Threshold Effects in Transition to Organic Dairy Production

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Abstract

Despite dramatic increases in retail demand for organic milk and steadily increasing organic milk prices over the past 15 years, transition from conventional to organic dairy production has been unsteady. In some years supply has not met demand, leading to shortages of organic milk, and in other years organic dairy processors have been forced to sell organic milk in the conventional market. Following the theory of investment under uncertainty we estimate the organic transition response of dairy producers to feed and milk prices while allowing for distinct regimes of investment, disinvestment, and inaction. Using a threshold estimation technique developed for panel data we estimate the threshold values that define these regimes. We find some support for a discontinuity in the organic transition response, though a double threshold model, including a sluggish transition regime, is rejected.

Key words: organic farming, threshold model, supply hysteresis, dairy production

Demand for organic dairy products has increased dramatically in recent years. Though organic milk accounted for only 1.5% of total fluid milk products sold in the U.S. in 2006, by 2012 it had surpassed 4.2% of all milk sold. Production has similarly increased. From 2000 to 2008, the number of certified organic milk cows increased from 38,000 nationwide to 250,000 (USDA-ERS, 2010; Figure 1). However, the rate of transition from conventional to organic production in the dairy sector has not been steady over this period. On a national level, the annual net increase in the number of organic dairy cows has been anywhere from less than 1% to 50%. Moreover, supply has not always matched demand, with organic producers forced to sell in the conventional market in some years and shortages of organic milk in others (Greene et al., 2009). This paper addresses the question of whether or not the organic certification of dairy cows in the U.S. exhibits hysteresis consistent with the theory of investment under uncertainty and a significant option value associated with delayed organic transition.

«PLACE FIGURE 1 HERE»

The transition from conventional to organic dairy production is not an easy one. Conventional dairy producers intending to achieve organic certification of their herd must complete a transition period of one year in which cows are managed organically but milk cannot be marketed as organic. All feed consumed by transitioning cows must be certified organic or produced on the transitioning farm from land in the final year of transition (USDA-AMS, 2013a). An organically managed dairy herd usually produces less milk per cow than a conventionally managed herd, and organic dairy feed is often much more expensive than conventional feed, making the transition a costly investment. Moreover, there is considerable uncertainty involved in organic dairy production. Though organic milk prices are generally more stable than conventional milk prices, the volatility of organic grain and forage prices combined with weather risk makes returns to organic dairy quite variable.

An investment in an asset with uncertain returns and at least partial irreversibility (i.e. sunk costs) has an option value (Dixit and Pindyck, 1994). That is, the option to delay investment and wait for additional information has a positive value, even if the expected present value of the investment is greater than the present value of inaction. In agricultural production, as well as in other investment decision problems, this option value can lead to hysteresis, or a delayed response to changing market conditions. In the context of organic dairy production, hysteresis caused by significant option values could be an explanation for the uneven rates of organic transition over the past 15 years, despite steady growth in consumer demand for organic dairy products.

Though the scale of the option value of an investment depends on the size of the unrecoverable investment cost and the riskiness of the investment, it has been shown that in agricultural applications the option value can be a significant barrier to technology adoption or land-use change. Purvis et al. (1995) found that uncertainty in dairy returns caused the rate of returned required to trigger investment in technology improvements to be more than double the trigger rate in a NPV formulation of the decision problem. Tauer (2004) found that the price of milk at which dairy farmers optimally exit the industry is significantly lower than the variable cost of milk production and the price at which market entry is optimal is substantially higher than the variable cost of milk production. Tauer (2004) found that there is a large range of prices for which neither investment nor disinvestment is optimal and that this range is larger for smaller farms. That is, in both cases, the option value of delaying investment is found to cause production hysteresis.

Following the theoretical framework of investment under uncertainty (Dixit and Pindyck, 1994; Abel and Eberly, 1994), this study empirically estimates the supply response (i.e. transition) of organic dairy cows to organic and conventional milk and feed prices. Explicit allowance is made for distinct investment regimes, and investment thresholds are estimated in terms of comparative organic and conventional dairy profitability. The threshold values are of particular interest because an accurate estimation will help predict future growth (or contraction) of domestic organic dairy production. Though Kuminoff and Wossink (2010) previously investigated the option value of waiting to convert conventional cropland to organic management, this study is the first to apply threshold estimation procedures to organic agricultural investment.

In addition to presenting a novel application of threshold estimation methods to organic dairy transition, this paper provides a valuable contribution to the understanding of the supply response of organic dairy production during a time of highly volatile commodity prices. Dramatic increases in both conventional and organic grain and forage prices in recent years are sure to alter the landscape of organic farm production in the U.S., though the ways in which high commodity prices affect organic certification rates are unclear. The impact of future price fluctuations, due to extreme weather, increased foreign production of organic commodities or changes in demand for organic foods will be more easily understood with a better understanding of the hysteresis present in investment in organic certification.

