University of Wisconsin-Madison
Department of Agricultural Economics
Staff Paper Series

Staff Paper No. 381
October 1994

October 1994 No. 381

LOW CAPITAL DAIRY STRATEGIES IN WISCONSIN: LESSONS FROM A NEW APPROACH TO MEASURING PROFITABILITY

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I. Introduction

This paper proposes a new way to evaluate the role of profitability and risk in the dairy industry, one that incorporates the effects of uncertainty about future returns when investments are irreversible, or sunk.[1] The usefulness of this new approach is demonstrated by the light it sheds on recent attempts by Wisconsin dairy farmers to develop low capital investment strategies and why these initiatives might be crucial to the vitality of the state's industry as a whole. The value of this paper, however, reaches beyond the contribution it offers to comparisons of the viability of alternative investment strategies in dairy, because it is applicable to evaluating profitability and risk in any economic activity, inside or outside of agriculture, where much of the investment is irreversible and uncertainty about future returns is important.[2]

The central argument is that the irreversibility of some types of investments becomes fundamental in evaluating profitability **when the risk of down-side losses are significant**. Irreversibility and uncertainty, together, create two valuable investment options for investors that are omitted from standard, long-term profitability analyses. One is the degree to which during bad times investors can adjust their strategy to avoid losses by selling off investments for a favorable salvage value. The other is the option to delay investment in order to wait and see how industry prospects evolve. Thus, farm analyses of cost structures and returns generated by alternative investment packages that omit these valuable options will be misspecified, if irreversibility and uncertainty are basic features of the investments being compared.

For participants who have already invested, the more irreversible is the investment, the more difficult it is to sell off and avoid down-side losses, if industry profitability erodes. The

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1 The various features of investments that make them irreversible, or sunk, are explored in section 3, but the fundamental point is that sunk investments cannot be easily transfered to another industry or location. The more costly it is to transfer, the more sunk is the investment.

2 Chavas (1994) and Dixit and Pyndick (1994) explore analytically the effects of irreversibility and uncertainty.

degree of irreversibility, in turn, depends on whether on the down-side the investment or capital asset can be transfered profitably to an alternative use or sold to a new investor at a price that permits the original investor to avoid large equity losses. In other words, constraints on exit caused by irreversibility limit the options of investors and in so doing reduce the expected value to the investor of a given investment relative to one that affords more flexibility. The flip side of the exit constraint is the incentive that irreversibility offers to investors to choose a flexible, "wait and see" strategy. The value in waiting arises, if industry conditions permit the investor to enter when long-term profitability conditions become more certain. In that case, the investor is able to avoid the bad times, if industry prospects turn down or continue to encounter large down-side risks, yet enjoy the good times if prospects turn up or uncertainty is resolved. By taking a wait and see approach, the investor earns a higher return by avoiding the bad times all together. If conditions continue uncertain, potential investors can remain on the sidelines or pursue better options.

The value of both the exit option and the wait and see option may have become crucial to understanding dairy sector profitability and entry in recent years. For a variety of reasons explored in Section 3, many dairy industry investments, especially in confinement-based systems, are highly irreversible. In addition, the down-side risk in the industry has dramatically increased, because of an approximately 50% decline in real milk prices since the early 1980s, increased volatility in dairy prices, and continuing uncertainty about future price prospects. Investment strategies that made sense when prices were higher and returns were more secure may no longer make sense. Yet, standard methods of evaluating profitability fail to account for either the value of being able to exit afforded by investment reversibility or the value of delaying entry in the presence of irreversibility and down-size risk. Instead, current profitability measures which use net-present value methods tend to view fixed capital as just another cost, which is reversible, and calculate this cost for a given period using depreciated basis, tax-adjusted basis, or market-replacement basis as their measure. In other words, the cost of capital, and thus the evolving value of an investor's holding, are not adjusted according to changing industry conditions and how these changes along with the irreversibility of the investment interact to affect equity values. Modifying current accounting methods to account for value of the exit option or the wait and see option can be done using a modified net-present value approach, but as discussed below accomodating these dimensions will require innovations in data collection and analysis.

In section 4, the omission of irreversibility and down-side risk in standard profitability measures are shown by way of a numerical example to be a potentially significant source of error. This omission could be quite meaningful for dairy farmers, industry participants, and policy-makers, because it means that efforts to evaluate the profitability of different technologies or capital investment strategies in dairying are for the most part improperly specified. Thus, low capital dairy strategies, such as seasonal rotational grazing or full-feed purchasing operations, which can reduce the proportion of irreversible investment in the operation, will be undervalued, because the increased flexibility they might afford for entry and exit and avoiding down-side losses is not fully incorporated into the analysis.[3] More specifically, modified profit measures could prove to be critical to the comparison of grass- and confinement-based dairying systems, because the former probably requires much less irreversible investment than the latter. Relatedly, grass-based dairying may encourage more entry and investment in Wisconsin dairy farming by offering both a more affordable and reversible technological package to farmers; however, this aspect of the technology would be unaccounted for in analyses of the industry unless profitability evaluation methods are modified in ways suggested below.

The rest of the paper is organized as follows. Section 2 motivates our consideration of low-capital dairy systems in Wisconsin by discussing some of the recent trends in this direction. Section 3 develops the concepts of irreversible investment and uncertainty more carefully, and explains why these tend to be omitted from standard profitability measures. Section 4 provides a simple numerical example of how irreversible investment and uncertainty interact to demonstrate the need for modifying profit measures in industries with

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[3] These options are not without risk, because these systems often lack carryover feed storage, and thus may face a higher variability in purchased feed costs. This feed price uncertainty effect would need to be factored into comparisons of different dairying systems as well. These could be offset with more flexible low-cost storage systems, too.

irreversible investments and uncertainty. Section 5 concludes with some reflections on private managerial and public policy issues regarding low capital dairy strategies in Wisconsin as well as on the data gathering and conceptual challenges that lie ahead of efforts to implement the new method in applied economics studies.

