Investment decisions of dairy farmers in south-west Victoria under price and yield uncertainty

by
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Abstract

This paper uses real-options analysis to examine the investment and disinvestment decisions of dairy farmers in south-west Victoria when there is uncertainty in milk price and yield. By investment and disinvestment we mean purchase and sale of properties rather than investment in the capital stock of properties. Optimal entry and exit thresholds were calculated for four different sizes of dairy farms and compared to the results from a conventional approach. The model identified lower exit and higher entry thresholds than would be indicated by the conventional approach that ignores the uncertainty of prices and yields. Our empirical analysis illustrates how these decisions vary between different farm sizes even with a moderate degree of revenue volatility, a relatively small amount of sunk costs, and changes of other parameters. Our work provides better explanations for some important issues in dairy farm investment, in particular, the advantages that accrue to farmers by delaying decisions to enter or leave industries. The wider range of entry and exit thresholds helps explain the stickiness of adjustment of the dairy industry in the face of volatility of revenue and production.

Keywords: Dairy, entry and exit, real-options, uncertainty

1.Introduction

Dairy is Victoria's second largest agricultural industry and makes a vital contribution to the economy. Victorian dairy exports were valued at $1.85 billion in 2012-13. Victoria accounted for 84 per cent of the value of Australia's dairy exports, with dairy products exported to almost 100 countries (Ridley, 2013). Australian dairy is a relevant and successful industry. To continue its success the industry must demonstrate sustainable productivity. This means ensuring investment activities are undertaken with consideration of how they will address the challenges and changing operating environment facing the industry. One of the challenges facing the industry is understanding how farmers make investment decisions when facing uncertainty in milk revenue.

The south-west region of Victoria has high rainfall (810mm) by Australian standards and dairying is conducted under dryland conditions, with limited supplementary irrigation from farm dams, groundwater and adjoining waterways. The region produces 23 per cent of Australia's total milk production. Recently, the region's dairy sector has been experiencing economic difficulties with below average rainfall and high exchange rate. In 212-13 returns declined sharply, falling to their lowest level since 2006-07. At the moment many dairy farmers are earning insufficient income to pay for the operating costs of production, and hence are not recovering overhead costs or earning positive returns to capital (DEPI, Dairy Industry Farm Monitor Project, 2013).

In order to tackle the challenges facing the industry, it is useful to address the issues facing individual (representative) farms. Some public policy questions are related to overall industry performance that relies on industry level based research which concentrates on total factor productivity (TFP) measurements. As a result, the response to public policy questions might not address the problems individual farmers face. Performance of individual farms depends on factors such as the price they receive for their product, the weather and the cost and timing of significant investments, but not on average productivity across the industry.

Watson (2005) argued that TFP estimates of average productivity of the whole dairy industry are not a substitute for an economic analysis of individual investment decisions. So it is important for policy makers to look at the experience of the individual farm and, even more, to look at the farm's financial prospects in their investment decision to improve the total factor productivity of the farm and then the industry.

Investment is one of the drivers of productivity. Investment in dairy production is risky due to the irreversibility of initial capital investment as well as uncertainty in future milk revenue. This study aimed at providing an economic explanation for investment decisions of a representative dairy farm and the reason for the sluggish adjustment of the sector.

The traditional approach to investment decisions, given perfect information and no adjustment costs, is to invest when product price is above long-run average total cost. In a multi-period setting, that would be when net present value (NPV) is positive. Similarly an active firm should abandon farming if the price falls short of the variable cost. In practice, however, firms do not invest despite a positive NPV. The real-world investment practices often provide little support to static, deterministic approach (Dixit and Pindyck, 1994).

