New methods for integrated models of animal disease control

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Selected paper prepared for the 2007 American Agricultural Economics Association Meetings, Portland, Oregon, 29 July-1 August 2007

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ABSTRACT

Accurate assessments of the epidemiological and economic impacts of an animal disease require the incorporation of feedbacks between disease spread and production incentives. This paper motivates a new modeling framework that is sensitive to the dynamics of disease, production decisions and incentives, different livestock production systems, and their interaction through the use of an integrated system dynamics framework. Preliminary simulation results are provided to demonstrate proof-of-concept of such an approach, with additional discussion given on extensions and implications of integrated methods.

Keywords: Animal disease control, simulation modeling, system dynamics

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Introduction

Economic analysis plays an increasingly important role in animal disease control models (Rich, Miller, and Winter-Nelson 2005). To date, the most sophisticated assessments of animal diseases have combined a form of benefit-cost analysis with epidemiological models of disease spread (e.g., state-transition models) to assess the costs and benefits of alternative control strategies (Miller, Tsai, and Forster 1996; Horst 1998; Ekboir 1999; Perry et al. 1999; Mahul and Durand 2000; Randolph et al. 2002; Perry et al. 2003; Rich and Winter-Nelson 2007). These tools have become increasingly sophisticated over the past several years, particularly on the economics side, with models evolving from relatively simple accounting frameworks towards analyses utilizing social accounting matrices, computable general equilibrium models, multi-market approaches, and spatial analysis (Rich and Winter-Nelson 2007). Consequently, such approaches have increased the diversity of information available to decision makers, incorporating spatial, dynamic, and poverty impacts for example, and allowed for a greater tailoring of analyses to meet the needs of diverse stakeholders.

While the integration of epidemiology and economics is becoming recognized as an increasingly important approach in conducting economic impact assessments of animal disease, a number of important methodological considerations remain under-researched. In particular, the true integration of epidemiology and economics requires the incorporation of actual feedbacks between economic and disease spread models in a manner that captures how the evolution of disease affects behavior and incentives and vice versa. Consider, for example, the implementation of a stamping out policy in which diseased animals are slaughtered to prevent the further spread of disease. In most analyses, shocks from an epidemiological model, such as the number of animals culled, are translated into an economic model to assess its impact. However, at each period of time, policies to control disease will influence economic incentives to control and producer behavior, which subsequently will affect the evolution of disease over time. Such incentives will differ on the basis of the production system as well. These feedbacks have potentially important (and overlooked) implications, particularly in terms of assessing the impact of alternative control programs and in the design of appropriate compensation programs to promote compliance with control measures.

Relatively few models in the animal health economics literature, however, have considered these feedbacks. The simulation models cited above, for example, only highlight the one-way impact of disease on the economy (production, etc.) without considering how changes in production decisions engendered by the disease might influence how the disease itself evolves and is eventually controlled. This is particularly important in dynamic analyses where the evolution and outcome of an outbreak will have both short- and long-run impacts on future production decisions and second-round effects on feed and input demand. An exception to this is Rich and Winter-Nelson (2007), who address dynamic economic feedbacks based on the outcome of an FMD outbreak in cattle in South America, but do not analyze discrete changes in production choices while the outbreak is taking place. The latter point is especially salient in the context of poultry and pig systems where marketing and re-stocking decisions take place at more frequent time intervals that correspond directly with the evolution of the disease.

A second category of models in the literature utilizes linear programming and optimal control theory to characterize producer decisions to market, test, and screen animals for disease subject to the dynamics of animal stocks and the process of disease evolution. Linear programming approaches generally come from the animal health economics applications found in the veterinary epidemiology literature – for instance, Stott et al. (2003) look at animal disease control decisions at a farm level through a farm planning/MOTAD model. An excellent example of the latter is the work of Bicknell, Wilen, and Howitt (1999). In their model, the authors analyze animal disease control from the standpoint of a profit-maximizing producer choosing levels of marketed animals, a testing strategy for cattle, and a harvest program for culling wildlife that acts as a reservoir for disease, subject to the biological evolution of disease in cattle and the population dynamics of the wildlife reservoir (in this case, possums). Based on this approach, an empirical model was constructed to examine the impacts of various types of public policies including enforced testing, no compensation, user fees for testing, and harvest subsidies for producers. A similar model is a recent contribution by Ranjan and Lubowski (2005), who derive first-order conditions of different policy responses in a more simplistic (and generic) optimal control model. Likewise, Horan and Wolf (2005) use optimal control theory in the context of managing wildlife diseases.

While the optimal control framework better characterizes the interactions between producer incentives and animal disease, four limitations are inherent in these present approaches. First, current models do not fully characterize the dynamics of livestock production itself, in terms of the progression of animals from gestation to maturity and producer decisions to hold back inventories for breeding, for example (Rosen 1987; Rosen, Murphy, and Scheinkman 1994). These complex interactions are an important consideration in the development of policies that induce producer compliance with disease control measures. Second, the models of Bicknell, Wilen, and Howitt (1999) and Ranjan and Lubowski (2005) do not endogenize price changes that would occur during an animal health outbreak. Ranjan and Lubowski (2005) consider how producer incentives might change in the wake of a price change in the steady state, but do not look at the process of price changes that both the disease itself and producer responses to it might cause. Third, optimal control programs assume that producers operate with full knowledge about the environment they operate in, especially in terms of the evolution of disease. In reality, however, and particularly among resource-constrained smallholders in developing countries, agents may instead be boundedly rational (Young 1998) and make their decisions and expectations on the basis of past actions and those of agents around them, with incomplete knowledge of how the disease may evolve. Finally, optimal control approaches focus primarily on the steady state rather than the evolution of either the disease or its response, which might be of importance to policymakers in the design of control measures.

This paper develops a novel modeling framework that embodies and integrates both the evolution of disease and the production behavior of producers over time. The conceptual framework of the model is rooted in a system dynamics simulation approach to fully and explicitly model the dynamics and interactions between disease and livestock production. System dynamics models have been successfully used to model production behavior in livestock systems, particularly in the analysis of decisions to breed and market livestock based on the biology of production (Meadows 1970; Ross and Westgren 2007). The approach taken here extends a recent model of Conrad (2004), who developed a system dynamics model of livestock and feed production to analyze a hypothetical FMD outbreak in the United States. Unlike Conrad (2004), however, this paper explicitly models the evolution of animal disease through the use of a simple Susceptible-Infected-Removed (or S-I-R) model commonly used in the epidemiology literature (Anderson and May 1991). The evolution and impacts of disease are directly linked to production and demand in a manner that allows for the analysis of the impacts of disease and strategies to control it. The framework is applied in the context of poultry production and a hypothetical disease outbreak, though the principles can be broadly generalized to other types of animal diseases. Preliminary simulations are conducted to demonstrate proof-of-concept of the approach, with the discussion and conclusions motivating extensions in future settings.