2. Recent Trends in Low Capital Dairy Systems in Wisconsin

Confinement-based dairying, the predominant technological package in Wisconsin and most of the North Central/Great Lakes and Northeast United States, is a high capital system, with major fixed investments in buildings and facilities for housing and milking the cows, food storage facilities, crop production and manure handling equipment, and land for producing the bulk of the forage and feed. Over the years, the underlying economic competitiveness of confinement systems was based on their high productivity in terms of various input measures. In an era of relatively high prices, these high productivity outcomes in all likelihood made the technology more profitable than alternative systems by economizing on key labor and land constraints and delivering high volumes of milk per unit input. Substantial changes in price-cost margins and increasing down-side risks in dairying, however, appear to be altering the competitiveness of this high capital system, and this is reflected in the observation that recent technology choices seem to be moving toward a more low capital approach to dairying.

On confinement farms, the move toward low capital is evident in the increased use of old farm equipment, or conversely the unwillingness of most dairy farmers to purchase newer equipment, especially for forage and feed production. On some confinement operations, the move is evident in the switch toward grazing as a basis for forage, which both reduces the need for farm equipment and storage and may cut production costs. On others, especially the large, multi-partner confinement operations which have been recently established, the ratio of purchased forage and feed to on-farm production is rising, and the ability to secure forage and feed in a timely fashion seems to allow a move away from the fixed costs of farm equipment and the opportunity to avoid major increases in land and facilities for storage of purchased forage and feed. Where new storage facilities are needed, the per unit feed storage facility costs have been reduced in two ways, one by moving toward structures with lower cost design and second by exploiting the economies of scale associated with larger storage structures. A contrasting example of the move toward lower capital systems is the expansion of intensive rotational grazing (IRG) systems, which put milking cows on the pasture to meet the majority of their nutritional requirements during six to eight months of the year. All of these examples can be viewed as part of a push by dairy farmers toward low capital systems, and especially reductions in irreversible investments.

The most dramatic shift toward low capital dairying in Wisconsin is certainly in the growing numbers of grass-based dairying operations. Although many farmers and industry participants seem to view this technology with considerable skepticism, a noteable number of dairy farmers (between 1,000 and 2,000 of 30,000 statewide) have already adopted grazing, to a significant extent, in their dairy operations.[4] Interest in this new technology was exemplified by the turnout of 500-600 people to the grazers' conference held in Stevens Point, Wisconsin, in March of 1994. Evidence of its potential is also reflected by the fact that grass-based dairying is the predominant technological package in New Zealand, Ireland, and Argentina, which have among the lowest unit production costs for milk worldwide. Not coincidentally, because of the surplus disposal policies of the European Community and the United States which shape international dairy prices, these countries, especially New Zealand and Argentina, have also been subject to more downside risk in their export markets.

Grazing proponents argue that IRG could offer a response to the declining fortunes of Wisconsin dairy farming, by providing farmers with a lower cost production method and lower capital investment requirements than the standard confinement-dairying technology. Although these features of IRG will not necessarily provide a magic bullet for the state dairy

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[4] Richard Klemme, Director of the Center for Integrated Agricultural Systems, views 1,000 as a conservative estimate based on the extent of participation that has developed around "grazer networks," informal groups of farmers exchanging information and experience about intensive grazing issues. Most farmers using grazing are mixing that technological approach with an extant confinement-based investment, so that there is actually a broad spectrum of farmers with different combinations of both technological approaches, many of whom may be in transition toward becoming primarily "grazers." Evidence from the ATFFI Family Farm Survey (see ATFFI, 1994) confirms this assertion and suggests that as of the end of 1992 there were about 1500 farmers in Wisconsin using grazing quite intensively in their dairying operations.

industry, and particularly for farmers trying to exit or transition away from confinement-style dairy operations, they could improve profitability and make it easier for new farmers to enter and exit (if need be), thus encouraging a recovery in production, which would in turn also ease the supply pressures facing processors. The viability of IRG clearly depends to a large extent on its competitiveness as a technology, i.e. its profitability. Therefore, ensuring that estimates of its profitability are done appropriately is fundamental to helping farmers, prospective farmers, and other industry participants to understand private and public investment options. Such estimates would also need to include the possible negative effects on processors' investments and thus farmer prices which could result from the seasonal fluctuations in milk production that are likely to be associated with extensive IRG adoption, particularly seasonal production systems. By the same token, if the technology helps to reduce the supply pressures on processors and the overall costs of production, then these seasonal fluctuations might be offset.

At a social level, the environmental implications of this new technology should also be incorporated into policy analysis, because at least at first glance grazing appears to be more environmentally sustainable in its use of resources and its management of waste. The emphasis on pasture over crop cultivation, and animal rather than farmer harvesting, results in significant reductions in fuel, herbicide, and pesticide usage, less soil erosion and run-off because of the permanent cover provided by pastures, and perhaps the more effective recycling of manure on the pastures.[5] With good pasture management practices in place, these factors all point toward potential improvements in ground water conditions, watershed management, and off-farm costs often associated with erosion and non-point pollution in dairy farms. Other positive features of IRG include more accumulation of organic matter on the farm, which should help to provide a greater sink for carbon dioxide absorption, and less pressure on the local environmental base that supports plant and animal diversity in surrounding areas. At a social level, IRG may also reinvigorate rural communities by

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5 The nutrient and waste management issues on grazing farms are currently receiving a significant amount of research attention. Concerns include the increased potential for nitrate leaching, spring thaw run-off, and streambed damage.

providing easier entry for young farmers, lower work loads for farm families, and thus more time and perhaps more net income for spending in their local communities. However, if the input reductions prove to be significant, the multiplier effect of IRG farm business-related purchases might be considerably less than confinement-based dairy systems. These environmental and social considerations are beyond the scope of this paper but worthy of deeper economic - environmental study as a complement to this paper's effort to improve the measurement of the on-farm profitability of alternative technologies.