The paper continues with an explanation of the theoretical framework of investment under uncertainty and supply hysteresis needed to motivate the empirical analysis. The next section provides an explanation and discussion of the econometric model used to identify investment thresholds and estimate transition response within each regime. This is followed by discussion of the data and model specification and presentation of the model results. The paper concludes with a discussion of the implications of the findings.

Conceptual Framework

Consider a conventional dairy farm manager who faces a decision of whether to manage the farm using organic or conventional methods. If organic management is chosen and the farm successfully navigates the organic transition period, the dairy herd can be certified as organic and the milk produced can be sold at higher prices than conventional milk (McBride and Greene, 2009). If a conventional dairy farm decides to initiate organic transition, the farm incurs transition costs, I. These costs may include the revenue lost due to a decrease in milk production during transition, the cost of learning organic dairy management techniques, and the cost of making changes to the farm (e.g. increasing pasture area) necessary to satisfy organic regulations. Though there could be some salvage value associated with improved pasture, and some lasting value may be associated with the knowledge acquired in learning about organic management techniques, these costs are at least in part irreversible. It is important to note that these transition costs will vary across specific farms and different regions of the country. For example, it may be less costly for pasture based dairies in the northeast and upper Midwest to transition to organic production than confinement operations that have limited pasture land and a heavy reliance on purchased inputs.

It is also the case that individual dairy farms (both conventional and organic) may use different management techniques and as a result have different levels of production per cow, ration formulations, and land requirements. However, for this simplified theoretical model these differences are unimportant and we need only assume that organic and conventional dairy operations generate returns to management. We do not assume that these returns are independent processes but only that they are observable. Also, let us ignore the role of pasture and cropland in the provision of feed to a dairy herd and assume that all farms have access to sufficient pasture to satisfy National Organic Program (NOP) and can thus feasibly use either production system. . The decision to undergo organic transition can then be simplified to a maximization of discounted present value of the dairy operation.

Let the value of the dairy operation be denoted by $V(\pi_c(t),\pi_o(t),x)$ where $\pi_c(t)$ and $\pi_o(t)$ are profits at time t to the conventional and organic dairy systems respectively and $x \in [c,o]$ is the state variable that denotes whether the production system is conventional or organic. The dairy manager's problem can be written as:

(1)

$$V(\pi_c(t),\pi_o(t),x) = max\left\{\pi_x(t)dt + e^{-rdt}EV(\pi_c(t+dt),\pi_o(t+dt),x), V(\pi_c(t),\pi_o(t),-x) - I_{-x}\right\}$$

where π_x is the current profits achieved by state x, r is the discount rate, E is the expectation operator, and I_{-x} denotes the investment costs required to switch from state x to state $-x$. Suppose the current state of the dairy farm is conventional management. Since the conventional dairy farmer is always free to initiate transition to organic management, the value of the conventional dairy farm is the maximum of the value of continued conventional operations and the value of organic operations net of the transition cost, I_o[1]. The value of continued conventional operations is comprised of the flow of profits to the conventional dairy, $\pi_c(t)dt$, as well as the discounted expected future value of the farm, $e^{-rdt}EV(\pi_c(t+dt),\pi_o(t+dt),c)$. This second term is a function of both conventional and organic profits because if the conventional dairy decides not to transition at time t, it retains the option to transition in a later period. Likewise, the value of the organic dairy, $V(\pi_c(t), \pi_o(t), o)$, is a function of profits to both systems, because the organic dairy is always free to abandon organic management and revert to a conventional system. We assume the abandonment of organic production is costless.

The real options theory outlined in Dixit and Pindyck (1994) explains that the option to transition to an alternative production system, along with transition costs and uncertainty in the return process, creates a range of conditions for which inaction is optimal regardless of the current production system. The inaction regime is bounded by an investment (i.e. organic transition) regime and disinvestment (i.e. organic abandonment) regime. To see this, let us assume that returns to both the organic and conventional systems follow independent processes of Geometric Brownian Motion of the form:

$$d\pi_c = \alpha_c \pi_c dt + \sigma_c \pi_c dz_c \tag{2}$$

$$d\pi_o = \alpha_o \pi_o dt + \sigma_o \pi_o dz_o \tag{3}$$

where α_i and σ_i are the drift and volatility parameters respectively for dairy production system i. The term dz_i is an increment of the Wiener process. Using Ito's Lemma, we can derive equations that characterize a solution to the decision problem in equation (1). Within the regime of inaction, in which the current production system is continued into the following period, the value function for each system must satisfy the equation:

$$\begin{aligned} rV(\pi_c, \pi_o, x) = \pi_x + \sum_x \alpha_x \pi_x \frac{\partial V(\pi_c, \pi_o, x)}{\partial \pi_x} + \sum_x \frac{1}{2}\sigma_x^2 \pi_x^2 \frac{\partial^2 V(\pi_c, \pi_o, x)}{\partial \pi_x^2} \\ + \rho \sigma_c \sigma_o \pi_c \pi_o \frac{\partial^2 V(\pi_c, \pi_o, x)}{\partial \pi_c \partial \pi_o} \end{aligned} \tag{4}$$

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[1] The time dimension of the organic transition (i.e. 1 year transition period) is not accounted for in this model as the transition from one system to the next is treated as instantaneous. However, the costs and revenue reductions incurred during the 1 year organic transition are included in I.

This "return equilibrium" equation states that the return on an investment in the amount of the farm value when in system x (left hand side) must be equal to the returns from the optimal operation of system x (right hand side). An inequality in (4) would imply that gains could be made by transitioning from system x to the alternative system $-x$.

There also must be a"value-matching condition" which says that at the boundary between regimes the value of the option must be equal to the value of exercising the option. Given that the transition from a conventional system to an organic system requires transition cost I_o, the boundary between inaction and investment in organic transition the value-matching condition will be:

$$(5) \qquad V^*(\pi_c, \pi_o, c) = V^*(\pi_c, \pi_o, o) - I_o$$

However, because abandonment of organic production is costless, at the boundary between the organic abandonment regime and the inaction regime, the value matching condition will be:

$$(6) \qquad V^*(\pi_c, \pi_o, o) = V^*(\pi_c, \pi_o, c) - I_c = V^*(\pi_c, \pi_o, c)$$

Finally, the "smooth-pasting conditions" which requires continuity of value function slopes at the regime boundaries:

$$(7) \qquad \frac{\partial V(\pi_c, \pi_o, c)}{\partial \pi_x} = \frac{\partial V(\pi_c, \pi_o, o)}{\partial \pi_{-x}} \qquad \text{for } x = c, o$$

This system of equations characterizes the solution to the dairy manager's maximization problem in equation (1) but it cannot be solved analytically for an application that is this complex. This conceptual model helps to illustrate how the relationship between organic and conventional dairy profits at time t will define the different regimes of investment in organic production. Letting $\rho_t(\pi_{ot}, \pi_{ct})$ denote the profitability of the organic system relative to the conventional system such that $\frac{\partial \rho_t(\pi_{ot}, \pi_{ct})}{\partial \pi_{ot}} > 0$ and $\frac{\partial \rho_t(\pi_{ot}, \pi_{ct})}{\partial \pi_{ct}} < 0$, there will be a threshold value of ρ_t^* below which $V^*(\pi_c, \pi_o, c) > V^*(\pi_c, \pi_o, o)$, and a manager of an organic dairy will revert to conventional management. There will be a second threshold value ρ_t^{**} above which $V^*(\pi_c, \pi_o, c) < V^*(\pi_c, \pi_o, o) - I$ and the conventional dairy manager will initiate organic transition. For $\rho_t^* < \rho_t < \rho_t^{**}$, equation (4) will hold and the manager's optimal decision will be to maintain the current system. In the empirical sections that follow the procedure for estimating the values of ρ_t^* and ρ_t^{**} will be discussed.

Econometric Model

There have been several studies that use threshold estimation techniques to estimate varying agricultural investment response within distinct regimes. Hinrichs et al. (2008) use an ordered probit model to estimate investment behavior within different revenue regimes in the German hog sector. Richards and Green (2003) use a similar model to analyze the hysteresis in California wine grape variety selection. Both studies explicitly define regimes of investment, disinvestment, and inaction and then separate their samples accordingly before testing for significance of the chosen thresholds and estimating investment response within each regime. Alternatively, the threshold estimation procedure developed by Hansen (1999, 2000) and used by Boetel et al. (2007) and Serra et al. (2009) estimates the threshold levels directly and tests their significance using a bootstrap method. In this study the threshold estimation procedures developed for balanced panel data by Hansen (1999) are used to estimate the rigidity of investment in certified organic dairy cows.

