Trade Dynamics under Policy Uncertainty

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Countries, and more precisely, producers, are frequently subjected to trade policy of temporary duration. The tariffs levied on steel imported into the United States in March 2002 were lifted in December 2003; in September 2009 the United States announced a three year policy of increased tariffs on some imported tires from China. In addition to the usual issues that arise from barriers to trade, these temporary policies commonly carry an extra component: uncertainty. The U.S. steel tariffs, for example, were lifted in December 2003, but were originally scheduled to persist until 2005. It is unclear for how long tariffs against Chinese tires will last.

In this article we study the link between the perceived length of a policy and the responses of inventory and investment during the worldwide ban of imported beef from Canada following the discovery of a cow infected with Bovine Spongiform Encephalopathy. We construct a model in which production requires "time to build" and in which it is possible to hold inventories. Here we add an additional element: producers do not know with certainty for how long the policy will be in place, but do know the probability that the policy will revert to the previous state. We find that long lived policies have stronger effects, on impact, than do short lived polices. When we calibrate the model to reproduce the drop in slaughter rates that occur at the onset of the ban, we find that the expected length of the ban implied by the model is 5.8 months. The actual ban lasted approximately 3 months. The calibrated model generates a 59 percent

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decrease in investment—the number of new calves put on feed—compared to a 55 percent decline in the data.

The cattle industry lends itself well to dynamic modeling. The production function is simple and the calf-cow-calf cycle fits neatly into the capital accumulation framework. Beef cattle production in Canada occurs in two major industries, cow-calf operations, which hold stocks of female cattle for breeding new calves, and feedlot operations which take young cattle and "finish" them by feeding a diet that brings the cattle to marketable weights. The focus of this paper is on feedlot operators, who must choose how many new cattle to place on feed—an investment—and how many finished cattle to market.

A large literature has studied cattle production focusing on the time to build aspects of the problem and the cyclical properties they induce, including contributions by Jarvis (1974), Murphy, Rosen, and Scheinkman (1994), and Aadland and Bailey (2001). In this study, we are focusing on short time horizons, in which breeding stock decisions are likely to be less important. While time to build does play a role in the model, the decision modeled here is more akin to a choice over inventory levels.

The recent literature on uncertainty and trade has highlighted the connection between permanent and transitory changes in trading conditions. These models typically feature a fixed (and sunk) market access cost that creates an option value to entering a foreign market. Ruhl (2004) uses this type of model to rationalize the unresponsiveness of trade to transitory business cycle fluctuations, while still generating the large changes in export flows that accompany permanent trade liberalizations. Alessandria, Kaboski, and Midrigan (forthcoming) model importers who make inventory decisions faced with uncertainty not over policy, but over local demand. They show how inventory adjustment plays an important role in explaining the response of trade to a sharp change in relative prices. The model presented here is similar in that inventories play an important role, but we focus on exporters faced with uncertain demand driven by changes in policy.

Bovine Spongiform Encephalopathy in Canada

On May 20, 2003 a cow in Alberta, Canada was reported as having a confirmed case of Bovine Spongiform Encephalopathy (BSE) or "mad cow disease." This announcement led to an immediate worldwide ban on imports of beef from Canada. The dramatic decrease of beef exports is visible in figure 1, which plots the exports of Harmonized System code 0201 (fresh or chilled beef) from the United Nations' Comtrade database. By September 2003, the United States—the recipient of almost 90 percent of Canadian beef exports—allowed imports of beef from animals under the age of 30 months with special permits, essentially ending the ban (Boame, Parsons, and Trant 2004).

The effect of the export ban on cattle prices was immediate. Figure 2 plots Canadian prices of cattle and calves. The price series is the Farm Product Price Index for cattle and calves from Statistics Canada. Between May and July prices fell more than 60 percent. Prices rebounded in September as the ban was lifted, but did not return to their pre-ban prices. This is partially driven by the prices before the BSE discovery: prices were at a cyclically high point in early 2003.