The development of the theory of financial options has opened a new perspective for understanding firm behaviour in making investment decisions. The real asset investment and disinvestment decision analysis was first applied by McDonald and Siegel (1985) and Brennan and Schwarz (1985) using financial option theory, commonly known as real option analysis. Dixit (1989; 1991) and Dixit and Pindyck (1994) formalised the application of real-options theory by considering irreversible investment under uncertainty. They demonstrate how the interaction between uncertainty about the future and sunk cost creates a zone of inaction where the wisest course of action is to wait until more information is gathered. Accordingly, scholars have drawn on real-options theory to emphasise that "if there is uncertainty about future payoffs, owners may be willing to accept low levels of performance with the hope that conditions will improve" (Gimeno et al., 1997)

There have been several applications of real option concepts to agricultural investment decisions. Luong and Tauer (2006) studied coffee growers' investment in Vietnam. Price and Wetzstein (1999) looked at investment in peach orchards in Georgia, United States. Schmit et al. (2009) analysed ethanol plant investment in the United States. A study by Seo et al. (2004) examined table grape farming in California. Seyoum and Chan (2013) analysed the investment decision of wine grape growers in north-west Victoria. For dairy investment decisions, Tauer (2006) investigated when farmers in the United States get in and out of dairy farming. Purvis et al. (1995) modelled the freestall housing investment as a real option problem and Engel and Hyde (2003) used real option methods to analyse the adoption of robotic milking systems.

We adopt a real-options modelling approach to take into account explicitly the impact of cost structures and revenue uncertainties on investment decision of dairy farmers in south-west Victoria.

The stochastic nature of milk revenue has important implications for investment decisions. While current farm revenues may be insufficient to pay variable production costs, it may still be rational for farmers to continue farming as the seasonal revenue may rise in the future. Exiting the current investment would incur loss of part or all of the initial investment and, more importantly, risk forsaking potentially high profits in the future.

In this paper we show that an economic analysis of investment, if ignoring the characteristics of irreversibility and uncertainty, could underestimate the economic value in waiting and provide misleading evidence for guiding industry policy to facilitate structural adjustment. In this study we address the following questions:

- Is waiting a rational option for farmers?
- What underpins the value in waiting?
- How significant is such value in waiting?
- What does it mean for policy development?

The real-options approach was applied to analyse the effects of volatile revenues, high sunk costs and prevailing hurdles to realising economies of scale on farm investment (entry) and disinvestment (exit) decisions. Four case studies covering small, medium, and large farms and the average farm for south-west Victoria were included to compare farm cost structures and implications for adjustment pressure and response.

The rest of the paper is divided into six sections. In section 2, we present the mathematics of the real-option model and specify the model for analysing investment in dairy farming. In section 3, we discuss the data used for modelling. In section 4, we present and discuss baseline results. Section 5 presents sensitivity tests on a selection of farm characteristics. Section 6 concludes the paper with a summary of key findings.

2. Model

The specification of the model is based on Dixit and Pindyck (1994) and Price and Wetzstein (1999). The Dixit and Pindyck model assumes only price uncertainty. Following the work of Hull (1997), Price and Wetzstein modelled both price and output uncertainty. As the result, revenue becomes a function of price and output and the correlation between them. Seyoum and Chan (2013) adopted this model to analyse wine grape vineyard investment decisions. In this paper both price, p, and yield, q, uncertainty in dairy production will be considered. The cost of production is assumed to be constant. This uncertainty may be represented by a geometric Brownian motion process:

$dp = \mu_p pdt + \sigma_p pdz_p$, and (1)

$dq = \mu_q qdt + \sigma_q qdz_q$, (2)

Where dp and dq represents the change in price per kilogram of milk solids and yield of milk solids, respectively, μ is the drift rate, σ is the standard deviation, and the subscript p and q denote parameters associated with price and yield, respectively. The increment of a Wiener process is dz , with $E(dz_p^2) = E(dz_q^2) = dt$, and $E(dz_{p,} dz_q) = \rho dt$, where ρ denotes the correlation coefficients between p and q .

Dixit and Pindyck (1994) assumed that farmers are risk neutral and maximise their expected net present value of investment. A further assumption is the log-normal distribution of $R = pq$, the product of price and quantity. The log-normal distribution has the theoretical desirable property of expected percentage revenue and associated variance being independent of the level of revenue. The stochastic process of revenue, R, is determined by the differential of the change in logarithm of R, $dr = d\ln(R)$, following Ito's lemma:

$$dr = \frac{\partial r}{\partial p} dp + \frac{\partial r}{\partial q} dq + \frac{1}{2}\frac{\partial^2 r}{\partial p \partial q} dpdq + \frac{1}{2}\frac{\partial^2 r}{\partial p^2} dp^2 + \frac{1}{2}\frac{\partial^2 r}{\partial q^2} dq^2 \quad (3)$$