In general the three regime threshold model (i.e. investment, disinvestment, and inaction) can be written as:

$$(8) \qquad y_{it} = \mu_i + \boldsymbol{\Gamma}' \boldsymbol{x}_{it} + \beta_1 z_{it} I(\rho^H < \rho_{it}) + \beta_2 z_{it} I(\rho^L > \rho_{it}) + \beta_3 z_{it} I(\rho^L \leq \rho_{it} \leq \rho^H) + \varepsilon_{it}$$

Where y_{it} is the level of investment for cross-sectional unit i at time t, μ_i is the individual-level fixed effect, bfx_{it} is a vector of regime independent explanatory variables, and z_{it} is a regime dependent explanatory variable. Coefficient estimates for regime independent and dependent variables are denoted by $\boldsymbol{\Gamma}$ and β respectively. $I(.)$ is an indicator function, ρ^H

and ρ^L are the upper and lower thresholds respectively, and ρ_{it} is the value of the threshold variable for unit i at time t, which can also be included in the vector of explanatory variables bfx_{it} or itself be the regime dependent variable z_{it}. The model is estimated with OLS following the fixed-effects transformation of panel data, and the thresholds are chosen by grid search such that they minimize the sum of squared errors. In practice the possible threshold values are limited to the set of unique values of the threshold variable in the sample.

It may also be the case that there is only one threshold, creating two distinct investment regimes. Equation (8) then becomes:

$$(9) \quad y_{it} = \mu_i + \mathbf{\Gamma}'\boldsymbol{x}_{it} + \beta_1 z_{it} I(\rho < \rho_{it}) + \beta_2 z_{it} I(\rho \geq \rho_{it}) + \varepsilon_{it}$$

where ρ is the single threshold value. In this model, the test for the significance of the threshold ρ is simply the test of the null hypothesis:

$$(10) \quad H_0 : \beta_1 = \beta_2$$

When a second threshold is added to the model, as in equation (8), its significance is tested by holding the first threshold constant and testing the hypothesis that the coefficient estimates that are dependent on the second threshold are significantly different:

$$(11) \quad H_0 : \beta_2 = \beta_3$$

Additional thresholds can be added, with the model significance tested in the same way, but this study focuses on the single and double threshold models. Of course, with no thresholds, the model becomes a basic linear model of the form:

$$(12) \quad y_{it} = \mu_i + \boldsymbol{\beta}'\boldsymbol{x}_{it} + \varepsilon_{it}$$

As explained in Hansen (1999), the significance of each threshold is tested using a likelihood ratio test. However, under the null hypothesis in (11), no threshold is identified and the distribution of the resulting F-statistic is non-standard, precluding the calculation of critical values. Hansen (1996, 1999) therefore suggests using a bootstrap procedure to obtain asymptotically valid critical values. The bootstrap method treats the regressors and threshold variable as constant, then draws repeated samples with replacement from the regression residuals, grouped by individual. Using these errors, a bootstrap sample is created and the models under the null (e.g. equation (12)) and alternative (e.g. equation (9)) hypotheses are compared.

Data and Model Specification

To estimate the organic dairy supply response to organic and conventional market conditions we need a measure of investment in organic dairy production, data describing the relative profitability of the two production systems, and information to account for other contextual issues or exogenous shocks that may affect the rate of transition. This study uses publically available panel data on the number of certified organic dairy cows in each state from 2000 to 2008 to represent investment in organic dairy production (USDA-ERS, 2010; Figure 1). The model's dependent variable is the year over year change in certified organic dairy cows for each state. Over this time period, the number of organic cows nationwide increased substantially, yet there are five states that have no cows certified in any year. There are also 17 states in which no cows were certified as organic as of 2005. Because these states have no more than 2 years of differenced data, they do not provide a long enough series to be useful in the estimation of transition thresholds, and they are left out of the sample . Once these states are removed, the sample consists of a balanced panel of 27 states and nine years (Figure 2). Presumably, the addition of data for years 2009-2011 will allow the inclusion of at least some states that are excluded from the present analysis. Summary statistics are presented in Table 1.

It is important to note that these data describe the aggregate number of certified organic cows in each state. An increase from year to year reflects a net increase in the state and it is likely that in some years individual farms may decrease the size of their organic herd or drop organic certification altogether without a net decrease being recorded for their state as a whole. Because different farms (within and across states) have different cost structures, productivity levels, and risk attitudes, we would not expect all farms in a given state to exhibit an identical transition response to changes in relative conventional and organic profitability. Farm-level financial and production data over time would allow for the control of the individual fixed effect and a more accurate modeling of the transition decision as described in section 2. However, these data are not available and we must attempt to identify investment response at the state-level. Fortunately, the feed costs and output prices faced by dairy producers are similar enough that we can reasonably expect hysteresis to be observable in aggregate data, though perhaps as a range of "slowed" investment, rather than a range of zero investment. Boetel et al. (2007) argues that if thresholds are detectable in aggregate data then we would certainly expect significant thresholds at the individual level.