Cattle marketings (the sales of finished cattle) and new *cattle placed on feed* fell sharply with the discovery of BSE as well: between April and May marketings fell 26 percent and new cattle placed on feed fell 55 percent. The data on cattle stocks are from Canfax and cover stocks in Saskatchewan and Alberta, Canada's largest cattle producing provinces. In response to the turmoil in the domestic cattle market, the Canadian government began a program to provide supplemental payments to cattle producers to bolster the price of finished beef cattle. The program began in mid-June and ended August 31, 2003. The program had some success in increasing slaughter rates from their June levels, but significant inventories remained.

Model

In this section we present a simple model of finished beef cattle production. In more general models, such as Murphy, Rosen, and Scheinkman (1994), producers choose which cattle to finish and slaughter and which cattle to keep as breeding stock. For simplicity, we abstract from the breeding stock decision. This may be a reasonable assumption given the short time horizons we are considering, but this assumption could be relaxed, providing richer dynamics and predictions on breeding stock outcomes as well. In what follows, we model the decision problem of a feedlot operator. Taking prices as given, the operator chooses how many calves to put on feed and how many of the stock of finished cattle to market.

In each period, the producer chooses the level of investment in calves to put on feed, x. An investment of x produces x^{α} finished cattle in the following period. This time to build assumption makes the production decision inherently forward looking. The parameter $0 < \alpha < 1$ adds concavity to the production of finished cattle. As we are abstracting from breeding stock decisions, this concavity reflects the fixed stock of breeding cows and restricts the ability of producers to quickly increase cattle stocks. The concavity in production also ensures a unique steady state. The cost of putting cattle on feed is p_x.

The producer also chooses how many of the stock of finished cattle to market, $c \leq b$. If the producer chooses $c < b$, he incurs a cost to keep the remaining cattle until the next period. We define the carried over inventory as $s = \max\{b - c, 0\}$ and the cost of holding inventory as the function $\eta(s)$, with η strictly increasing, strictly concave, and $\eta(0) = 0$. The cost of holding inventories is paid in units of the investment good. We denote the beginning of period stock of finished cattle b. Next period's stock of finished cattle is made up of the newly fed cattle and the finished cattle held over,

(1) $$b' = b - c + x^{\alpha} .$$

Finished cattle prices follow a first order Markov process, so the state variables of the producer are the stock of finished cattle and the price of finished cattle. The producer maximizes expected discounted profits; the problem can be formulated recursively as

(2) $$V(b, p) = \max_{x,c,s} pc - p_x x - p_x \eta(s) + \beta EV(b', p') ,$$

subject to the law of motion (1), $s = \max\{b - c, 0\}$, and $c \leq b$. At an interior solution, the first order condition with respect to c implies

(3) $$p + p_x \eta'(b - c) = \beta EV_1(b', p') .$$

The left hand side of (3) is the marginal value of selling an extra unit today: the price earned from the sale plus the savings in inventory holding costs. The right hand side is the discounted, expected marginal benefit of holding one more unit of finished cattle in the next period, where V_1 denotes the derivative of the value function with respect to b. The first order condition with respect to x is

(4) $$p_x = \alpha x^{\alpha-1} \beta E V_1(b', p') ,$$

which equates the cost of putting cattle on feed with the discounted expected marginal value of finished cattle in the next period.

The producer's choice over inventory and investment depends on the expected value of the marginal unit of cattle in the future. In states where the price of finished cattle is low—during the export ban—the marginal value of holding an extra unit of finished cattle is low. The longer the ban is expected to last, the stronger is the effect on the expected future value of holding inventory. It is through this channel that uncertainty in trade policy will impact the producer's decisions.

Modeling an Export Ban

The ban on imports of Canadian beef, as well as the decrease in domestic demand, led to a sharp drop in the price of cattle in Canada. This is evident from figure 2: the average price of cattle from June to August is 51 percent lower than it was from March to May. We model the import ban as an unforeseen decrease in the price of beef cattle, with an uncertain duration.

Formally, we model the ban as a two state Markov chain: the price of cattle can be high, p_H, or low, p_L. The probability of continuing in the low state is π_{LL}, thus the probability of exiting the low state is $\pi_{LH} = 1 - \pi_{LL}$. For simplicity, we assume that the high price state is absorbing, $\pi_{HH} = 1$. These assumptions create a scenario in which the producer is surprised by the export ban; the ban lasts, on average, $1/\pi_{LH}$ periods; and once the ban is lifted, it is never reapplied.