Note that

$\partial r/\partial p = 1/p, \partial r/\partial q = 1/q, \partial^2 r/\partial p^2 = -1/p^2, \partial^2 r/\partial q^2 = -1/q^2, and\ \partial^2 r/\partial p \partial q = 0,$ equation (3) reduces to

$$dr = \frac{1}{p} dp + \frac{1}{q} dq - \frac{1}{2p^2} dp^2 - \frac{1}{2}\frac{1}{q^2} dq^2 \quad (4)$$

Equation (1) and (2) can be substituted for dp and dq , respectively, noting $(dt)(dz)$ is of order $(dt)^{3/2}$ and, in the limit, every term with dt raised to a power greater than one will go to zero faster than dt . This substitution yields

$$dr = (\mu_p + \mu_q - \frac{1}{2}\sigma_p^2 - \frac{1}{2}\sigma_q^2)dt + \sigma_p dz_p + \sigma_q dz_q \quad (5)$$

Thus, $r = \ln(R)$ follows a simple Brownian motion of general form $dr = \mu_r dt + \sigma_r dz_r$ implying dr over a time interval T is normally distributed with mean (μ_r)

$$(\mu_p + \mu_q - \frac{1}{2}\sigma_p^2 - \frac{1}{2}\sigma_q^2)T \quad (6)$$

and variance (σ_r^2)

$$(\sigma_p^2 + \sigma_q^2 + 2\rho\sigma_p\sigma_q)T \quad (7)$$

Applying Ito's lemma to $R = e^r$, the geometric Brownian motion for

$$dR = \mu_R Rdt + \sigma_r Rdz_R \quad (8)$$

Where, $\mu_R = \mu_r + \frac{1}{2}\sigma_r^2$

Based on a stochastic process of milk revenue the model is expressed algebraically as:

$$V_0(R) = BR^{\beta} \qquad (9)$$

$$V_1(R) = R_H/(\rho - \mu_R) - C/\rho + AR_H^{-\alpha} \qquad (10)$$

where $V_0(R)$ is the value of a new investment and, $V_1(R)$ the value of an existing investment.

At entry trigger point R_H, the value of a new investment (the value of option to invest) must be equal to the value of the existing investment minus the sunk cost (K). At exit trigger point R_L, the value of the option to abandon the farm is equal to the value of the existing investment minus the cost of abandonment (X). This is the value-matching condition. The smooth-pasting condition requires that the two value functions meet tangentially and these two equalities lead to a system of four equations:

$$R_H/(\rho - \mu_R) - C/\rho + AR_H^{-\alpha} - BR_H^{\beta} = K \qquad (11)$$

$$1/(\rho - \mu_R) - \alpha AR_H^{-\alpha-1} - \beta BR_H^{\beta-1} = 0 \qquad (12)$$

$$R_L/(\rho - \mu_R) - C/\rho + AR_L^{-\alpha} - BR_L^{\beta} = -X \qquad (13)$$

$$1/(\rho - \mu_R) - \alpha AR_L^{-\alpha-1} - \beta BR_L^{\beta-1} = 0 \text{, where} \qquad (14)$$

$$-\alpha = \frac{\sigma^2 - 2\mu_R - \left((\sigma^2 - 2\mu_R)^2 + 8\rho\sigma^2\right)^{1/2}}{2\sigma^2} < 0 \qquad (15)$$

$$\beta = \frac{\sigma^2 - 2\mu_R - \left((\sigma^2 - 2\mu_R)^2 + 8\rho\sigma^2\right)^{1/2}}{2\sigma^2} > 1 \qquad (16)$$

parameters α and β are the two roots of the quadratic equation (Dixit, 1991) and ρ the opportunity cost of capital (the firm discount rate). We use a risk-adjusted interest rate rather than risk-free rate appropriate under contingent valuation (Dixit and Pindyck (1994)). A and B are coefficients, along with R_H and R_L, to be determined.

To account properly for the fact that the exit option also includes the ability to re-enter, these four differential equations should be solved simultaneously. The above equations are nonlinear in the thresholds (R_H and R_L), and an analytical solution in closed form does not exist. The thresholds need to be solved numerically. This is done with the use of MATLAB software. These thresholds define the level of revenue at which the firm finds it optimal to enter, R_H, and optimal to abandon, R_L. At revenue between these limits, an idle firm does not invest and an active firm doesn't exit.