«PLACE FIGURE 2 HERE»

The explanatory variable of primary interest is a ratio of the profitability of organic to conventional dairy production. We use a ratio of profitability measures on a per cow basis, as this most accurately captures the profit maximizing decision that a dairy manager makes. There are two potential candidates for measures of dairy farm profitability. Though a milk-feed price ratio (MF) has long been used as a proxy for dairy profitability, in recent years income over feed cost (IOFC) has become a more widely used measure (Wolf, 2010). However, IOFC requires more information than the MF to calculate, notably the production per cow and assumptions regarding feed efficiency, or the efficiency with which a cow can produce milk from feed. As data on organic dairy production by state is limited and some additional assumptions are required to calculate state-level organic IOFC, this study estimates the threshold model separately using MF and IOFC.

«PLACE TABLE 1 HERE»

For the calculations of conventional MF and IOFC, milk price is the "mailbox price" published monthly by USDA-AMS for a selection of dairy producing states and regions. Feed cost is the 16% protein dairy ration price published for select states by USDA-NASS. This ration is composed of 51% corn, 41% alfalfa, and 8% soybean and is widely used as a representative ration for measuring dairy feed costs. An annual state average of "milk production per cow" is used (USDA-NASS, 2013) and a feed efficiency of 1.4 is assumed for both conventional and organic production (Wolf, 2010). Organic milk price is the "mailbox price" paid by Organic Valley and varies by region. These data are available from 1999-2011. Though conventional commodity prices are already accounted for in the 16% dairy ration data that is released each month by USDA-NASS, there is no similar data on organic 16% dairy ration cost. Therefore, the cost of an organic 16% dairy ration is calculated using organic commodity price data from several sources (Streff and Dobbs, 2003; Center for Farm Financial Management, 2012; USDA-AMS, 2013b). Because regional organic commodity prices are not available no attempt is made to calculate region specific feed prices, which we acknowledge as a limitation of the study.

«PLACE FIGURE 3 HERE»

It is certainly intuitive that the dairy manager's transition decision is made for year t based on the market conditions experienced prior to year t. Because of the complexity of the organic transition and the planning that is necessary to transition successfully, many farmers report actively considering and researching organic production systems for years before they are finally certified. However, given the management requirements to certify cropland and dairy cows as organic, the years $t-3$ and $t-1$ are particularly relevant for the decision to adopt an organic dairy system. Cropland requires three years of management according to organic standards before it can be certified. Livestock requires organic management, including the provision of organic feed, for 1 year before it can be certified.

Many dairy farms grow some or all of the feed for their herds, thus the minimum time that it takes to transition a conventional crop and dairy farm to organic management is 3 years. The amount of time it takes to transition a dairy that purchases all feed is one year. The market conditions in year $t-3$ are likely more important for the decision to transition cropland than dairy cattle as some crop and dairy farms may take three years to transition their cropland only to decide not to transition the dairy herd if market conditions are no longer favorable. Moreover, there is no delay in the abandonment of certified organic management and market conditions in $t-1$ are probably most relevant for the abandonment decision. Profitiability measures (either IOFC or MF) from both time periods are included in the model, though time period $t-1$ is of primary interest.

In addition to the relative profitability of the organic and conventional dairy systems, the decision to transition to organic production is effected by other policy and social factors. The organic dairy industry developed earlier in certain states providing a more robust infrastructure and network of other organic producers than in late adopting states. Therefore, a measure of the maturity of the organic dairy industry in a given state is likely important in a model attempting to explain transition rates. There have also been policy changes and macroeconomic shocks that have likely affected transition rates over the time period covered by the production data. In 2002 the national organic standard went into effect, providing a national standard for organic production and replacing a patchwork of state-level standards. This policy likely impacted transition rates through stricter regulations or a perceived strengthening of the organic "brand". The recession of 2008-2009 also likely had an impact on organic transition as U.S. demand for organic products in general and organic milk in particular decreased temporarily (Li et al., 2012). During this time, some dairy processors instituted limits on the amount of the milk that they would purchase from each farm and stopped adding new suppliers[2].

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[2] Although the current data set does not include data from 2009, when this effect is likely seen, this shock will be accounted for in the updated model.