Numerical Experiments

A full quantitative accounting of the export ban in Canada is outside of the scope of this paper. Nevertheless, the experience of the Canadian cattle industry is informative in setting parameter values, and it places the results into context. Our goal is to use the model to understand how different beliefs about the export ban affect the producer's choices and to measure the expected length of the ban at its inception.

Parameter Values

We set the period length to one quarter and set $\beta = 0.99$. The export ban on Canadian beef lasted about one quarter: it was in place from the last week of May to the end of August in 2003. Our choice of period length implies that the export ban in the model lasts one period. This also implies, however, that the time it takes to feed a calf to marketable weight is one period. This is at odds with biology; depending on the beginning weight of the calf it can take between 6 months and one year to finish an animal. While a model with several periods of time to build would be more suitable, it also comes at a substantial cost in terms of state variables. The extra time to build would create more complex dynamics, but it would not change the qualitative nature of our findings.

Since we are not modeling the breeding stock decision, we chose to make the production function for turning feeder calves into finished cattle concave. This is meant as a stand in for further time to build; we are essentially making it costly to adjust the stock of cattle quickly. We set $\alpha = 0.6$, implying substantial concavity in the production function.

The inventory cost function is parameterized as a quadratic, $\eta(s) = \xi s^2$. We set ξ based on the feed and non-feed costs of finishing cattle. As a fraction of the total cost of finishing cattle, feed makes up about 70 percent (Comerford et al. 2001). In our baseline calibration, we assume that holding a finished steer requires half the ration of feed, so that feed costs are 35 percent of the cost of finishing a steer. We assume that the non-feed costs stay the same (30 percent), so the total cost of holding finished cattle relative to the cost of finishing cattle is 65 percent. We set ξ so that the cost of holding the entire steady state stock of cattle as inventory is 65 percent of the cost of feeding the same number of new calves; that is, we choose ξ so that $0.65 p_x x_{ss} = p_x \xi (b_{ss})^2$. This implies $\xi = 0.84$. We will check the sensitivity of the model to different values of ξ.

We normalize the price of investment, p_x, to one. We model the export ban as a 51 percent decrease in the price of finished cattle, p. This is the change in the quarterly average price from the 3 months prior to the ban and the 3 months of the ban. We set the probability that the ban is removed to 0.99, implying that the average duration of the ban is 1.01 periods. This implies that the producers in Canada correctly assumed that the ban would last one quarter. By varying this parameter and comparing the responses in the data and the model, we can gain insight into how long the ban was expected to last.

A Permanent Export Ban

Before turning to the effects of an uncertain policy, it is useful to discuss the impact of a permanent export ban. When the export ban is temporary, the producer has an incentive to hold stock over to be sold when the price recovers. Holding inventories is costly, though, so the producer decides how many units to hold in inventory according to (3). When the ban is permanent, the producer understands that the price of finished cattle will never recover so there is no incentive to hold costly inventories. Figure 3 plots the marketings of cattle (sales) and the new cattle placed on feed (investment) when the ban is permanent. The stocks of finished cattle that were ready when the ban was imposed are sold immediately. The number of cattle placed on feed falls immediately as well, and the economy transitions to the new steady state. In this steady state with permanently lower prices, stocks and sales are 34 percent of their pre-ban values.

A Temporary Export Ban

To analyze the effects of a temporary export ban, we start the economy in the steady state with the high price. We then subject it to the export ban, lowering prices by 51 percent. The ban lasts for one period—three months—as it did in 2003. Figure 4 plots the marketings of finished cattle in the model for various levels of π_{LH}. The impact of the beliefs over the length of the ban is clear: when producers expect the ban to be short ($\pi_{LH} = 0.99$) the marketings of cattle fall 65 percent as producers accumulate inventories and wait for the price to recover. As the probability of the ban ending is lowered, the producer increases marketings, as the cost of carrying inventory is offset by the lower expected profit from holding an extra unit.