The traditional approach which ignores uncertainty is used as a comparison. Under this setting, the entry trigger is the variable cost plus the interest on the establishment cost (C+δ K), and the exit trigger is the variable cost minus the interest on exit cost (C-δ X). As both K and X tend to zero, both R_H and R_L tend to common limit C, thus the sunk costs are essential for hysteresis (inactivity).

3. Data and Parameter Estimates

Empirical application of the entry/exit model requires data on establishment cost, variable cost of production, opportunity cost of capital (discount rate), milk price, milk production, and number of cows. The data on establishment cost and variable costs were for 2012-13 financial year and were obtained from the Department of Environment and Primary Industries (Dairy Industry Farm Monitor Project, 2013). The opportunity cost of capital (for 10 years bond rate) was obtained from Reserve Bank of Australia. Dairy Australia provided the milk price and yield data.

Like other agricultural industries, the distribution of farm size in the dairy industry is heterogeneous. According to Dairy Australia (2013) the distribution of farm size in south-west Victoria consists of 18 per cent small farms (less than 150 cows), 42 per cent medium size (151-300 cows), 27 per cent large (301-500), and the remaining proportion include extra-large farms. In this analysis, four representative farm sizes were evaluated. The first refers to a small farm with 115 cows, the second refers to a medium farm with 211 cows, the third refers to a large farm with 376 cows and the last refers to the average of south-west Victoria, 369 cows.

Individual farmers have varied cost structures and may invest and disinvest at different levels of milk revenue as our later analysis demonstrates. Investment and disinvestment also depend upon expected revenue dynamics, which will be modelled identically across farms.

The establishment cost includes upfront capital costs for land, livestock, building and installing on-farm infrastructure, equipment and machinery etc. Most of these inputs, once put in place, cannot be relocated (unlike broadacre farms), or used on-site for other purposes in line with commodity price fluctuations, demand shift, weather and environmental influences on milk yield (table 1). For both cost components (table 1 and 2), unit cost estimates per kilogram of milk solids are generally lower for farms with a larger number of cows. The unit cost savings are attributable to economical use of feed and other key inputs, livestock and land.

Table 1: Establishment costs by farm size ($/kg MS) for 2012-13

Item	Small	Medium	Large	SW Average
Livestock	4.08	3.32	2.97	3.11
Feed	0.28	0.10	0.09	0.21
Other	0.27	0.00	0.60	0.15
Building	2.74	3.22	1.96	2.27
Land & leased land & associated water	24.75	20.96	18.68	12.89
Fixed plant and equipment	2.06	2.08	2.50	2.24
Total	34.18	29.69	26.79	25.38

Source: DEPI, Farm Monitor Project (2013)

Averaged estimates of variable costs by farm size are listed in table 2. Labour (inclusive of hired and family labour) and feed costs are a major part of the total variable cost. Expenditures related to feed such as fertiliser, hay and silage making, fodder purchases, grain concentrates and other feed related costs are included under this category. Expenses on animal health, calf rearing and Artificial Insemination (AI) and herd testing are categorised under herd cost. Expenses for shed power are listed under shed cost.

Depreciation is another key cost component of the variable cost. This cost was imputed for depreciable assets and included under other variable costs. Following Dixit and Pindyck (1994), it was assumed that the investment in milk production has an infinite life and therefore depreciable assets need re-investment to maintain the capital capacity. At the same time, milk yield rates (kg MS/cow) vary across different farm sizes: 362 for small, 496 for medium, 532 large and 505 for the average of south-west Victoria. Together, the unit cost and yield estimates suggest significant economies of size in milk production.

Table 2: Variable costs by farm size ($/kg MS) for 2012-13

Item	Small	Medium	Large	SW Average
Herd costs	0.26	0.21	0.25	0.24
Shed costs	0.20	0.21	0.21	0.21
Feed costs	2.22	2.54	2.64	2.60
Labour cost	2.75	1.52	1.08	1.40
Other costs	0.93	0.70	0.76	0.75
Total	6.36	5.18	4.93	5.21

Source: DEPI, Farm Monitor Project (2013)

Dairy farming involves considerable initial investment. However, for many dairy farmers a significant amount of initial investment can be recovered upon exit. Cows are liquid and land always has value. However, other establishment inputs such as fixed plant and equipment have little or no resale value (the salvage rates for these inputs were estimated at between zero and 20 per cent of their market costs).