Modeling framework

The basic premise for a truly integrated epidemiological-economic model is in its ability to capture the feedbacks that exist between the evolution of disease and producer responses to an outbreak. Two direct impacts, and their interactions, can be identified, as illustrated in figure 1. First, the introduction of an animal disease, particularly one with impacts on productivity (e.g., FMD) or which induces significant mortality (e.g., avian influenza) will directly affect the stock of animals held by producers, while control measures such as stamping out will likewise reduce inventories. For some diseases, such as FMD or Rift Valley Fever, there will be pronounced impacts among younger animals and on breeding stocks, which will affect inventories in later periods. Second, an animal disease will influence demand, either through a reduction in domestic demand due to perceived food safety concerns (particularly for zoonotic diseases such as avian influenza or BSE) or international demand through trade bans, or both. In both cases, producers will make decisions on the marketing and holding of animals which in turn will have an impact on the evolution of disease itself. For instance, the reported distress selling of infected birds by smallholders in Indonesia due to avian influenza could potentially modulate the long-distance spread of the disease. As noted in the figure, public policies such as compensation, vaccination, or mass culling can further have an impact on producer incentives, which in turn will influence the progression of disease and demand.

<< INSERT FIGURE 1 HERE >>

Accordingly, the next two subsections demonstrate the mechanics of the epidemiological and economic components of a proposed integrated model in a system dynamics framework, with the following section illustrating how each model is linked in an integrated fashion.

Epidemiological model

The epidemiological component of the integrated model follows standard techniques from the epidemiology literature and employs state-transition methods, in which animals (or herds) are partitioned into different states of nature depending on the evolution of disease over time. The most common state-transition model is an S-I-R model (Anderson and May 1991). Animals in an S-I-R model can be either susceptible to disease (*S*), infected (*I*), or "removed" (*R*) from the system. In many models, the removed state is partitioned into two states – animals or herds that are "removed" due to recovery from disease and those that are "immune" due to vaccination. The differential equations that characterize the S-I-R model are presented below in equation (1), where *S*, *I*, and *R* are the population states as defined above and the parameters β and α represent the transition rates from Susceptible to Infected and Infected to Removed, respectively:

$$\frac{dS}{dt} = -\beta SI$$
$$\frac{dI}{dt} = -\alpha I + \beta SI \qquad (1)$$
$$\frac{dR}{dt} = \alpha I$$

The model in equation (1) is simplistic in the sense that it assumes a closed population such that the total population, *N*, remains fixed and that the total number of susceptible, infected, and removed animals at any time period must equal a pre-determined and fixed *N*. In reality, however, animals will enter and leave the population based on migration, births, market movements (e.g., sales of animals for slaughter or export), and mortality that is either attributable to disease or natural. In addition, control measures such as vaccination will further modulate the dynamics of the system – in such cases, there will be an additional transition between susceptible animals and removed animals that will depend on the rate of vaccination.

Figure 2 illustrates these additional components in a system dynamics framework as modeled in STELLA (http://www.iseesystems.com). In the figure, the boxes represent the stocks of animals at time *t* that are in the states Susceptible, Infected, or Removed. The arrows between stocks denote flows of animals between states based on the evolution of disease and the entry (and exit) of animals from the system. The model relaxes the assumption that the total population in the system is fixed, and will vary depending on the number of animals that enter and leave the system in each period. At each time period, a certain number of animals enter the system as susceptible animals based on the birth of new animals (here, denoted by the parameter "hatching"). If there is no disease, animals remain in the state Susceptible until they are either sold for slaughter or die naturally. <<INSERT FIGURE 2 HERE>>

In the event of a disease outbreak, animals will move between the states Susceptible and Infected based on the rate of contact between susceptible and infected animals and the level of infectivity of the disease, the product of which defines β as in equation (1). Once infected, animals will either die from the disease depending on the rate of mortality inflicted by it or will recover after a certain period of time as noted by the duration of infectivity in the figure (α in equation (1)). Control measures such as vaccination can be modeled (as shown in the figure) by incorporating a transition rate directly between Susceptible and Removed that depends on the rate at which susceptible animals can be vaccinated. Other control measures that can be analyzed include movement controls, modeled by reducing the contact rate between susceptible and infected animals, and the stamping out of exposed, susceptible herds that can be modeled by including an additional flow of animals exiting the stock of susceptible animals and calibrated by the rate of contact slaughter.

Economic model

The economic model employed in this paper models the population dynamics of animals between different states of nature (based on animal ages) that is integrated with the movement of supply, demand, and prices over time. The structure of the model, as illustrated in figure 3, is based on the system dynamics models of Meadows (1970) and Conrad (2004) that were applied to hogs and cattle, respectively. The application in figure 3 illustrates a hypothetical integrated poultry system, in which birds move from eggs to chicks to growers and finally to mature birds for slaughter. Certain growers are reserved as breeding stock to replenish the system. Such a system more accurately characterizes village poultry systems rather than specialized industrial poultry settings for broiler or layer production (Johnston 1991; Rushton 1996; Kitalyi 2000; Udo et al. 2006). At the same time, the model is a simplification of village settings in the sense that the entry and exit of chicks and growers, for example, from purchases or sales, is assumed to be zero, although modeling these markets explicitly can be easily incorporated.

<<INSERT FIGURE 3 HERE>>

Following Rushton (1996), birds are assumed to remain in the state Eggs for three weeks until they are hatched and become chicks. Chicks mature over a five-week period after which they move into the Growers state, where they remain for 14 weeks. Growers can be moved into the Breeding Stock during this period or can be sent to the market for slaughter. Birds that move into the Breeding Stock remain there for an assumed period of one year (52 weeks), after which they are sent to slaughter. The movement of birds from Growers to Breeding Stock will depend on the number of birds desired by producers to be held in stock and which is influenced by changes in market prices. As meat prices rise, producers will want to hold more birds in stock to take advantage of these price movements (Conrad 2004).

On the demand side, birds that are slaughtered are held in inventory from which sales of poultry meat are drawn. The model assumes that retailers hold two weeks of inventory of poultry meat (this could be frozen meat, for example). Following Whelan and Msefer (1996), changes in meat inventories drive price changes in the system dynamics model that equilibrate supply and demand. When demand exceeds supply, inventories are drawn down below desired levels of inventory, causing prices to rise. This rise in prices reduces demand and increases supply to move supply and demand closer to equilibrium, although this process of inventory adjustment may take many periods to eventually equate supply to demand.

A number of impacts arising from an animal disease outbreak in this system can be considered. First, the disease could cause productivity losses or mortality in the production cycle. In figure 3, mortality is modeled through the exit of birds from each of the different states of nature based on the rate of mortality caused by a disease. While not modeled in the figure, productivity losses could increase the amount of time birds remain in different states due to the need to feed birds for longer periods of time. Alternatively, productivity losses may influence the conversion rate of live birds to meat such that the slaughter weight of live birds that were affected by disease is lower. A second impact, also not modeled explicitly in figure 3, could be the distress selling of animals by producers in each state, which could be represented by a second flow of animals exiting each stock.[1] In addition to these productivity shocks, certain animal diseases (particularly zoonotic diseases such as Avian Influenza or Rift Valley Fever) may also have demand effects that reduce demand for meat during the period in which an outbreak is taking place. Even for non-zoonotic diseases, diseases of international trade such as foot-and-mouth disease may reduce international demand as a result of trade bans, for example, as noted earlier.