3. How Irreversible Investment and Uncertainty Affect Profitability Measures

This section explores in detail the factors that make for irreversibility, or more precisely the factors that determine where on the spectrum investments fall between full reversibility and full irreversibility. It also offers a brief discussion of the concept of uncertainty, and why the interactions of irreversibility and uncertainty suggest the need for modifying standard profitability measures and investment decision analyses.

3.1 The Concepts of Irreversible Investment and Uncertainty

Investments have a degree of irreversibility whenever they have attributes that make the capital specific to the firm, a product, or an industry, or else costly enough to move and relocate that the value of the capital becomes effectively tied to its original use. Examples of this type of product-specific and physically sunk investment on dairy farms would be barns, silos, milking and cooling systems. Outside of dairying, their economic value will be severely limited, and even the costs of moving them to a nearby farm will erode much of their resale value. Beyond the farmgate, processing plant facilities provide another example of a major and largely irreversible investment in dairy, because their use is limited to milk processing. Again, moving the facility requires large disassembly and reassembly costs, which makes this type of investment sunk.

At first glance, farm equipment, such as tractors and combines, might seem to be a good contrast because of their mobility relative to the product-specific and/or location-specific nature of the dairy industry investments just mentioned. On the product-side, tractors and combines could conceivably be applied to grain production, independent of dairying, although actually most dairy farms use the second hand and smaller equipment purchased from cash grain operators. Meanwhile, on the location side, the physical costs of moving this sort of equipment to new locales is low relative to the value of the capital investment, with the only apparent cost being the fuel or hauling cost of relocation. Above and beyond the visible transaction costs of moving capital into production in a new location, three factors make farm equipment, and perhaps other apparently reversible investments, more irreversible than they might appear inherently.

> 1. The "Market for Lemons" Effect, identified by Akerloff (1974), which tends to reduce the resale price of used equipment because of the asymmetry of information between what the seller knows and what the buyer does not know about the condition and effectiveness of the specific piece of equipment. Buyers will tend to offer a price that corresponds to the average quality in the market, which means that sellers will be reluctant to sell equipment of above-average quality. This asymmetry of information between seller and buyer tends to lower the average quality and hence the price of resale markets for many goods, but it helps to explain why the resale value of much equipment may be well below the purchase cost, even if the equipment is almost new. The extent to which the Market for Lemons Effect reduces farm equipment resale prices is an empirical question which could use further research.
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> 2. The "Same Boat" Effect occurs when the adverse shock, or the realization of down-side risk which is prompting the sale of farm equipment by one producer, has been widely felt in the industry. In this case, many sellers of similar equipment, all of whom are in the same financial boat seeking to reduce their down-side losses, will tend to reduce resale prices, because purchasers of the equipment will face many sellers attempting to sell under adverse conditions. When adverse conditions are only local or regional, then the distance the equipment has to be moved to find a profitable locale will likely have two downward effects on the net resale price, one being the higher transport costs of relocating it and the other being the greater "Market for Lemons Effect" in a distant market.
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> 3. The "Investment Package" Effect arises when certain equipment may be essential to the continuing operation of the farm, and hence in maintaining the value of other irreversible investments. This further reduces the sellers' expected return to resale of the farm equipment, making the investment in equipment more

irreversible than it would be if its resale value could be evaluated independent of its effects on the value of other linked investments.

Were it not for the Investment Package and Same Boat Effects, cows would probably be the one major investment in dairying that would be nearly completely reversible. First, cows can be moved at relatively low cost to more profitable regions. Second, in most farms, the supporting documentation can be provided to demonstrate their productivity levels, which can reduce the Market for Lemons Effect. Despite these features, the other two effects can also make cows significantly irreversible investments. The Same Boat Effect may be especially important, because one of the major down-side risks faced by farmers involves the industry-wide effects of declining milk prices, which in turn can depress cow prices at a time when a farmer might want to sell off some or all of the herd. The Investment Package Effect, especially in confinement dairying is clear, when one recognizes the link between the presence of a herd and maintaining the value of other irreversible investments. In so far as IRG decreases the extent of linked investments by reducing the investment in other farm structures and equipment, IRG makes other investments more reversible, and could thus encourage more entry by making exit or retrenchment in bad times easier.

Irreversibility, as a concept, can also be applied to the labor and managerial skills that farmers and other individuals develop plying their trades, whenever a gap emerges between the value of the skills individuals have in their current and in alternate lines of work, or whenever their skills have farm-specific, firm-specific, or industry-specific features. There are certainly some of these attributes about human capital developed in dairy farming which contributes to "irreversibility." On the farm, the knowledge that farmers gain about their micro-climates, the soil quality, the animals, and other location-specific factors would be one source. At the firm level, the managerial experience a farmer develops concerning the sources of efficiency or premium quality milk production within his operation may not be particularly valuable to other enterprises, off the farm, or even on another farm. At an industry level, the skills developed by a dairy farmer may or may not be transferable to other activities.

Irreversibility on the human capital side can also be associated with two other attributes of dairying in Wisconsin. One is the "family farm" organizational unit, and the other is the potentially isolated location of the farm. Because family farms generally embody both the physical (or financial) and human capital of families, the Investment Package Effect discussed above can tend to magnify the irreversible nature of both investments by making exit seem especially costly. Moving to take advantage of labor opportunities, say for the farm operator, means both breaking the "family contract" of passing on the farm or a way of life as well as potentially losing much of the value of the irreversible investments embedded in the farm. Isolated locations make the interdependence of irreversibility in farm and human capital even more stark, because isolation reduces the option of diversifying household risks through off-farm employment of either the spouse or the main farm operator. Put differently, proximity to alternative employment opportunities can reduce the degree of irreversibility on the labor side and the down-side risks associated with dairying, thereby making partial exit more possible and thus entry more attractive.