In the period that the ban is lifted, sales surge in the cases where producers held back large inventories. In the case where the producers expected the ban to last much longer than it actually did, sales fall relative to the pre-ban levels. The dynamics of sales in the period following the ban are not only driven by inventory decisions but also investment decisions. Figure 5 plots the cattle placed on feed, the investment in finished cattle for next period. When the ban is expected to be only one period long, the investment decision changes little; the time to build nature of production implies that the calves will be ready for market as the price recovers. If the ban is expected to last longer than the time it takes to produce a fed steer, the investment rate falls. In the case where $\pi_{LH} = 0.01$ the investment rate falls by so much that when the ban is over—unexpectedly—the cattle on hand are actually less than pre-ban levels. This producer, anticipating low prices for the coming future, had liquidated his stock to save on inventory costs and moved to the lower levels of cattle associated with lower prices.

Expectations in Canada

We can use the model to make an inference about the expected length of the ban. In Canada, the number of cattle marketed in June 2003 fell by 26 percent from May of the same year. To generate a fall of 26 percent in marketings in the model, we need $\pi_{LH} = 0.41$. This implies that the expected length of the ban is 7.3 months, about 2.4 times longer than it was in reality. Given the expected length of the ban, the number of new cattle put on feed in the model falls by 59 percent. In the data the number of cattle put on feed in June fell 55 percent from the value in May. Despite the simplicity of the model, its behavior is consistent with the data.

We report the sensitivity of our findings to the inventory cost parameter, ξ, in table 1. The second column of table 1 displays the ratio of sales in the first period of the ban to sales in the previous period. Not surprisingly, the larger are the costs of holding inventories, the smaller are inventories held over, and the larger are sales in the first period of the ban. In the third column we list the value of π_{LH} that is needed to match the decline in sales that we see in the data. The second row is our baseline calibration: with $\pi_{LH} = 0.41$ the expected length of the ban was 7.3 months. With higher inventory holding costs, the probability of returning to high prices must be 0.52 to generate enough inventory accumulation. The implied length of the ban in this scenario is 5.8 months.

Conclusion

Uncertain policy is a fact of life. For industries in which production requires time to build and in which inventories are important, the amount of uncertainty surrounding trade policy can change—both quantitatively and qualitatively—the impact of a policy. Producers rationally hold costly inventories if they believe that conditions will improve in the future. If the expected improvement is small, or perceived as unlikely, producers will liquidate their stocks to save on inventory costs. Using a simple model, and the behavior of inventories and investment during the ban on Canadian beef, we find that Canadian producers expected the ban to last 5.8 months, compared to the 3 months it actually lasted.

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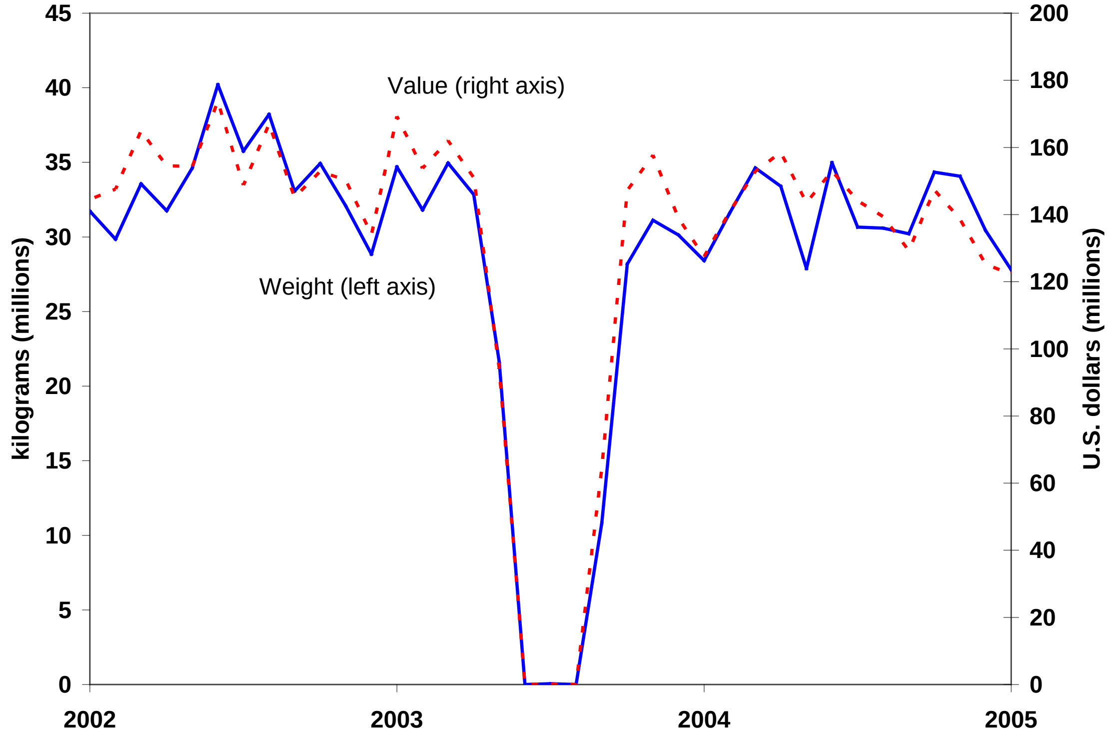