The economic model in figure 3 is simplistic in the sense that it omits many important market dynamics that may further influence this system, including sales of immature birds, cost implications in terms of feed, and substitution effects in other markets. Nevertheless, it highlights the dynamic complexities inherent in livestock systems and provides a generic framework for understanding the multi-dimensional impacts of animal disease.

Integration of epidemiological and economic models: methods and preliminary results

The integration of the two models presented in the previous section requires three main adjustments. First, rates of entry and exit for the epidemiological model must be equivalent to the rates of breeding (hatching) and slaughter in the economic model. Slaughter rates must be distributed according to the proportion of birds in the epidemiological model that are in the states Susceptible, Infected, and Removed. This adjustment subsequently links the population dynamics with the evolution of the disease. Second, the impacts of the disease itself from the epidemiological model must be linked with market and population dynamics in the economic model. In this case, the death rate in the epidemiological model that removes infected birds from the system must be distributed across the different states of nature in the economic model (Chicks, Growers, Birds for Sale, and Breeding Stock) according to the proportion of the population in each stock. While certain diseases cause higher levels of mortality for different ages of animals (e.g., younger animals), for simplicity, we assume the same level of mortality for all age groups. In addition, the evolution of the outbreak, as noted by the number of infected animals in the system, may have impacts on demand. In such cases, we can model a leftward shift in demand over the duration of the outbreak, which is measured by the number of time periods in which there are non-zero numbers of infected birds. Finally, it must be the case that the total stock of birds in the economic model (Chicks, Growers, Birds for Sale, and Breeding Stock) is equal to the total number of birds in the states Susceptible, Infected, and Removed.

Figures 2 and 3 highlight these integrative measures between the two models. Hatching and slaughtering flows from the economic model (figure 3) modulate the entry and exit, respectively, of birds into the epidemiological model. Conversely, the death rate in the epidemiological model calibrates the number of birds that exit each stock in the economic model. Shifts in demand resulting from the outbreak are generated by adjusting the intercept of the demand curve for the period of time in which there are outbreaks, measured by the stock of infected birds in the system.

A number of simulations were run with the model to demonstrate the utility of this approach. One should note that parameters chosen for these simulations are all assumed by the author and are merely designed to show proof-of-concept rather than calibrated to any specific empirical application using market data. First, the economic model was calibrated such that initial population levels and supply/demand parameters adjusted to equilibrium values quickly. Simulation results from this exercise set initial values of birds in the economic model at the following: Birds for Sale (13), Growers (182), Chicks (66), Eggs (40), and Breeding Stock (13). The initial price for meat was set at $4/kg and birds for sale were assumed to weigh 2 kg. Elasticities for demand and supply (breeding stock) were assumed to be -1 and 0.15, respectively. Time delays between stocks were assumed as discussed in the previous section following the model of Rushton (1996). For the epidemiological model, the total number of susceptible birds is the total population of Birds for Sale, Growers, Chicks, and Breeding Stock (274). We used parameters from a generic S-I-R model of Sterman (2000) for contact rates (6), infectivity (0.25), and the duration of infectivity (2 weeks).

The model runs using weekly time steps, with an outbreak seeded at the end of a one-year period in week 52 through the introduction of one infected bird. The first set of simulations modeled the impact of a hypothetical animal disease outbreak in which no control measures were taken and which killed one-quarter of the birds that were infected. Figures 4 and 5 highlight the changes in prices (panel 1), sales and packing (panel 2), animal stocks (panel 3), and the evolution of disease (panel 4) for a disease that has just a supply effect and one with both a supply and demand impact, respectively. We assume that demand falls by 20 percent during the outbreak in the latter.

When a disease induces impacts on the supply side only, there is a significant increase in price that occurs with a lag, as the impact of the disease on the production cycle is delayed until enough affected stock is sent to market (figure 4, panels 1 and 2). These price increases cause a noticeable decline in sales which persists and remains below pre-disease levels even one year after the first outbreak. The rise in prices induces a short-lived increase in breeding stock to rebuild animal inventories once the outbreak has subsided, but subsequent waves of endemic disease depress animal stocks, causing lower and cyclical behavior in supply and demand (figure 4, panels 2 and 3). The lack of control efforts in the baseline creates dampened waves of disease that recur as new susceptible animals enter the system (figure 4, panel 4), with the peak infection occurring during the first outbreak. When demand is assumed to decline as well due to the disease (figure 5), price behavior is more changeable, with an initial fall in prices at the onset of the outbreak, and a price spike (with a lag) due to a combination of reduced inventories from disease and the demand curve shifting back to normal as the disease abates (figure 5, panel 1). The disease causes sales to initially plummet, which subsequently recover sharply owing to lower prices once the disease has been controlled (figure 5, panel 2). However, this is short-lived, as the impacts of the disease-induced inventory shock work their way through the system just after week 60 (figure 5, panel 3), causing a sharp rise in prices and concomitant fall in sales, with cyclical behavior tracking the future waves of disease. <<INSERT FIGURE 4, FOLLOWED BY FIGURE 5>>

While not readily apparent in figures 4 and 5, the evolution of the disease is affected by whether the disease causes only a supply shock or a combined supply and demand shock. Figure 6 graphs the evolution of infected animals under different assumptions of demand shocks (no shock, 12.5 percent, 25 percent, 37.5 percent, and 50 percent reduction in demand, respectively). The evolution of the initial outbreak is not noticeably affected by whether there is a demand shock, but future waves of infection are slightly influenced (figure 6). In particular, large shocks in demand (label 1 on figure 6) lead to slightly more dampened outbreaks relative to those cases where demand is less influenced by the disease, ostensibly due to the greater initial disruption to animal stocks caused by shocks to supply and demand that reduce the total future number of animals potentially susceptible to disease. This has potentially important ramifications in the design of control strategies and suggests a need for greater sensitivity to the effects market behavior may have on the evolution of disease.

Figure 7 illustrates the impacts in this system from a vaccination program that begins four weeks after the first outbreak is detected. We assume that the program vaccinates 80 percent of susceptible birds at the height of the outbreak (i.e., when the number of infected birds is greater than 5) and 50 percent subsequently. This simulation also assumes a supply and demand shock as highlighted before in figure 5. With a vaccination program, we find similar results as without control in terms of the movements of prices and sales as in figure 5. The main difference in this case is that the magnitude of impacts is lower – while prices fall due to a decrease in demand, the rise in prices associated with the (lagged) reduction in inventories is mitigated by the shorter duration and fewer number of birds affected by the disease (figure 7, panel 1). Impacts on sales follow price movements, while effects on animal inventories are noticeably more modest and recover to pre-outbreak levels relatively quickly (figure 7, panels 2 and 3). Likewise, the vaccination strategy leads to a relatively short outbreak that affects only a small number of birds (less than 10, see figure 7, panel 4). Changes in the timing of the establishment of the control program considerably impact the dynamics of this system, as shown in figure 8. In this figure, we illustrate the impact on market prices resulting from both a three-week delay in mobilizing a vaccination strategy and a strategy that begins three weeks earlier. While the pattern of price movements is similar, the price spike and fluctuations in future periods are noticeably reduced by an earlier vaccination policy. The effects of other control strategies were not modeled in this application, but simulation analysis along the lines of Schoenbaum and Disney (2003), for instance, that assessed the combined market-disease impacts of alternative control strategies at the level of the production system would be quite relevant.