As mentioned above, irreversible investments demand a modification in our conventional measures of profitability and evaluations of investment decisions**only when** uncertainty, or specifically down-side risk, is present. Otherwise, there is no reason for investors to be concerned with the lack of flexibility or the value of waiting. By uncertainty, we are refering to situations, where future returns, or key variables that affect future returns, cannot be predicted with certainty. It should be apparent than for almost all economic activities, some degree of uncertainty is inherent. As an example, consider an industry in which there is a 50% chance that prices will fall by 10 cents. next year, a 25% chance that prices will stay the same, and a 25% chance they will rise by 20 cents. On average, these differences balance out to an expectation of no price change (-0.1*0.5+0.2*0.25 + 0*0.25 = 0); however, the possibilities create uncertainty.

Down-side risk arises, when there is a significant probability that future prices, costs, output fluctuations, or other factors could result in losses rather than profits on an investment. In the example above, if a 10 cts price decline resulted in losses for producers, the industry would be one where the uncertainty carried down-side risks. Examples of the type of factors that are likely to increase the uncertainty of future returns, and down-side risk, in the Wisconsin dairy industry are the continuing expansion of U.S. milk production especially in the Southwest and Northwest regions, the passage of trade liberalization agreements, such as the North American Free Trade Agreement and especially the General Agreement on Tariffs and Trade, the controversy around and potential surplus milk production resulting from the introduction of recombinant bovine Somatotropin, possible changes in the federal milk marketing order system, and 1995 farm bill proposals to eliminate the price support program. The effects of these types of trends and policies on future price levels are difficult to predict, but any, or some combination of them, could cause significant further declines in dairy prices and profitability in Wisconsin.

3.2 Irreversible Investment and Uncertainty - Why They Matter?

The impact of irreversible investment and uncertainty on measures of profitability is examined carefully in Section 4 by developing a numerical example. The basic argument is that uncertainty about down-side risks makes the degree of irreversibility, or conversely flexibility, an important determinant of investment behavior. In particular, irreversibility provides disincentives to exit and to enter; for the former because it can mean big capital losses in bad times, and for the latter because it creates a value to waiting to see how the uncertainty about future conditions might be resolved. Standard profitability measures fail to accomodate the degree of flexibility afforded by investments, and thus the option value of exit in bad times, or the value of entering only in good times, in industries where both irreversibility and down-side risks are present.

The reason this is true is that most profitability measures which examine longer term investment decisions look at the life of a project, take the fixed costs or investments involved in the project and depreciate them using either their expected physical life, the tax depreciation schedule, or their replacement cost, apply those costs to each time period accordingly, and then sum up the projected discounted stream of costs and benefits over the life of the project. The problem with applying standard present value approaches to long-term investments with irreversibility is that they examine the project over a full life, once and for all. In the process, they ignore the option value in any given period of exiting the activity and putting the remaining resources to use in other activities, an option value which, in turn, depends on how sunk the original investment is and the type of revenue stream it can generate in its original or in an alternate use. The standard net present value approach also ignores, as a result, the value of waiting to see how conditions are likely to evolve in an industry before investing. In industries with significant irreversible investments and uncertainty, these omissions mean that standard profitability measures will tend to give inappropriate indicators for investment and entry decisions, because they do not include the value of an exit option or the value of a wait and see decision.

4. A Numerical Example of How Irreversibility and Uncertainty Affect Investment Decisions

Two cases are presented below. In the first case, we show how profitability measures are unaffected by the degree of irreversibility in investment when there is no uncertainty or down-side risk. In the second case, we introduce uncertainty, specifically down-side risk, and illustrate how the combination of irreversible investment and uncertainty make conventional measures of profitability inappropriate for investment decisions. The key effect will be that the standard measure of profitability does not account for the option values, the value of being able (or unable) to exit or the value of waiting to invest, that is created in the presence of irreversibility and down-side risk.

Consider the following investment problem. At time t =1, a firm has the option of investing in a capital good. The investment cost is \$C. The capital good can provide services for two periods: t =1 and t =2.[6] After two periods, the capital is fully depreciated or physically used up. After an initial investment in the capital good, production activities take place. The capital good is a necessary input in the production process; without it, no production can take place. With investment, the return over variable (or operating) cost is P_1 at time t = 1, and P_2 at time t = 2. The firm has to make two decisions.

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6 The two period model is chosen for simplicity. A multi-period model would require forecasts of future prices, costs, and uncertainty to devise projections of the future salvage value of the project, making its construction and explanation considerably more difficult.

1. At time t = 1, the firm has to decide whether to invest. If the firm does not invest, it receives \$0. If it decides to invest, it pays \$C in investment cost and receives the return \$$P_1$.

2. At time t = 2, the firm has to decide whether it wants to continue production after an initial investment in period 1. If it discontinues production, it would sell the capital good and receive its salvage value \$S. It it continues production, it would receive the return P_2. Note that the salvage value of an investment is related to its irreversibility. The lower is the salvage value, the greater is the irreversibility.

For simplicity, we ignore discounting between periods 1 and 2, and also assume risk neutrality in both cases, so that the firm maximizes expected return. This approach is comparable to the net present value approach, but abstracts from the discount rate on investments.

Case 1: No Risk, High Returns

$$\text{Let } C = 8.2,\ P_1 = 4.5,\ P_2 = 4.5, \text{ and } 0 \leq S \leq 4.5.$$

S can be no larger than 4.5, because that is the maximum it could be worth to another buyer in this example given that it will provide the buyer one period of production at a return of 4.5. In this case, if the firm decides to invest at time t = 1, it will also decide to produce at time t = 2, since $P_2 \geq S$. Thus, the return at time t = 2 is $P_2 = 4.5$. The total return over the two periods is:

i.) either \$0 if the firm decides not to invest, or

ii.) $(P_1 - C) + P_2 = 4.5 - 8.2 + 4.5 = 0.8$.

Since 0.8 > 0, the firm would invest at time t = 1. Thus, the optimal decisions of the firm is to invest in period 1 and to produce during both periods. This result is independent of the salvage value of capital S, or its irreversibility, because there is no reason to consider the option of selling out in period 2. Therefore, no down-side risk means that irreversibility is not an issue in the original invesment decision. This outcome can be viewed as analogous to conditions in an industry where price supports are sufficient to guarantee no or minimal down-side risks.