Figure 1. Total monthly exports of beef from Canada.

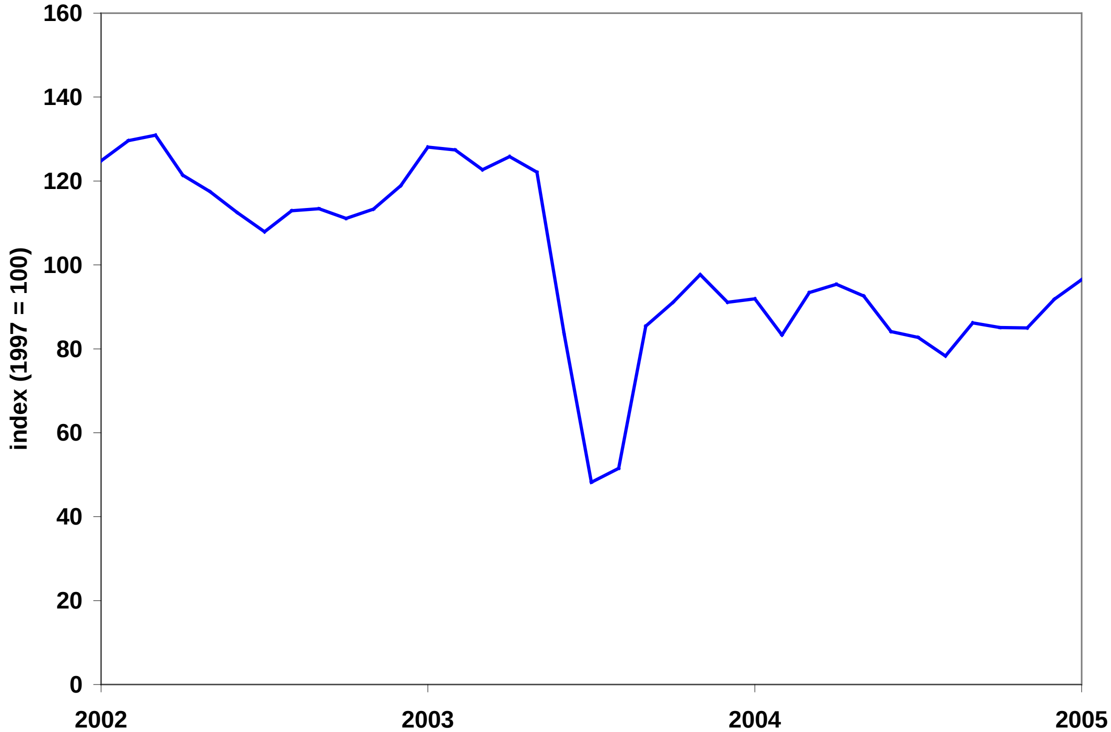

Figure 2. Price index of Canadian cattle and calves.