The preliminary results from this integrated framework illustrate both the multi-faceted impacts of animal disease and the need to understand the close synergies between economic behavior and disease evolution. Future research and extensions of this approach, as discussed in the next section, will enrich this platform and provide greater insights on the relative importance of specific parameters that might have policy relevance during disease outbreaks.[2]

Discussion and future extensions

Integrated analyses of the epidemiology and economics of disease are of critical importance to capture the behavioural implications of proposed animal health interventions. The proposed methodology is unique in that responses to a disease outbreak, both from the standpoint of the disease itself and responses to it by producers and markets, are captured simultaneously. This adds value to previous analyses that viewed either the epidemiology or the economics of the disease as an exogenous "shock" to the other and failed to realize the feedbacks between each that have policy ramifications. For example, preliminary model results highlight that despite delays in disease impacts due to lags in production coming to market, prompt policy responses may be required to mitigate against price fluctuations in the market caused by an outbreak.

The presented model was necessarily simplistic and would be augmented by a number of important extensions and if calibrated to actual outbreaks. Most critical among these extensions is to model household production systems with more precision and in a manner that recognizes the multi-faceted contributions of livestock to livelihoods and behavioral responses of household shocks to income (Behrman, Foster, and Rosenzweig 1997; Fafchamps, Udry and Czukas 1998). For instance, one could conceive extending this system in a manner that looks at the asset decision patterns of households and which takes into account the production dynamics of livestock, market relationships and feedbacks, and the evolution of specific diseases on these decisions. The interaction of household systems with industrial production could likewise be included. Additional extensions would look into the interactions in livestock production with other goods, including feed, and the substitutability of diseased livestock products with other non-impacted meat products (e.g., substituting beef for poultry during an avian flu outbreak).

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Figure 1

Framework for an integrated epidemiological-economic model of animal disease control