Case 2: Risky returns in the second period and lower overall expected returns than case 1

Let C = 8.2, P_1 = 3, P_2 = {10 with probability 0.5; -4 with probability 0.5}, and $0 \leq S \leq 3$.

In this case, we have chosen prices that are both uncertain and offer a lower overall expected return than in case 1. This is meant to capture in a stylized way the types of changes that have occurred in the dairy industry in recent years. The mathematical expression for the expected return from production in period t = 2, based on the information available in the first period, is $E(P_2) = 0.5(10) + 0.5(-4) = 3$. Just as in the last example, viewed from the first period, the salvage value of the investment must range between 0 and 3.

If all decisions are made in a planning sense in the first period, if the firm decides to invest at time t = 1, it would also "plan" to produce at time t = 2, because $E(P_2) = 3 \geq S$, the salvage value it could obtain from selling out.

The total expected return over the two periods, as viewed from the first period is:

i.) either $0 if the firm decides not to invest;

ii.) or $(P_1 - C) + E(P_2) = 3 - 8.2 + 3 = -2.2$, if the firm decides to invest.

These results obtained under standard profit analysis, which considers the investment options as viewed from the first period, without adjustment for potential exit would suggest that the firm would "plan" not to invest at time t = 1, because $-2.2 < 0$.

This conclusion would, however, be erroneous if P_2 were revealed prior to production in the second period.[7] The reason is that the above decision is based only on the information available at time t =1. This reasoning neglects the opportunity the firm could have to react to the information about returns in period 2 and to sell its capital equipment for S at time t = 2, if the return for P_2 were revealed to be lower (-4) rather than higher (10).

In other words, if S = 3 in the example given above, then the firm would sell the investment for scrap value in period 2 when $P_2 = -4$. Overall returns in that case would be

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[7] This knowledge of prices in the second period is an important assumption. A more realistic example would perhaps have the uncertainty about prices in the second period reduced by recent experience and information but perhaps not fully eliminated. This would require additional complexity but would not change the basic conclusions of the example developed here.

3 - 8.2 + 3 = -2.2. However, the other half of the time, when P_2 = 10, returns would be 3 - 8.2 + 10 = 4.8. Thus, on average, given a relatively high scrap value the expected returns to investing in period 1 would be .5*(-2.2) + .5 *4.8 = 1.3, which is positive. The difference between the profitability and investment outcomes of this case and that given by the standard approach is due to the option of selling out for scrap value in period 2 if returns are low or staying in business if returns are high. We illustrate below that, as the scrap value falls, or the investment becomes more irreversible, the option value of bailing out decreases, and the increased risk of down-side losses will, in fact, tend to discourage investment.[8]

These results suggest that the option to sell investment for scrap value in period 2 requires a distinction between "planning decisions" derived from standard profitability measures and "optimal decisions" based on incorporating irreversibility and uncertainty.

In the inflexible planning decision approach, only information available in the first period is incorporated, and so the comparison is made between i.) and ii.) above or 0 and -2.2. In mathematical terms, that choice would be expressed as:

(1) $\pi^p = \max \{0, P_1 - C + \max \{E(P_2), S\}\}$,

where max denotes choosing the maximum of what is inside the brackets {.,.}, which given the figures above makes the last term max $\{E(P_2), S\}$ equal to 3 regardless of scrap value.

In the flexible optimal decision approach, information available in both periods is incorporated into the decision about investment in period 1 as is the option to sell the capital for salvage value in period 2. In mathematical terms, that decision choice would be expressed as:

(2) $\pi^* = \max \{0, P_1 - C + E\{ \max (P_2, S)\}$,

8 It is worth noting here that the salvage value S is being varied arbitrarily. In practice, the salvage value of the investment would depend on two factors: the degree of the price shock experienced in the industry and the value of alternative uses for the investment.

where the second term denotes the expected value of the maximum of either P_2 or S, which given the figures above is either 10 or 3 with a probability of 0.5 each, or 6.5, overall, so that the overall expression is {0, -5.2 + 6.5 = 1.3}.

The difference between equations (1) and (2) is thus in the last term and involves the option value that the firm would have, if it invested in period 1, to sell the capital for the scrap value in period 2 in order to avoid making losses. This option value (V) reflects the flexibility of responding to new information, as it becomes available, and is defined in equation (3) as:

(3) $V = E\{\max (P_2, S)\} - \max \{E(P_2),S\}$.

Note that equation (3) is the difference between the last terms in equations (2) and (1). In simple language, this difference reflects the value to the firm of being able to choose the greater of either the returns to producing in period 2 or the salvage value compared to choosing their investment strategy in period 1 and not being able to adjust.

One key characteristic of the option value V is that it is always non-negative or $V \geq 0$, because the opportunity to exit in bad times dominates staying put. This can be interpreted to mean that the value of flexibility (the firm's option to respond to new information) is always non-negative. This also implies that $\pi^* \geq \pi^p$, or that "optimal decisions" are always at least as good as "planning decisions."

Another key characteristic of the option value V in equation (3) is the fact that it depends on the salvage value S. The greater is the salvage value, or resale value of the original investment, the higher is the option value of having the opportunity to sell in bad times. Conversely, if the scrap value is low or zero, then the option value decreases accordingly.

In our two period example, the following numerical relationship exists between option value V in equation (3) and the salvage value S:

	S = Salvage Value	$V = E\{\max (P_2, S)\} - \max \{E(P_2), S\}$
(no sunk cost)	3	3.5 = (0.5*10 + 0.5*3) - 3
	2	3 = (0.5*10 + 0.5*2) - 3
	1	2.5 = (0.5*10 + 0.5*1) - 3

0	2	= (0.5*10 + 0.5*0) -	3

The results in this table are important because the salvage value S indicates the extent of irreversible investment (i.e. the part of the original investment cost $C that cannot be recovered in the event of later disinvestment). As S declines, because of lower prices or declines in the value of the alternative uses for the investment, the extent of the investment cost that is sunk, or irreversible, rises. As the numerical results indicate, the ability of the firm to respond to new information (as measured by the option value V) declines as capital investment becomes sunk.