Given these data and proposed specifications, the general 3-regime investment model in equation (8 can be re-written for the state level transition decision as:

$$\begin{aligned} cows_{it} - cowsi,t-1 = &+ \mu_i + \Gamma_1 2002 + \Gamma_2 cows_{i,t-1} + \Gamma_3 \rho_{i,t-3} \\ &+ \beta_1 \rho_{i,t-1} I(\rho^H < \rho_{i,t-1}) + \beta_2 \rho_{i,t-1} I(\rho^L > \rho_{i,t-1}) \\ &+ \beta_3 \rho_{i,t-1} I(\rho^L \leq \rho_{i,t-1} \leq \rho^H) + \varepsilon_{it} \end{aligned} \tag{13}$$

where $cows_{it} - cows_{i,t-1}$ is the change in certified organic dairy cows for state i from period $t-1$ to period t and μ_i is the state-level fixed effect. A dummy variable for the year 2002 is included to account for any effect that that year's establishment of national organic standards had on the transition rate. The one year lagged number of certified organic cows ($cows_{i,t-1}$) is included as an explanatory variable to account for the degree to which the organic dairy industry is established in state i at time t. The ratio of organic to conventional dairy profitability (either IOFC or MF) for state i in time period $t-3$ is included as a regime independent explanatory variable ($\rho_{i,t-3}$) while this measure in year $t-1$ is used for both the regime dependent variable $\rho_{i,t-1}$ and the threshold variable. The upper and lower thresholds are denoted by ρ^H and ρ^L respectively and $\varepsilon_{i,t}$ is the error term for state i and time t.

Although the conceptual framework discussed in the previous section predicts organic transition behavior consistent with the double threshold model in equation (13), the estimation procedure identifies thresholds sequentially. That is, the first step identifies a single threshold then this value is used to identify a second threshold. Therefore, a single threshold model, including only two investment regimes is necessarily estimated and can be written as:

$$\begin{aligned} cows_{it} - cowsi,t-1 = &+ \mu_i + \Gamma_1 2002 + \Gamma_2 cows_{i,t-1} + \Gamma_3 \rho_{i,t-3} \\ &+ \beta_1 \rho_{i,t-1} I(\rho < \rho_{i,t-1}) + \beta_2 \rho_{i,t-1} I(\rho > \rho_{i,t-1}) + \varepsilon_{it} \end{aligned} \tag{14}$$

where ρ is the single threshold separating the "high" investment and "low" investment regimes.

Results

The double threshold model in equation (11) and the single threshold model in equation (12) were estimated using the MATLAB code that accompanies Hansen (1999) . Two separate profitability measures (MF and IFOC) were considered and both single and double threshold models were tested against the null hypothesis of no thresholds. Threshold estimation results and the accompanying confidence intervals for model specifications using the IOFC and MF ratios as the threshold variable are presented in Table 2. Table 3 presents the F-statistics and p-values resulting from the bootstrap procedure used to test the significance of the threshold models compared to the null hypothesis of a simple linear model. Although two thresholds are identified for both the IOFC and MF models, Table 3 shows that there is no evidence that the double threshold model describes the true investment response behavior better than the simple linear model.

«PLACE TABLE 2 HERE»

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Results are slightly more encouraging for the single threshold model using the IOFC specification. The p-value for the single threshold model is 0.19 which, though certainly not definitive, suggests that there may be a discontinuity in the organic transition response to organic and conventional dairy profitability. There is no evidence of a significant threshold in the MF model, though this is consistent with recent research suggesting that the MF ratios do not accurately describe changes in dairy profitability in times of high price volatility. The identification of two distinct investment regimes rather than three is at odds with the conceptual model presented above. Real options theory predicts that the uncertainty of future profits combined with sunk costs associated with organic transition would cause hysteresis in the organic dairy supply response. A single threshold however, does not necessarily suggest hysteresis but rather a non-linear relationship between organic transition and relative organic and conventional probability. In order to interpret this result, it is informative to look at the value of the threshold estimate for the IOFC model. The single threshold estimate is an organic to conventional IOFC ratio of 1.776. This is a relatively high level and was surpassed in only 5% of the total observations in our data set. It may be the case that the lower threshold, whose existence is predicted by real options theory and separates the inaction regime from the regime of abandonment of the organic system, is simply not detectable with the available data. As discussed in data section above, the true transition thresholds are found at the individual farm level though we are working with state level data. If the organic abandonment threshold varies widely enough over individual farms, aggregation of transition response may blur the threshold enough that it is not detectable at the state level.

Coefficient estimates for both IOFC and MF model specifications are presented for the single and double threshold models in Tables 4 and 5 respectively. In the IOFC single threshold model, the only coefficient estimate that is clearly significant is that on the number of certified cows in the preceding year, which has a negative sign. The coefficient estimates for the organic to conventional IOFC ratio are positive and negative for the upper and lower regimes respectively, as we would expect, but neither estimate is significant. Given that neither specification using the MF ratio nor the double threshold model using the IOFC ratio exhibits significant thresholds, it is not particularly helpful to interpret the coefficient estimates from these models.