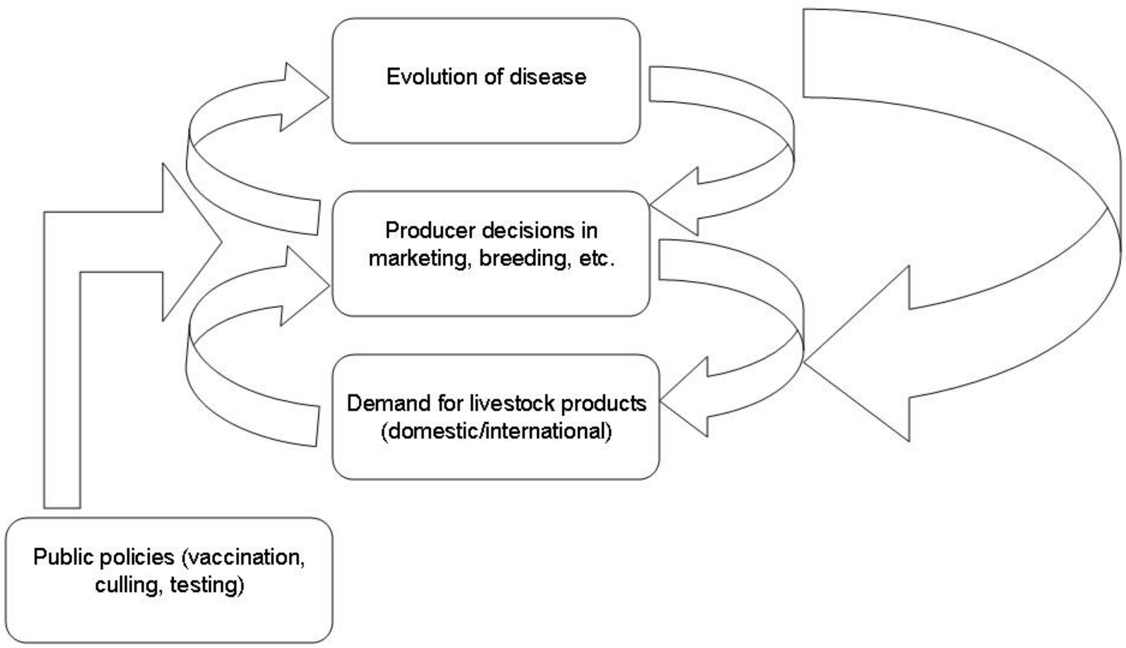


Figure 2

Epidemiological component of an integrated epidemiological-economic model

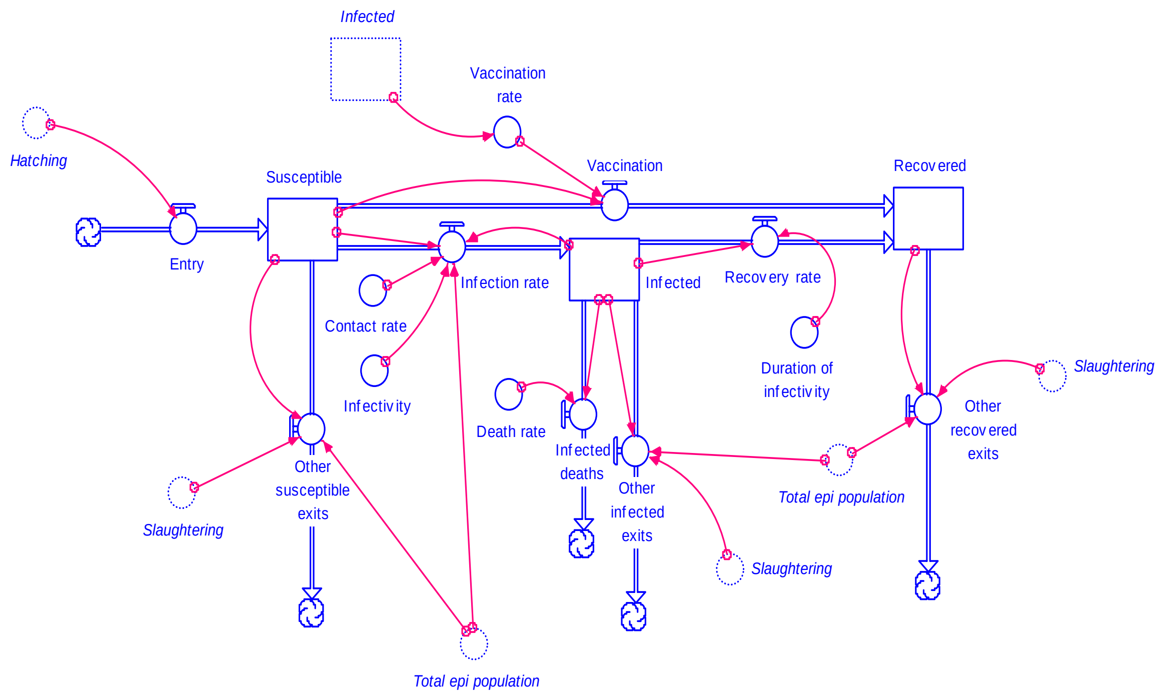
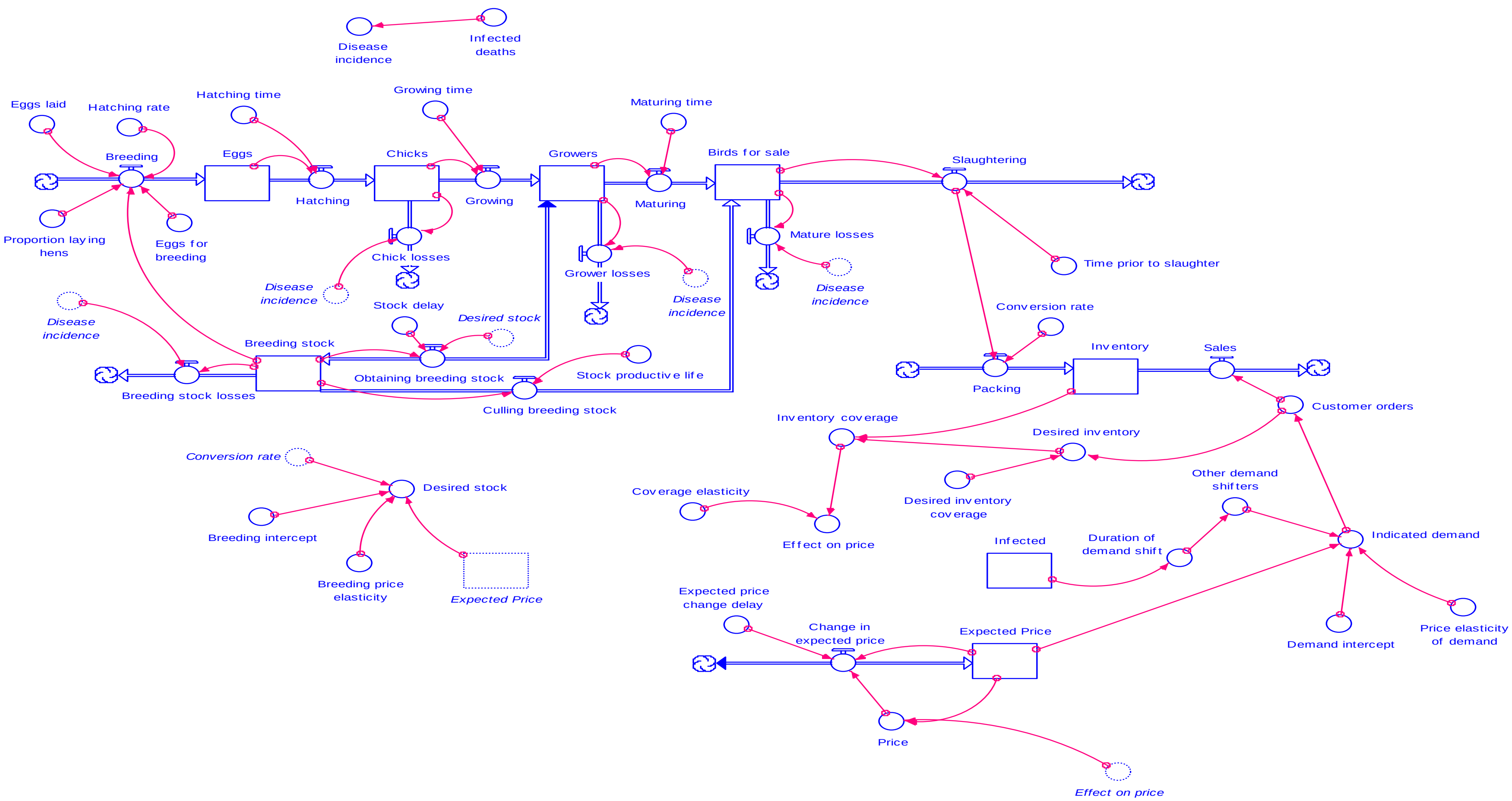


Figure 3

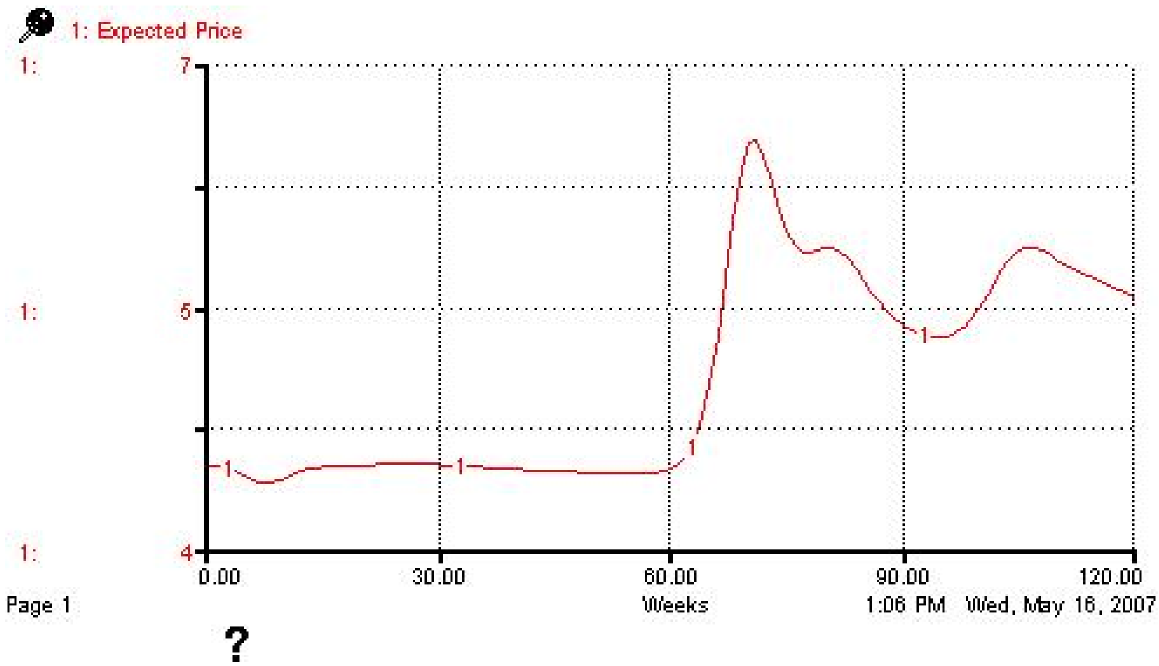
Economic component of an integrated epidemiological-economic model



Source: Adapted from Meadows (1970), Whelan and Msefer (1996), and Conrad (2004)

Figure 4

Impacts of a hypothetical animal disease outbreak on prices, sales, inventories, and evolution of the disease itself (with no demand shift)