Using the example, we can compare the optimal and planning decisions with different salvage values to see how sunk costs affect our evaluations of profitability.

	S = Salvage value	Profits under Optimal Decisions $\pi^* = P_1 - C + E\{\max(P_2, S)\}$	Profits under Planning Decisions $\pi^p = P_1 - C + \max\{E(P_2), S\}$
(no sunk cost)	3	1.3= 3 - 8.2 + 6.5	-2.2= 3 - 8.2 + 3
	2	0.8= 3 - 8.2 + 6	-2.2= 3 - 8.2 + 3
	1	0.3= 3 - 8.2 + 5.5	-2.2= 3 - 8.2 + 3
	0	-0.2= 3 - 8.2 + 5	-2.2= 3 - 8.2 + 3

These values illustrate the effect of sunk cost on "planning decisions" and "optimal decisions." Planning decisions neglect new information, and thus generate expected profits that are always lower than optimal decisions. While planning decisions would suggest not to invest (as portrayed above), optimal decisions would suggest to invest as long as sunk investment costs are not too high ($S > 0.4$). Planning decisions thus provide misleading information to decision-makers, because they neglect the effects of sunk costs and uncertainty on investment decisions and can generate inappropriate investment recommendations.

Note also that the differences between planning decisions and optimal decisions disappear in the absence of uncertainty (as in case 1 above). With uncertainty, and particularly down-side risks, sunk costs affect investment decisions, because sunk costs reduce the ability of the firm to respond to the new information that will be revealed. One implication is that in a situation of higher uncertainty the option value will tend to rise, making the role of sunk cost in investment decisions and firm survival more important. Reductions in sunk costs (lower C or larger S) would therefore enhance the ability of the firm to respond to new information (as measured by the option value V in equation (3)), and in so doing would contibute to increasing current investment

One more important point can be made using the numerical example. If we were to allow firms to choose to enter in the second period at the same investment cost of C = 8.2 for production of only one period, then a third option to consider would be the decision not to invest in the first period but to invest in the second period. For the firms that chose this option, half of the time, they would earn zero profits because they would not enter when returns in period 2 were low, and half of the time, they could earn profits of 1.8 (10 - 8.2), when returns in period 2 were high. The expected returns for this strategy of waiting till the second period to invest would be 0.9. Given that production is limited to two periods by the construction of the example, the real value of waiting is, in effect, underestimated relative to more realistic conditions of being able to produce for more than one period. Nonetheless, if we compare the expected profits from this strategy to those in the table on the previous page using the optimal decision approach, the strategy of delaying investment decisions until period 2 (and earning an expected profit if conditions are favorable of 0.9) would be optimal as long as salvage costs $S \leq 2.2$. In other words, another option value that can arise in industries with uncertainty and down-side risk is the one gained from delaying investment (or not entering in the current period). Note that as the level of sunk costs increases, or the salvage value S decreases, the option value of delaying investment grows.

In conclusion, standard profit measures ignore how the degree of irreversibility and uncertainty interact to affect the potential profits associated with different investment strategies. In particular, they omit consideration of how these features create disincentives to exit and enter. The disincentive to exit arises because the salvage value of investment in bad times is reduced by irreversibility, making it less attractive to sell out. This disincentive to exit also creates a disincentive to enter by reducing the expected profitability associated with investing in an industry with down-side risk. An additional disincentive to enter is created by the option value associated with postponing investment until the uncertainty regarding good or bad times is revealed. In so far as good times lead to a later investment and bad times lead to no investment, the strategic value created by delaying investment until uncertainty is resolved or reduced is a disincentive to invest. Understanding the entry and exit behavior of participants in an industry depends on uncovering when and to what degree irreversible investment and uncertainty affect their investment decisions.

5. Managerial, Policy, and Future Research Implications

To varying degrees, private decisions, public policy evaluations, and research on investment and profitability in dairy and other agricultural activities could all be improved by incorporating the effects of irreversible investment and uncertainty on the profitability and viability of different technological and investment packages. The extent of the possible improvement hinges on the degree of irreversible investment and uncertainty present in any particular context and the magnitude of the decisions under consideration. This final section attempts first to illustrate some of the possible implications for farmers, processors, and policy-makers in Wisconsin's dairy industry and second to suggest the broad elements of a research agenda for further work by academics, extension agents, and other industry analysts on this topic.[9]

5.1. Implications of Irreversibility and Uncertainty in Dairy for Farmers and Processors

For dairy farmers and prospective dairy farmers, the implications of irreversibility and uncertainty could be quite important well into the future. The primary source of uncertainty confronting farmers continues to be dairy prices. In real terms, they have fallen by nearly 50 percent since the late 1970s, and they have been fluctuating significantly in recent years.

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[9] The authors are currently developing simulation analyses of alternative technological packages for dairy investment in Wisconsin, incorporating the effects of irreversibility and uncertainty on their viability.

Moreover, given current farm policy trends at a national and international level no reduction in price uncertainty or down-side risks seems likely to occur soon. Simultaneously and perhaps relatedly, the range of choices farmers are making in terms of dairying technologies, scale of operation, and degree of irreversibility in the associated investments, seems to be increasing both within regions (in Wisconsin: grazing versus confinement or medium-scale single family farms versus large-scale, multi-family operations) and across regions (feedlot operations in the Southwest with herds of more than 1,000 versus confinement operations in the Upper Midwest of 50 to several hundred). This range of choice suggests that investment decisions may increasingly be designed at least in part with the aim of reducing the degree of irreversible investment in dairy farms. Not totally unrelated are the lifestyle implications for dairy farmers of these alternative technology packages which reduce sunk costs in farm equipment and involvement in the on-farm production of feed grains.