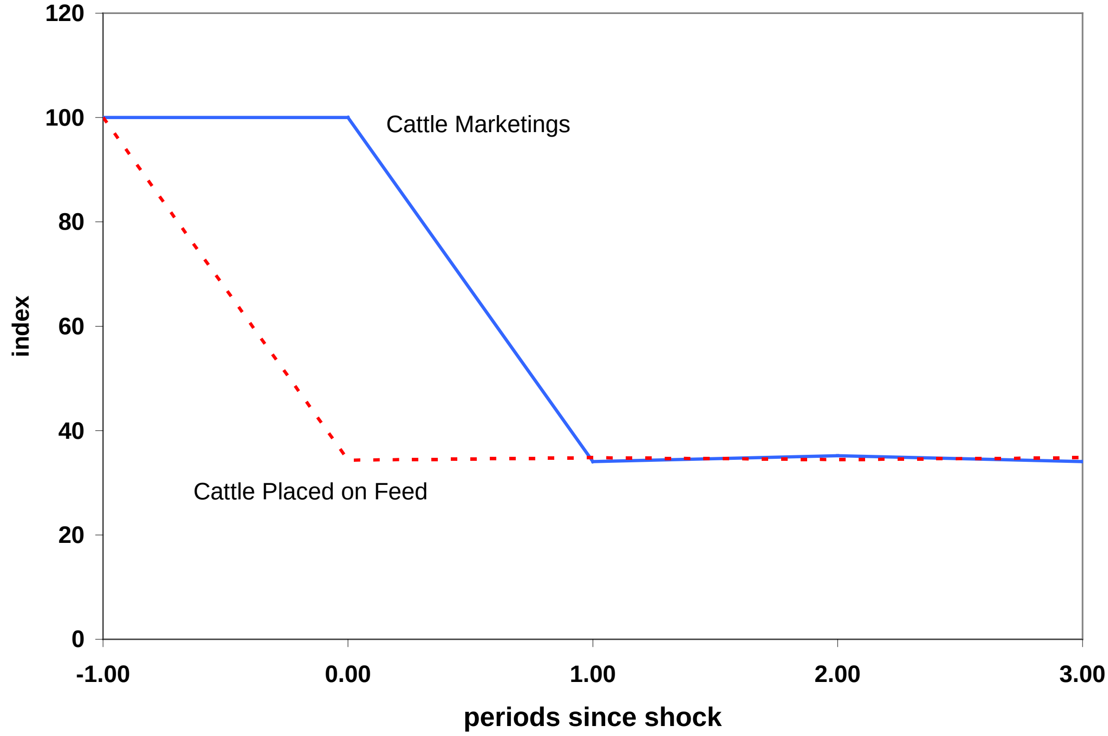

Figure 3 Cattle marketings and new cattle placed on feed under a permanent export ban.