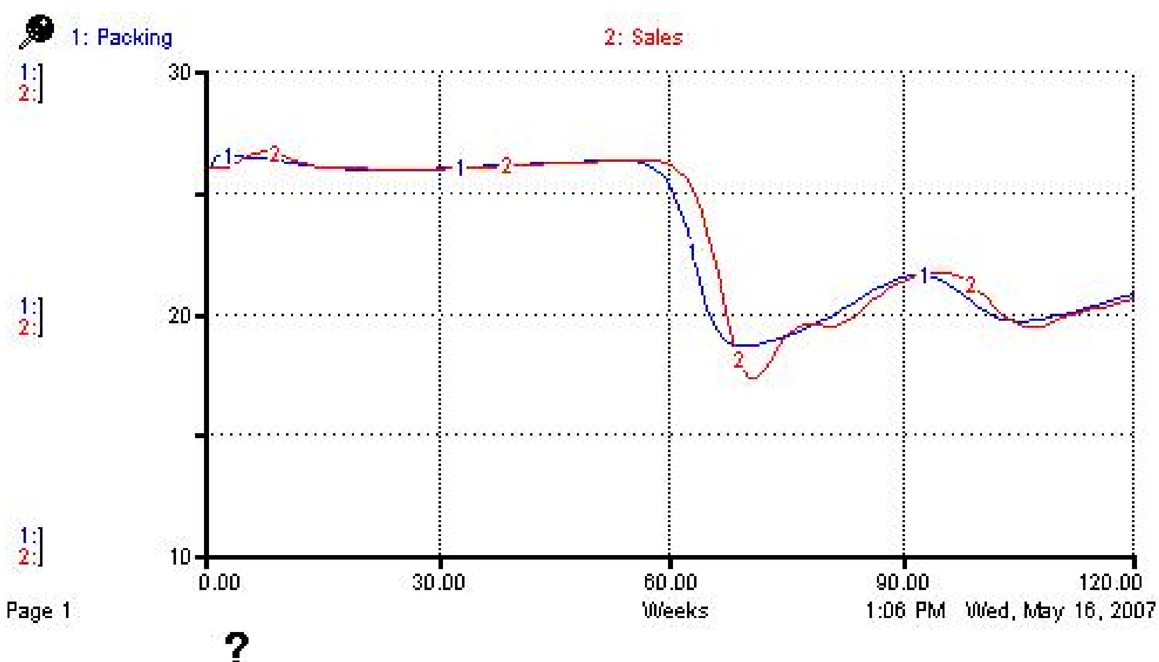
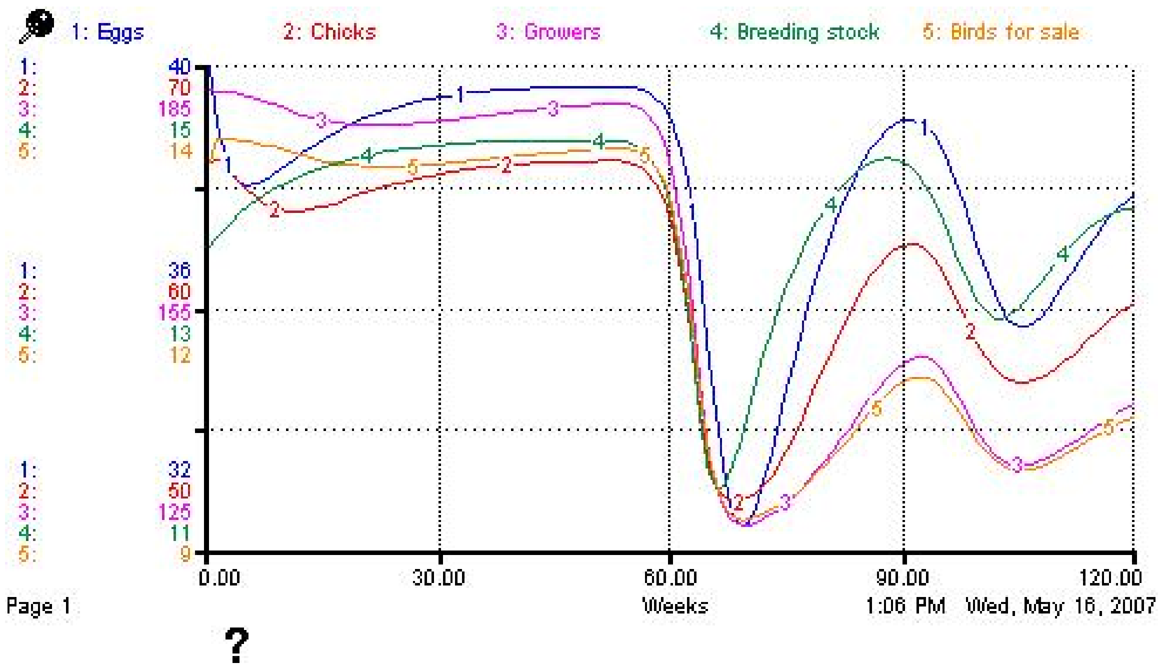