The types of decisions facing current and prospective dairy farmers are in certain ways quite distinct. For the prospective dairy farmer, the value of future flexibility can be factored fully into the basic decision about whether or not to enter, at any given point in time, so that the choice of technology and scale of operation is most likely to achieve the maximum expected returns. This is another way of saying that entering farmers have the potential advantage of being more flexible in their technology choice, scale of operation, and the timing of their entry. Thus, they can choose to go slow and see what the future might hold or to invest in a technological package that cannot be readily achieved by an active farmer without writing off equity losses from previous technological choices. By contrast, for the active dairy farmer, because much of their investment capital is already sunk on the farm, only the decisions on future investments or on currently reversible investments can be treated the way an entering farmer can treat the whole package. To move quickly toward a more flexible technological package in many cases means writing down asset losses on previous investments, which can be difficult to do at the same time the farmer is attempting to invest in an alternate approach. Because of sunk costs (and perhaps because of capital constraints and inertia as well), the tendency will be for active dairy farmers to move slower in changing technology than if the previous investments could be easily reversed. Indeed, this is the essence of irreversibility.

In Wisconsin, the contrast between prospective and active dairy farmers can be better understood by considering what the active farmer faces in seeking to move from a standard confinement operation to a grass-based dairy operation in order to possibly improve returns and/or change lifestyles. That farmer faces two basic options. One is to sell the current operation and start afresh elsewhere on a farm with less or no sunk investments in confinement operations. The other is to make the transition on the existing farm. These options may not be very different from an economic perspective, if the farmer's perception of the value of confinement farms is reflected in the market by way of a relatively low salvage value for many of the assets in the confinement farm. Both options mean that the active farmer has to accept the prospect of equity losses, either selling the farm at a price that may be much lower than the original purchase price, or letting investments, such as silos, parts of the barn, and farm equipment sit idle or be sold off as individual items at low salvage values. If the current farm operation is saddled by heavy debt levels (the average dairy farm in Wisconsin has a 25% debt to asset ratio, and more than a quarter have greater than a 40% debt to asset ratio), then it may be quite difficult to finance a rapid shift from confinement to grass-based dairying at the same time equity losses are being experienced. Clearly, if the gross returns from the transition exceed the operating costs and the costs of new investments at a greater margin than is possible under the old confinement package, only financing constraints and uncertainty about the technology package would be likely to hold farmers back from making the transition quickly.

By contrast, the prospective entrant into grass-based dairying is not faced with the immediate loss of equity value unless their farm purchase is made at a price that does not reflect the true value of the operation. Presumably though, the entrant will purchase an active farm at its salvage value or else an inactive one, and make the investments necessary in improved pasture, electric fencing, and so forth to make the operation a viable grazing operation.[10] The lower sunk costs involved, compared to the traditional confinement operator, will leave the new entrant with more capacity to change course, if for farm-level or industry-level reasons the investment does not work out as hoped. All other things equal, this flexibility should over time increase the likelihood of investment in grass-based versus confinement operations by new entrants. What remains to be seen is whether all other things are equal, or more precisely how competitive the alternative technological packages are in different circumstances.

Active processors in Wisconsin face a situation that is similar to active confinement farmers. They have incurred significant irreversible investment expenditures in processing facilities and perhaps to a lesser extent relationships with farmers and local marketing and distribution channels. At the same time, they are paying more for manufactured milk in Wisconsin than do competitors (or other company divisions) in most other parts of the U.S. If processing investments were perfectly reversible, and milk supply were reasonably elastic elsewhere (as it appears to be at present in the West), more of Wisconsin's dairy processors would have moved already, in order to obtain lower cost milk. Processor decisions to move or exit do, however, hinge on the degree of irreversibility they face in their investments and the views they have on prospects for future absolute and relative prices. Those that are closer to the time where much of the existing capacity needs replacement, have less in the way of other irreversible local investments, or have adopted lower sunk cost technologies are more likely to move sooner, as are those who are more optimistic about securing an adequate and secure supply of low cost milk elsewhere. In summary, irreversible investments mean that for both farmers and processors adjustments take time, and are not as smooth as they would otherwise be. If strides can be taken to reduce either the degree of irreversibility or the down-side risks of dairy farming or processing, then investment should be stimulated. Because much of the down-side risk in dairy processing relates to the relative costs of farm

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10 New entrants also have other options, including renting land and facilities, cows, buying feed, which in various combinations can reduce their sunk costs.

milk purchases, any improvements that can be made to improve investment and production in Wisconsin dairy farming should reduce the exit incentives of local processors.

5.2. Public Policy Implications of Irreversibility and Uncertainty in Dairy

The challenge facing the Wisconsin dairy industry at present is that there is no guarantee that the adjustment path of dairy farms will match the investment decisions of the processors. Whereas conventional economic models would have the forces of milk supply and demand adjusting smoothly to match farm production to the processing capacity and visa versa, the fact that both sectors are confronting periods of heightened uncertainty and irreversible investments means that the decisions which underly these adjustments may not necessarily work out smoothly. Suppose low-capital dairy systems, especially rotational grazing, proves at the farm level to be a competitive way of producing milk that enables farmers to be more flexible and less vulnerable to down-side risks and that, accordingly, increasing numbers of farmers adopt the technology. It appears likely that under such a system processors will face significant seasonal fluctuations in the milk supply for their facilities because of higher production volumes from grass farms in the summer and lower volumes in the winter. As such, processors may have problems managing the throughput in an efficient way that reduces the capacity costs of their operations, and this may constrain their competitiveness with processors in other regions, even if the average cost of producing milk in Wisconsin is otherwise competitive. The resulting price instability or uncertainty about regular milk supplies could increase the down-side risks for processors with irreversible investment and thus discourage the processing capacity investment which will be essential to a recovery or expansion in Wisconsin dairy farming. The offsetting factor could, of course, be that if seasonal milk production using grazing techniques proves to be lower cost, the seasonality concerns could be offset by lower priced milk. Alternatively, grazers might respond to a price "backlash" by milking some of their herd year around to smooth production levels.