It was assumed that upon farm closure, 10 per cent of the building costs and 20 per cent of fixed plant and equipment can be recovered through the sale of such assets. Land and livestock can be sold at market prices. The estimates of salvaged asset values are summarised in table 3.

Table 3: Salvage asset value by farm size ($/kg MS)

Item	Small	Medium	Large	SW Average
Total land value (100%)	15.53	18.22	11.13	12.90
Building (10%)	0.27	0.32	0.20	0.20
Plant &equipment (20%)	0.41	0.42	0.50	0.45
Livestock (100%)	4.08	3.32	2.97	3.10
Total salvage value	20.29	22.28	14.80	16.65

Source: Authors' estimation based on cost data as presented in Table 1 and expert advice on salvage rate

The price used in the model is the average annual price for manufactured milk being paid to farmers which has been recorded annually from 1989 to 2011 by Dairy Australia. The milk yield per cow is also recorded for the same period.

The real-options analysis requires that the stochastic variables of price and yield each follow a random walk. This was confirmed by unit root tests as follows.

Annual kilograms milk solids yield per-cow q and per-kilograms of milk solids price, p, were both modelled in the form of:

$$D_{it} = \lambda D_{it-1} + u_{it} \qquad (17)$$

where λ=1, D_{it} alternately represents the price and quantity at time t, and u_{it} is independent error with zero mean and constant variance σ_u^2. Subtracting D_{it} from both sides of equation (17) yields:

$$D_{it} - D_{it-1} = \lambda D_{it-1} - D_{it-1} + u_{it} \quad (16)$$

$$\Delta D_{it} = \gamma D_{it-1} + u_{it} \quad (17)$$

where $\gamma = (\lambda - 1)$.

Under the null hypothesis that the coefficient $\gamma = 0$ (i.e. $\lambda = 1$), the formulation is consistent with a random walk model. The hypothesis was tested for three variants of the random walk model: (i) no constant and no trend; (ii) with constant and no trend; and (iii) with constant and trend:

$$\Delta D_{it} = \gamma D_{it-1} + u_{it} \quad \text{(i)}$$

$$\Delta D_{it} = \alpha_{it} + \gamma D_{it-1} + u_{it} \quad \text{(ii)}$$

$$\Delta D_{it} = \alpha_{it} + \gamma D_{it-1} + \kappa t + u_{it}. \quad \text{(iii)}$$

Using annual price data from 1989 to 2011, the Dickey–Fuller unit root test did not reject at 1 per cent statistical significance the null hypothesis that the price series follows a random walk for all three variant models. Similar test results were achieved for the yield series, the null hypothesis was not rejected for all three random walk equations. Given these unit root test results, it was considered reasonable to assume that both the price and the yield series follow a random walk.

The statistical randomness in prices and yields means that trend extrapolation could be a treacherous method for predicting the future. As a case in point, although milk prices have in the past few years retreated considerably from their previous peak levels, it remains equally likely—in a statistical sense—that prices may continue to fall, or may soon bottom out and start to rise. A contextual understanding of local and global market forces shaping the outlook for the sector can help substantiate the projection of future revenue levels.

The estimates of the drift and variance for the price and yield series were derived using the method outlined by Hull (1997). Table 4 shows the baseline parameter values of the real-options model.

Table 4: Baseline model parameters

Parameter	Description	Estimate
μ_p	Price drift rate	0.032121
σ_p^2	Price variance	0.018772
μ_q	Yield drift rate	0.024126
σ_q^2	Yield variance	0.012142
ρ_{pq}	Price and yield correlation	-0.11189
$\sigma_r^2 = \sigma_q^2 + \sigma_p^2 + 2\rho_{pq} * \sigma_q \sigma_p$	Revenue variance	0.027536
$\mu_R = \mu_r + \frac{1}{2}\sigma_r^2$	Revenue drift rate	0.054558
δ	Opportunity cost of capital	0.08

4. Results and discussion

Baseline results reveal significant inertia in the adjustment of farm businesses to profit pressures. Table 5 presents estimates of the revenue thresholds for entry and exit under the conventional and real-options approaches.