Figure 4, continued



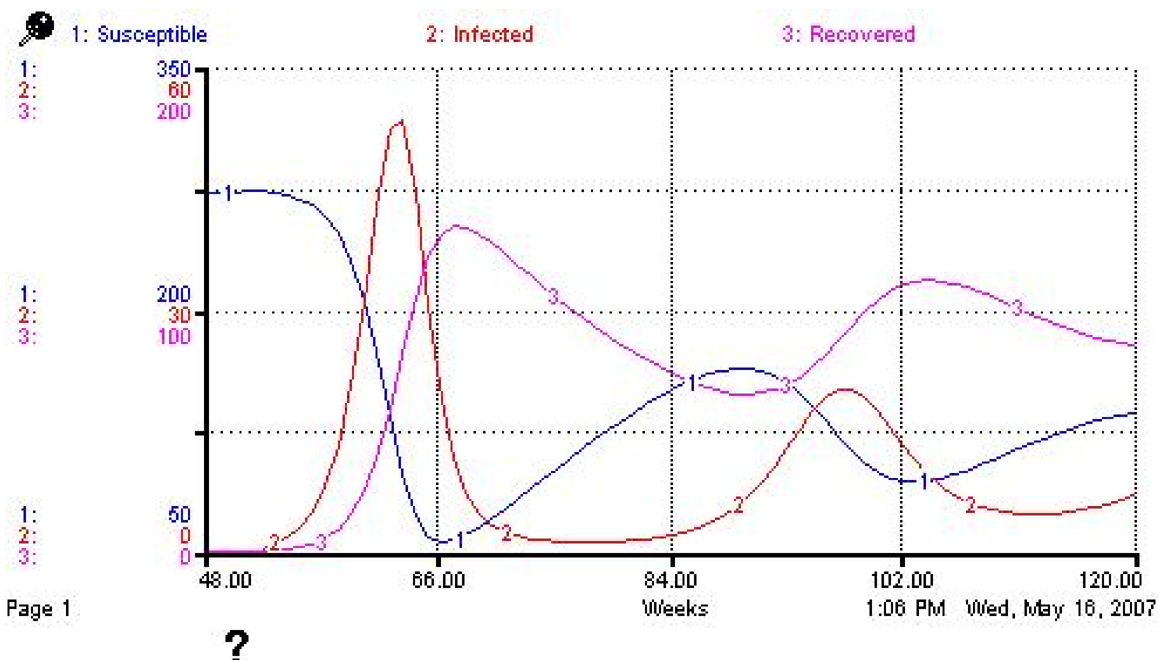
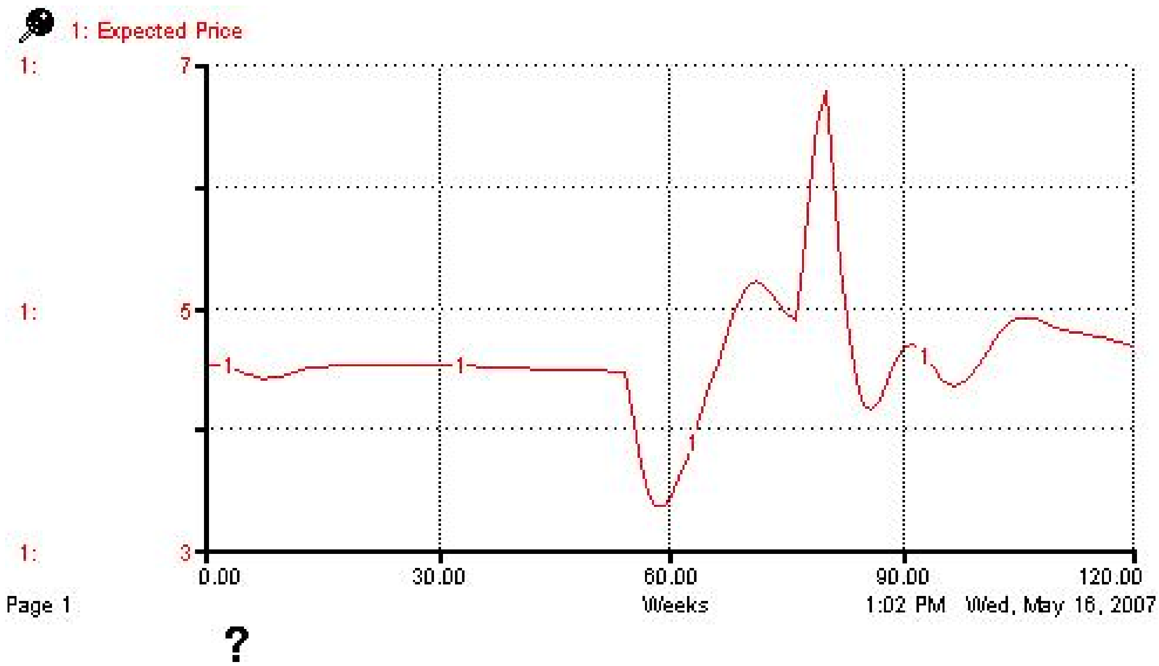


Figure 5

Impacts of a hypothetical animal disease outbreak on prices, sales, inventories, and evolution of the disease itself (with demand shift)



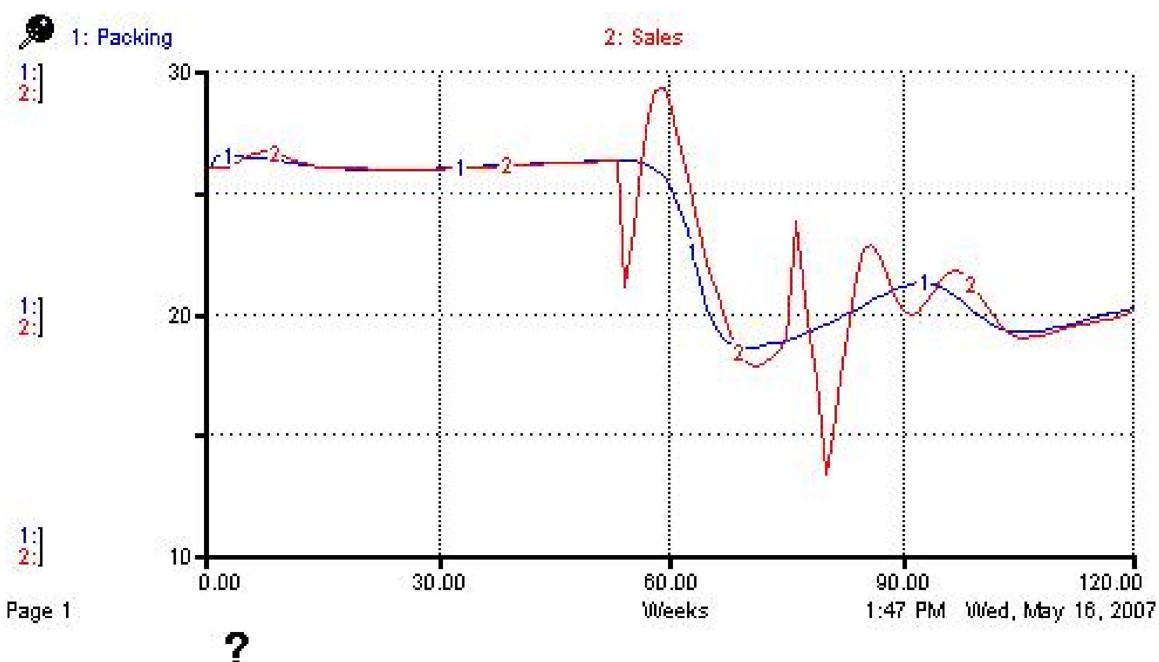
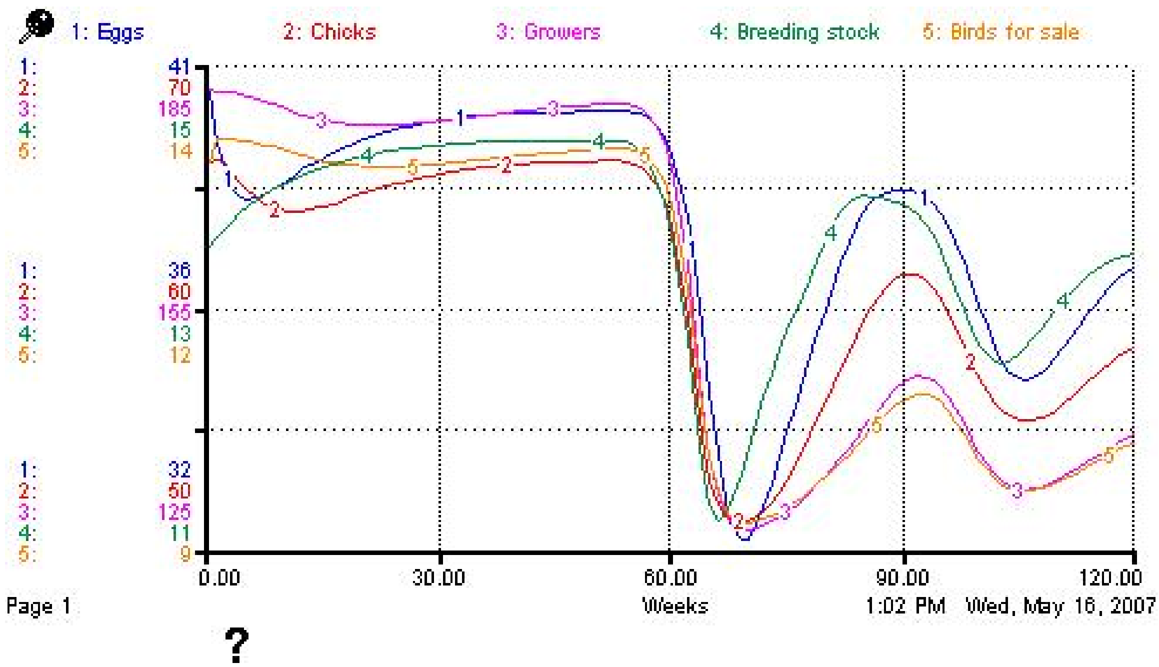