«PLACE TABLE 4 HERE»

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Conclusion

The goal of this study is to frame the decision to transition from conventional to organic dairy management as a problem of an investment with uncertain returns and partially irreversible investment costs. The "new" theory of investment under uncertainty predicts a significant option value, leading to a range of market conditions under which it is optimal to neither invest nor disinvest in the risky asset, which in this case is organic transition of dairy cows. This supply hysteresis could be an explanation for the uneven organic transition rates in the U.S. dairy industry despite steady consumer demand growth and relatively stable, increasing organic milk prices. If significant supply hysteresis could be identified, policy measures directed at reducing the transition costs associated with the adoption of organic dairy systems could prove beneficial.

Using aggregate state-level data on the number of certified organic dairy cows from 2000 to 2008, this study attempted to estimate the threshold values, in terms of relative conventional and organic dairy profitability, that separate the regimes of investment, inaction, and disinvestment. Separate model specifications using organic to conventional IOFC and MF ratios were estimated for single and double threshold models. Although results are disappointing and there is no support for a double threshold with either profitability measure, there is some (weak) evidence of a single threshold with the IOFC specification. This suggests that there may indeed be a non-linear transition response to changing profitability conditions, though with the current data set the precise value of this threshold remains uncertain and a second, lower, threshold cannot be identified. It is possible that an organic abandonment threshold does exist at the farm level as predicted by theory, but that these threshold levels are different enough from each other that an aggregate threshold is not identifiable. With additional data on organic transition rates of U.S. dairy farms from 2009-2011, the threshold estimation procedure described in this study is likely to provide a more definitive answer regarding the presence of supply hysteresis in the organic dairy market.

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Figures

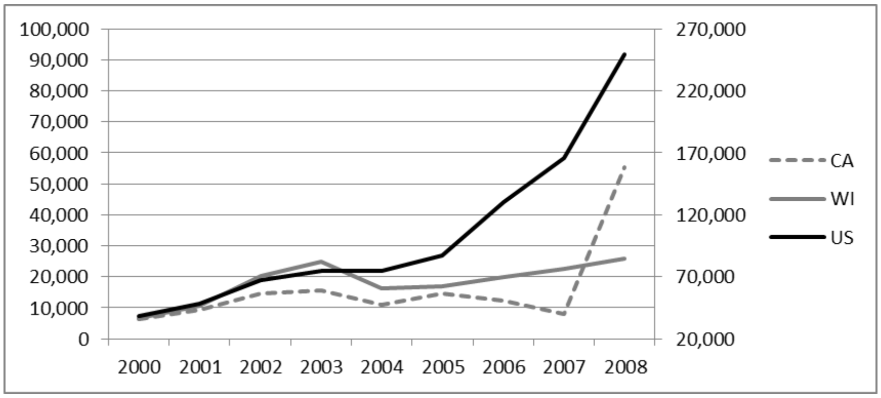

Figure 1. Number of Certified Organic Dairy Cows in CA and WI (left axis) and the U.S. (right axis) from 2000 to 2008.