Table 5: Revenue thresholds for entry and exit by farm size

	Small	Medium	Large	SW
Conventional approach:				
Entry ($/kg MS)	9.10	7.55	7.07	7.26
Exit ($/kg MS)	8.00	6.98	6.10	6.55
Real-options approach:				
Entry ($/kg MS)	11.01	9.04	8.59	8.72
Exit ($/kg MS)	5.28	4.95	3.95	4.49

Source: Authors' estimation based on model parameters from Table 4

As a starting point for comparison, the conventional thresholds indicate the entry and exit criteria based on a static, myopic assessment of investment value. The conventional criteria would justify exit when revenue falls below the breakeven point defined by total operating cost, and would justify new investment and entry when revenue is greater than the annualised establishment cost.

Between the entry and exit thresholds is an indeterminate revenue range—a zone of hysteresis or inactivity—where investment incentives are muted. This indeterminacy reflects the role of sunk costs in discouraging exit of an operating business from its existing investment that no longer has the prospect of yielding the required return on capital.

By accounting for price and yield uncertainties in a real-options context, the modelling yielded higher estimates of the entry threshold and lower estimates of the exit threshold than the conventional approach. This effect of increased investment hysteresis depends on the interaction between sunk cost and uncertainty. If there were no sunk costs, there would be no hysteresis; with sunk costs, uncertainty becomes an important factor in the decision to invest or disinvest. When farmers are operating in the zone of hysteresis, both the willingness for further investment and the residual funding to undertake additional investment are at their lowest level. By analogy, willingness or unwillingness to invest in new properties implies willingness (or unwillingness) to invest in capital equipment on farming. Capital investment is the basis of technical improvements that lead to greater productivity.

The significance of a strategic perspective on investment, provided by this analysis, is most apparent in the small-farm model. The real options approach rectified the omission of a strategic investment value in conventional calculation, yielding a more rigorous estimate of the exit threshold at $5.28/kg MS for small farms. This represents a 34 per cent downward adjustment from the conventional breakeven point ($8.00/kg MS) on account of the value in waiting to exit later. Many small farms may operate at a loss and yet could prefer to stay in business with the expectation that the future would be better. However, exit is rational if their revenue falls below the critical level where the loss is too great to offset against the value in waiting.

Likewise for medium-sized farms, the strategic exit threshold that is estimated at 29 per cent below the conventional breakeven point highlights the economic rationale for enduring operating losses. Large farms would show even less inclination to exit as they were earning a positive return ($5.15) over total operating cost.

Across all farm-size groups, the strategic entry threshold was estimated to be much higher than the conventional threshold for new investment. This amounts to increasing the required return on capital from an assumed rate of 8 per cent to roughly 14 per cent. Consequently, the conventional approach understates the financial hurdle for attracting new investment to dairy farming in south-west Victoria.

5. Sensitivity Analysis

The analysis so far assumes that any variation in net revenue is from milk price and yield change since the cost of production per kilogram milk solid is held fixed. However, since some variations in cost of production have occurred on Victorian dairy farms, we analysed the sensitivity of investment thresholds to changes in total variable cost and liquidation value. The analysis was conducted primarily for small farms because they are the most vulnerable to exit pressures (as confirmed by baseline modelling results).

According to the cost estimates shown in table 2, the variable cost of small dairy farms is 23 per cent more than the medium farms. We conducted a sensitivity analysis assuming that if small-sized farms were able to catch up with medium-sized farms in efficiency terms and reduce their variable cost to that of medium farms, the exit trigger would lower by 20 per cent and the entry trigger would lower by 15 per cent. At the same time if variable cost increases by 20 per cent the exit and entry trigger increases by 17 and 13 per cent, respectively.

The dairy industry in south-west Victoria is dominated by medium-size farms so the performance of those farms is crucial for the industry. So we examined the impact of a change in variable cost from the base scenario on their investment decision. For example if medium-sized farms are able to reduce their variable costs by 10 per cent both the exit and entry trigger are reduced by approximately 10 per cent. At the same time if variable cost increases by 10 per cent, the exit trigger increases by 10 per cent and the entry trigger increases by 12 per cent. For the average south-west dairy farm the reduction of variable cost by 10 per cent lowers the exit trigger by 9.1 per cent and reduces the entry trigger by 7.4 per cent.