These sorts of coordination problems between farmers and processors, while perhaps heightened by the seasonal fluctuations that might be associated with widespread adoption of grass-based dairying systems, are not limited to this particular technological package. For example, heightened uncertainty about the future of farm-level returns could discourage or delay entry or expansion in dairying sufficiently that production levels continue to fall or stagnate. If processors, in turn, begin to exit or even announce their anticipated exits, the expectation will grow among industry participants that in the future there will be reduced processing capacity and hence the need for lower volumes of milk. This, in turn, could heighten uncertainty about farm-level returns and further discourage exit. The point is that with irreversible investments the uncertainty about future returns can effectively discourage investors who might otherwise seek to take advantage of currently higher milk prices. In this sense, a vicious circle can begin, and develop momentum unless something is done to either reduce the irreversibility of investment through the innovation of new technological packages or to reduce the down-side risks facing processors and producers. Both of these avenues, if bolstered by more careful analyses, could provide a basis for public-private coordination to overcome the potential private market failure associated with irreversible investments, uncertainty, and coordination failures.

5.3 Implementing the Concepts of Irreversibility and Uncertainty in Investment Analysis

The tasks involved in integrating irreversibility and uncertainty into the analysis of investments and measures of profitability are formidable. In a nutshell, their integration requires incorporating a series of possible future outcomes and determining in addition to the normal stream of returns to an activity what value future options of exiting, temporarily laying-off, partially scrapping, and entering hold for the investor or firms involved. The challenges lie in both developing reasonable scenarios for the major variables for which uncertainty exists, such as price, costs, yields, and so forth and then estimating how the various scenarios will affect the salvage value and the wait and see value of investments. As shown in the numerical example above, both of these values affect the profitability of investments, and hence the eventual ranking of different investment options.

Part of the challenge is one any forward looking economics model faces, namely the task of developing reasonable future scenarios for key variables. This requires being able to assign probabilities to the likelihood of different outcomes or at least to test the sensitivity of investment decisions to different probabilities that might be assigned. It also requires identifying the degree to which investments are likely to be reversible under different scenarios, because irreversibility, or the salvage value, will in many cases vary systematically with the extent of down-side risk. In other words, a very adverse shock in an industry could deepen the irreversibility of investments and visa versa. Because the salvage value and the wait and see option of an investment matters at every stage of the analysis, a full-blown dynamic analysis would have to calculate these values at every stage or time period. The permutational demands of this sort of multi-period analysis can quickly become quite demanding given even a limited range or summary set of feasible outcomes.

In their recent work, Dixit and Pindyck (1994) show how dynamic programming techniques and contingent claims analysis can be used to examine investment opportunities like the ones described in this paper. Although conceptual discussion of these or alternative dynamic simulation methods is beyond the scope of this paper, the empirical challenge of implementing them is worthy of a few additional remarks, because they can be brought to bear more directly on farm economic analyses and future efforts to apply these sorts of techniques to the specific situation of the dairy industry in Wisconsin.

One major concern is that current accounting techniques used in private farm records and in farm economics studies do not collect data that is essential to calculating the salvage value of investments. The lack of data is a serious impediment to testing the value of the conceptual contribution raised in this paper and by other economists. The data shortcomings arise for several reasons.

First, as discussed above, capital is treated as an asset that depreciates either according to a tax or physical schedule or else in terms of its "physical replacement value" rather than its current economic (salvage) value. This treatment means that neither private nor public accounting efforts systematically collect data relevant to the salvage value of different investments, such as the resale value of distinct investment components and packages over time. A public effort to do so would require a more careful monitoring of resale markets, from auctions to farm press advertizements. For initial estimates, industry experts could be queried.

Two, only physical capital is generally even considered on the books as an investment. Labor or management services are treated by most accounting methods as a cost to be expensed, not in terms of the investment they embody. Depending on the skills and practices, these human capital investments could be more or less reversible and increasing or decreasing in value over time. In other words, some potentially important irreversible investments are not fully accounted for by standard methods. The same argument of omission could be applied to the firm- or industry-specific efforts that are made to develop relationships or ties with suppliers, purchasers, other producers, and so on, which depending on the institutional circumstances in an industry can represent important investments.

Third, most accounting methods do not put much emphasis on collecting and analyzing either individual or social data on the variations in key economic variables over time, which would be crucial for generating everything from estimates of salvage value under different scenarios to price forecasts for the industry. While none of these tasks would be easy or costless to implement, the increased availability of computers, and the potential for developing user-friendly software, to help with computations, data storage, and data retrieval do not make these tasks, even for individual operators, as foreboding as they would have once been. To make progress on this front would require substantive changes in the accounting techniques being taught and communicated, however, and so should not be taken lightly.

Another major concern is that many of the calculations which incorporate the effects of uncertainty and irreversibility are very likely to be quite sensitive to the forecasts developed for that purpose. Although a variety of economic forecasts could be used to demonstrate the degree of sensitivity present in the investment analysis, and hence to help decision-makers understand the range of possible outcomes, the inherent uncertainty in forecasting the probability of distinct outcomes will make use of these techniques seem much less precise than current methods, despite the fact that the approach would be including potentially critical features that are otherwise omitted. Simply put, the complexity and uncertainty of the methods could undercut their acceptance.

Finally, there is the very problem of irreversibility in current practices and information. Major changes in the status quo can be painful, especially when individuals are asked to push beyond some of the techniques and skills they have gathered and to learn new ones, with uncertain payoffs. A reasonable reaction from these people would be to say, why do differently if previous methods seem to work. Perhaps the only convincing response will be that for many farm commodities and farm producers, the major decline since the 1980s in real prices, not only in dairy but in most major commodities, means that previous methods may not be as applicable as they were when the problem of down-side risk was not as severe as it is today in farming. If this is true, what worked in the past may not really be working today, and then the danger is that current practices could be part of the problem confronting private and public analysis rather than part of the solution.

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