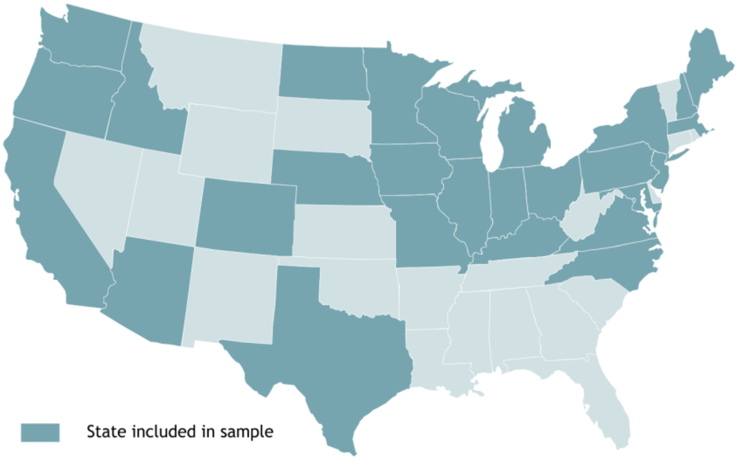

Figure 2. Map of States Included in the Analysis

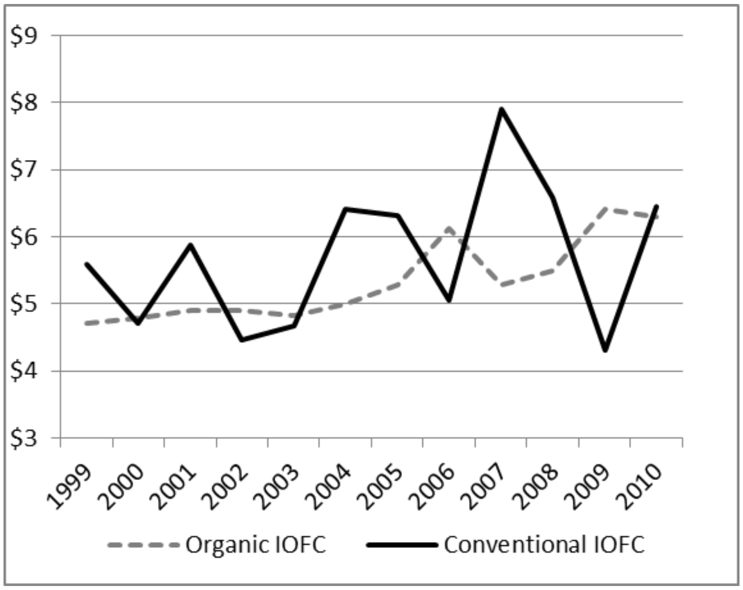

Figure 3. Midwest Organic Income Over Feed Cost (IOFC) and U.S. Conventional IOFC From 1999-2010

Tables

Table 1. Summary statistics for organic dairy cow investment, conventional and organic income over feed cost (IOFC) and conventional and organic Milk-Feed Price Ratio (MF)

Variable	N. Obs*	Mean	Std. Dev.	Min	Max
$cows_t - cows_{t-1}$	189	979.2	4379.5	-11618	47387
Conventional IOFC	189	5.268	1.244	3.035	8.112
Organic IOFC	189	5.914	1.058	4.191	8.125
Org.:Conv. IOFC ratio	189	1.183	0.341	0.589	2.198
Conventional MF ratio	189	3.579	0.779	2.28	6.432
Organic MF ratio	189	3.025	0.431	2.244	3.809
Org.:Conv. MF ratios	189	0.881	0.224	0.525	1.551

* 7 time periods and 27 states.

Table 2. Threshold estimates for model using lagged Organic:Conventional Income over Feed Cost (IOFC) and Organic:Conventional Milk-Feed Price Ratio (MF) as Threshold Variable.

	$\rho_{t-1} = \text{IOFC Ratio}_{t-1}$			$\rho_{t-1} = \text{MF Ratio}_{t-1}$		
	Estimate	95% Conf. Int.		Estimate	95% Conf. Int.	
Single threshold model						
$\hat{\rho}$	1.776	0.796	1.837	0.854	0.529	1.551
Double threshold model						
$\hat{\rho}^L$	0.895	0.676	2.117	0.903	0.529	1.418
$\hat{\rho}^H$	1.776	0.796	1.837	1.551	0.529	1.551

Table 3. Tests for threshold effects

	IOFC	MF
Single threshold		
F_1	8.453	3.550
P-value	0.187	0.717
Double Threshold		
F_2	1.846	1.332
P-value	0.973	0.997

Table 4. Coefficient estimates for the single threshold models.

	———IOFC——-		———MF——-	
	Estimate	S.E.	Estimate	S.E.
Regime independent explanatory variables				
$Cows_{t-1}$	-0.385	0.103	-0.478	0.108
ρ_{t-3}	-575.702	879.471	-10096.7	4024.977
2002 dummy	-675.044	605.142	-2603.76	1044.239
Regime dependent explanatory variables				
$\rho_{t-1}I(\hat{\rho} \leq \rho_{t-1})$	1324.872	963.409	-737.792	2963.778
$\rho_{t-1}I(\rho_{t-1} < \hat{\rho})$	-398.394	867.425	-2166.100	2463.562

Table 5. Coefficient estimates for the double threshold models.

	———IOFC——-		———MF——-	
	Estimate	S.E.	Estimate	S.E.
Regime independent explanatory variables				
$Cows_{t-1}$	-0.361	0.105	-0.491	0.109
ρ_{t-3}	-635.138	879.253	-10568.501	4050.027
2002 dummy	-599.225	607.279	-2724.258	1050.530
Regime dependent explanatory variables				
$\rho_{t-1}I(\hat{\rho}^H \leq \rho_{t-1})$	3209.103	1827.572	-737.792	3051.248
$\rho_{t-1}I(\hat{\rho}^L \leq \rho_{t-1} \leq \hat{\rho}^H)$	2085.927	1148.405	-2166.100	2532.613
$\rho_{t-1}I(\rho_{t-1} < \hat{\rho}^L)$	133.325	970.793	725.388	2832.495