The overall results show that a small change in variable cost will influence the exit decision of dairy farmers. This implies that, any policy which leads to lower variable cost will encourage dairy farmers to enter the industry and those inclined to exit to stay on the farm and continue producing.

The analysis so far assumes farmers can recover their land and livestock value in full and a fraction of other initial investment costs upon exit. If almost all investment can be recovered, then the entry price falls and the exit price increases. That is because there is little capital loss to exit and re-enter farming. There is no lost capital to repeatedly exit and enter the industry, so exit will occur whenever the milk price falls below the total cost of production, and entry will occur whenever the milk price moves above the total cost of production. However, it has been noticed in the past that land values in south-west Victoria have been sensitive to economic conditions. Hence, land and livestock are not as liquid as assumed in the initial analysis. Hence, we conducted a sensitivity analysis with liquidation costs at eighty per cent for land and sixty per cent for livestock for all farm sizes. Lower salvage values upon exit lowers the exit trigger further by 10 per cent compared to the base model and increases the entry trigger by 1 per cent for a small farm. This exit value ($4.77) is much lower than the variable cost of production ($6.36) for small farms, which produces operating losses, but selling the farm produces less revenue, and there is the chance that prices might get better if the farmer stays in the business.

Lowering the salvage value for medium-sized farms, lowers the exit trigger by 13 per cent, for large farms 9 per cent and for the average south-west dairy farm 11 per cent. The entry trigger increases by 2.4 per cent for medium farms, 0.1 per cent for large farms and 1 per cent for the average south-west dairy farm.

It should be noted that these findings might not fit the experiences and circumstances of particular farmers because they were based on modelling of averaged price and yield behaviour as well as averaged cost structures of dairy production. There may be other financial and non-financial factors impacting entry and exit decisions, and exit causes have recently been estimated. Older farmers simply are at the age to retire and have difficulties in learning a new skill to start a different business. In addition, some farms might have been a family business for generations and hard to leave given the availability of off-farm employment, and other factors. Having said that, despite its narrow focus on economic rationality the present model contributes to identifying the strong influence uncertainty has on the slow pace of sectoral adjustment.

6. Conclusion

This study set out to investigate the sluggish adjustment of dairy farms in south-west Victoria in response to persistent profit pressures in recent years. Through the lens of real options analysis, the study delved into the incentive constraints behind farmers' decisions to exit or stay in business. A series of research questions were posed and structured—as laid out at the beginning of this paper—to focus on the dominant economic drivers of farm investment and disinvestment. These questions were addressed using modelling evidence of investment behaviour of dairy farmers with farms of different sizes.

Key findings in relation to these research questions are summarised below:

Is waiting a rational option for farmers?

The modelling identified wide tolerance for low revenues where farmers could find it worthwhile to stay in business, despite not earning an attractive rate of return on their capital investment or even not earning enough to cover operating costs. As of 2012-13, small and medium-sized farms were on average operating at a loss, but the situation was worse for small farms. For medium-sized farms their revenues remained greater than the exit thresholds that were estimated to account for the possibility of future revenue improvement.

In other words, many dairy farms were probably not yet past the tipping point for exit in the reference year—although the likelihood of exit depends on the milk price: if it continued to fall or not. There was an economic value in waiting (or equivalently, an opportunity cost for not doing so), and that value provided the economic rationale for enduring operating losses over an extended period. However, exit will be a rational choice if their operating losses become too great to offset the value in waiting.

What underpins the value in waiting?

Significant sunk costs and volatile seasonal revenues for dairy farming underpin the value in waiting to enter or exit. For existing farms, both factors contribute to investment hysteresis and muted adjustment response to mounting profit pressures. The sunk costs incurred gave them an incumbency advantage to hang on. The volatile revenues gave them hope for a better future.

For new investment, initial capital requirements represent a high price for entering the sector to start farming. Revenue volatility increases the propensity to enter at a later time when the revenue outlook becomes sufficiently attractive.

How significant is such a value in waiting?