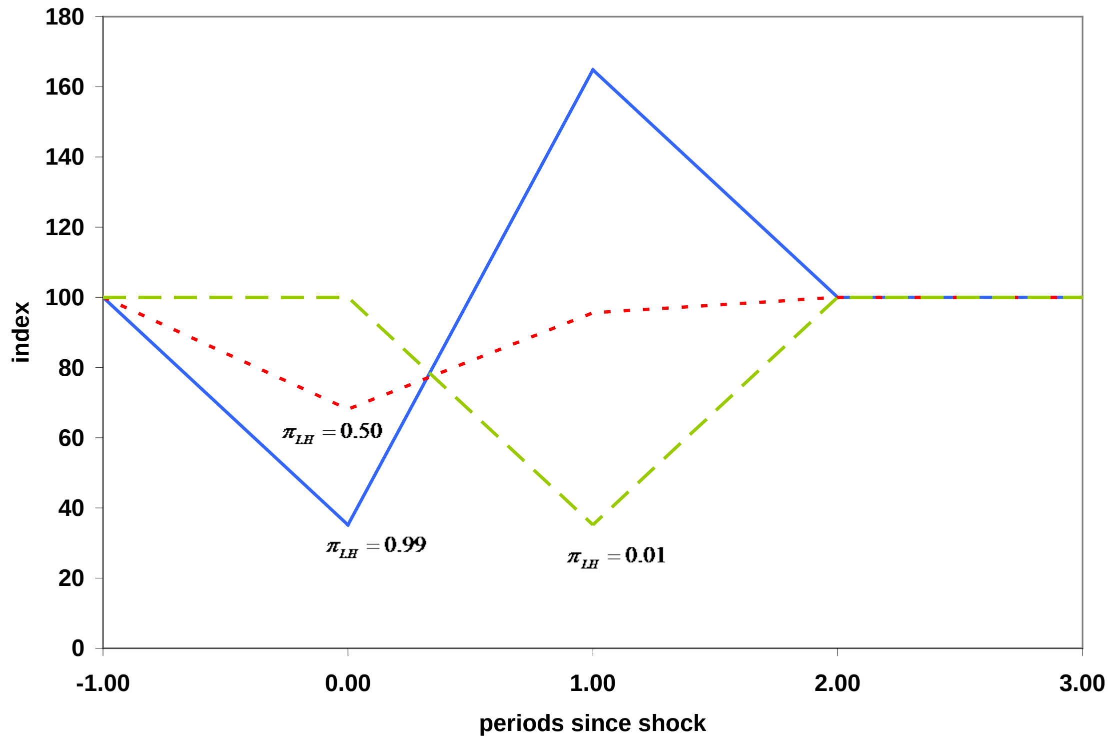

Figure 4. Marketings of finished cattle. π_{LH} is the period probability that the ban is lifted.

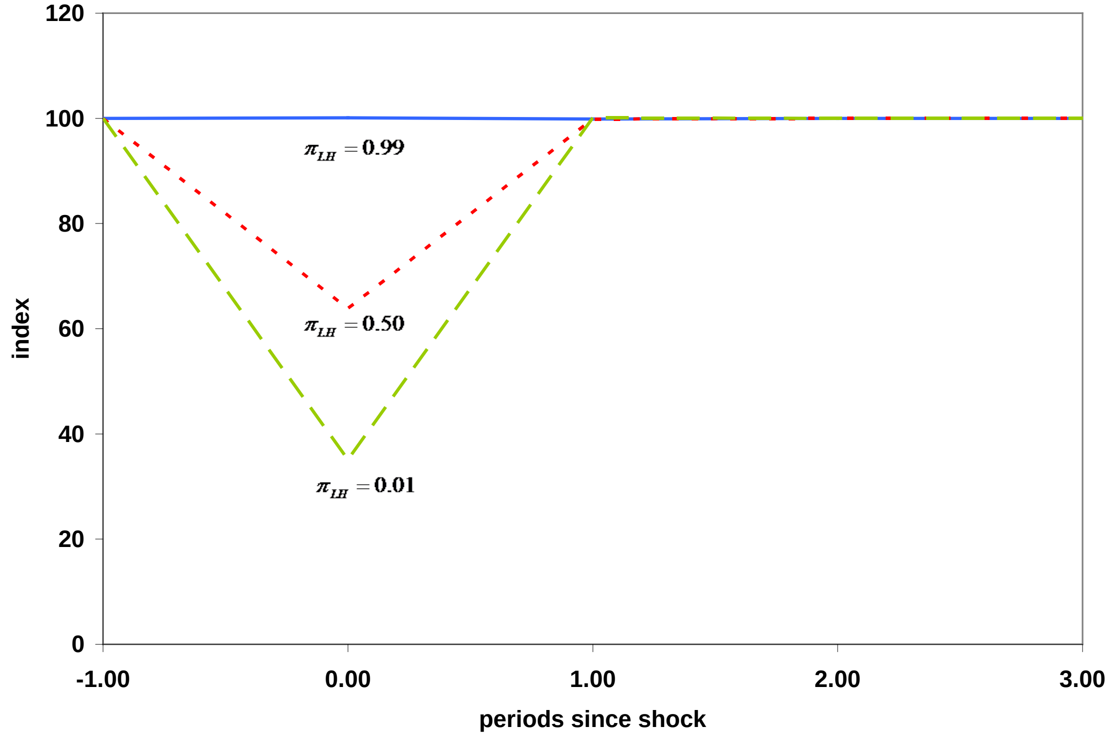

Figure 5. New cattle placed on feed. π_{LH} is the period probability that the ban is lifted.

Table 1. Sensitivity to Inventory Holding Costs

Inventory Holding Cost	c_0 / c_{-1}	Calibrated π_{LH}
$\xi = 1.11$	0.516	0.52
$\xi = 0.84$	0.352	0.41
$\xi = 0.39$	0.000	0.19

Notes: c_0 / c_{-1} are the cattle marketings in the first period of the ban relative to the period prior to the ban, for various values of the inventory holding cost parameter. These values are calculated holding fixed the remaining parameters. Calibrated π_{LH} is the probability of the ban being lifted that is needed to generate a 26 percent decrease in sales in the first period of the ban.