological argument about exploiting an animal's genetic potential is correct, it is also a highly limited approach unless one has a corresponding understanding of the marginal costs associated with the marginal revenue gained from the marginal milk produced.

   When marginal cost equals or exceeds marginal revenue, a 'tipping point' is reached, beyond which profit is no longer maximised.

The LUDF work therefore provides critical empirical validation to the conceptual arguments raised earlier in this paper – and falsifies the argument that there is always a binding trade-off between improved environmental outcomes and farm profitability.

PART 3: ARE CURRENT MITIGATION TECHNIQUES LIKELY TO RESULT IN LEAST COST ABATEMENT?

The previous section showed it is highly likely that the vast majority of New Zealand dairy farms are overstocked and therefore producing milk at a point where marginal costs are greater than marginal revenue. The corollary is that in the process of aligning marginal costs with marginal revenue, farm profitability is likely to improve (as marginal costs are likely to fall faster than net changes in revenue) with simultaneous environmental benefits (primarily due to fewer cows). Moreover, as the LUDF showed, it is also possible that the milk volume can increase, even on farms with high per cow and per hectare levels of production to begin with.

As a result, the supposed trade-off between farm profitability and environmental outcomes is shown to be illusionary.

While a profit-maximising combination of inputs is both laudable and necessary, it may not be sufficient – as one could easy imagine regulations that impose environmental bottom lines considerably more stringent than what the 'optimised' profit maximising farm could achieve. In this situation, and in the absence of technological innovation, the trade-off does become binding as the 'free lunch' associated with a 'one off' Pareto gain has already been consumed.[11]

In this situation the ability to profit-maximise subject to a constraint becomes even more critical – as a thorough understanding of marginal costs will identify the least cost method to meet the environmental constraint (or constraints) having already 'right sized' and optimised the farm. However, in

[11] A major difference, however, is the farm is much better placed to deal with binding environmental constraints due to improved farm profitability to begin with.

the absence of this information a farmer is unlikely to be unaware that s/he is overstocked to begin with, and as a result consider measures that treat the **symptoms** of overstocking – albeit from a financially inferior position.

For example, using nitrogen inhibitors to address the affects of urine patches is a seemingly sensible practice – and in many cases it is. However, if the starting point is overstocking, then 'right sizing' the herd is a better approach as it addresses 'the cause' of the problem rather than treating its symptoms (i.e. leaching and GHGs from urine patches). This questions whether, beyond rudimentary environmental measures (e.g. nitrogen budgets, keeping stock out of waterways, planting riparian strips) and in the absence of knowledge about a profit-maximising herd size (and corresponding level of output per cow) whether the existing suite of mitigation measures (e.g. nitrogen inhibitors, feed pads, herd homes, effluent ponds etc.) actually provide cost effective mitigation or even whether such measures are being used in a cost effective way.

More worryingly, the claim that 'the future of New Zealand dairy farming is indoors' combined with a focus on 'mitigation technologies' is increasingly seen as a way to continually increase milk production whilst meeting environmental standards (as wastes can be controlled and contained).

Notwithstanding perception issues associated with factory and semi-factory farming, marginal analysis shows such approaches are likely to be economic madness – because if the international price of commodity milk powders rise to the extent that it is economic to turn milk from feedlots into powders, then the likes of North America (or even Australia) is likely to become the 'swing producer' as their marginal costs are significantly lower than New Zealand's due to the size and scale of their arable sectors.[12] [13]

Questionable economics notwithstanding, the question remains of what to do with all the liquid waste that has been successfully contained – for example, if catchments in New Zealand are already struggling at four or fewer cows per hectare then how will catchments cope with the likes of 80?[14] [15]

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12 However, a pastoral system in South America or the former Soviet Union is likely to be cheaper still.

13 Due to biofuel and other Government subsidies, the US has an enormous corn industry that can produce plentiful quantities of relatively low cost animal feed as a bi-product.

14 Figure based on Fonterra's 'state of the art' farms in China.

15 For example, 2,000 could be housed in a space of only 25 hectares – but assuming effluent can be sprayed on pasture equivalent to three cows per hectare that 25 hectare milking platform would require a 'spray platform' of 667 hectares.

This suggests that there is also likely to be economic as well as environmental constraints on milk production in New Zealand – that ultimately will make further production in New Zealand either uneconomic or undesirable (or both). However, until that time comes a great deal of unnecessary angst can be avoided – and if the LUDF is indicative – substantial monies made simply by understanding the difference between average cost and marginal cost and focusing on the latter.

It also suggests that rather than putting cows into buildings one is likely to be better off finding low-cost grazing land elsewhere in the world and replicating the long-run marginal cost curve there.

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