The strategic value in waiting was found to be significant for both options of entry and exit across dairy farms of different sizes. That value was enough to lower the revenue threshold for exit to over 30 per cent below the conventional breakeven point. On the other hand, it increased the rate-of-return hurdle for new investment to over 17 per cent compared with the conventional criterion of 8 per cent.

What does it mean for policy development?

A strategic options value in existing dairy farm operations affects the incentive for farmers to change and adjust and also the timing for adoption of new technology. This needs to be taken into account when designing policy to facilitate industry restructuring and transformation. The conventional approach is deficient in capturing important value drivers of investment. It understates the extent of inertia with capital adjustment and the endurance of businesses facing declining profitability. Real-options analysis rectifies this deficiency by highlighting the rationality of ‘wait-it-out’ as a strategic response to profit pressures. It points to a legitimate role for government intervention in easing the adjustment process in order to expedite the realisation of efficiency gains from industry restructuring.

7. References

Brennan, M. and Schwartz, E. (1985) Evaluating Natural Resource Investments, *Journal of Business,* 58, 135–157.

Dairy Australia (2013) (various years' statistics), Dairy Compendium, Melbourne, Victoria.

DEPI (2013) Dairy Industry Farm Monitor Project, Annual Report 2012-13, Department of Environment and Primary Industries, Melbourne, Victoria.

Dixit, A. K. (1989) Entry and Exit Decisions under Uncertainty, *Journal of Political Economy*, 97, 451–471.

Dixit, A. K. (1991) Analytical Approximations in Models of Hysteresis, *The Review of Economic Studies,* 58,141-151.

Dixit, A. K and Pindyck, R. S. (1994) *Investment under Uncertainty*, Princeton NJ: Princeton University Press.

Engel, P.D. and Hyde, J. (2003) A Real Options Analysis of Automatic Milking Systems, *Agricultural and Resource Economics Review* 32(2): 282-294.

Gimeno, J., Folta, T.B., Cooper, A.C., Woo, C.Y. (1997) Survival of the Fittest? Entrepreneurial Human Capital and the Persistence of Underperforming Firms, *Administrative Science Quarterly*, 42, 750-783.

Hull, J. C. (1997) *Options, Futures, and other Derivatives*, Englewood Cliffs NJ: Prentice-Hall.

Luong, Q. V. and Tauer, L. W. (2006) A Real Options Analysis of Coffee Planting in Vietnam, *Agricultural Economics*, 35, 49–57.

McDonald, R. and Siegel, D. (1985) Investment and the Valuation of Firms when there is an Option to Shut Down, *International Economic Review*, 26, 331–349.

Marshall, A. (1920) *Principles of Economics: An Introductory Volume*. Macmillian: London.

Price, J. T. and Wetzstein, M. E. (1999) Irreversible Investment Decisions in Perennial Crops with Yield and Price Uncertainty, *Journal of Agricultural and Resource Economics*, 24, 173–185.

Purvis, A., Boggess, W.G., Moss,C.B. and Holt,J. (1995) Technology Adoption under Irreversibility and Uncertainty, *American Journal of Agricultural Economics* 77(3):541-551.

Ridley, L. (2013) *Victorian Food and Fibre Export Performance 2012-13*, Department of Primary Industries, Melbourne, Victoria.

Schmit, T. M., Luo, J. and Tauer, L. W. (2009) Ethanol Plant Investment using Net Present Value and Real Option Analysis, *Biomass & Bioenergy*, 33, 1442–1451.

Seyoum, E and Chan, C (2013) What is Making Vineyard Investment in Northwest Victoria, Australia, Slow to Adjust? *Journal of Wine Economics,* 8, 83–102.

Seo, S., Salin, V., Mitchell, P. and Leatham, D. (2004) *Effect of Revenue Insurance on Entry and Exit Decisions in Table Grape Production: a Real Option Approach*, Paper Presented at American Agricultural Economics Association Meeting, Denver, Colorado, USA, August 1–4.

Tauer, L. W. (2006) When to Get in and Out of Dairy Farming: Real Option Analysis. *Agricultural and Resource Economics Review,* 35, 339–347.

Watson, A. (2005) Productivity and the Dairy Industry, *Australasian Agribusiness Review, 13, Paper 18.*

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