Figure 5, continued



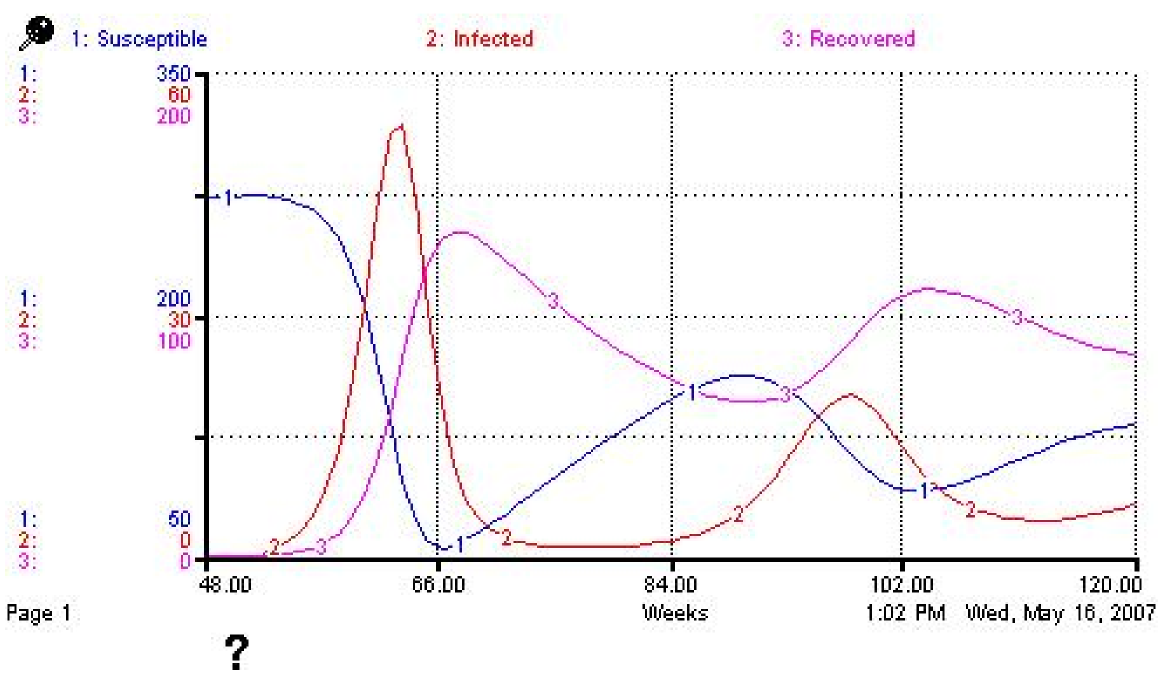
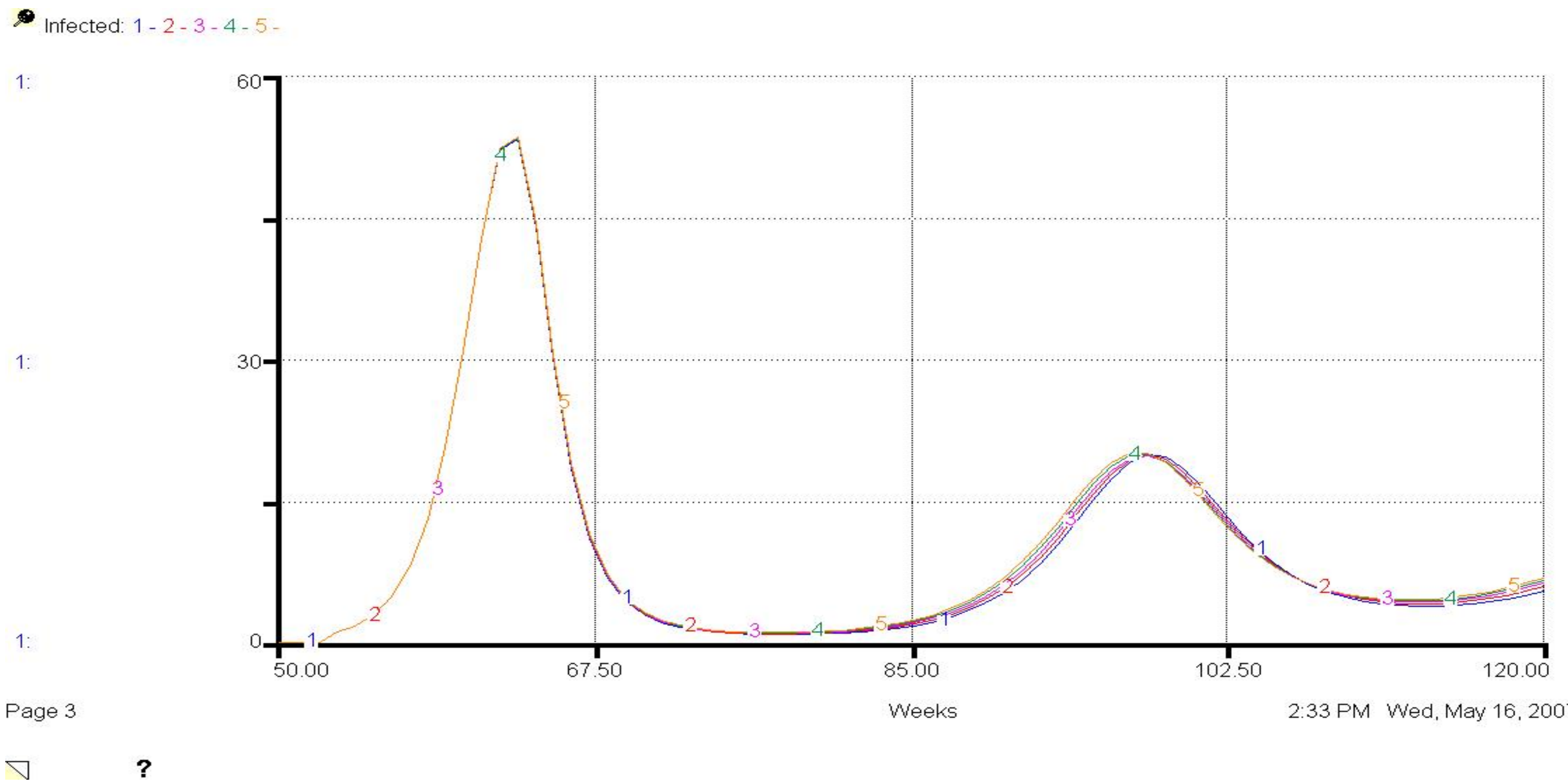


Figure 6

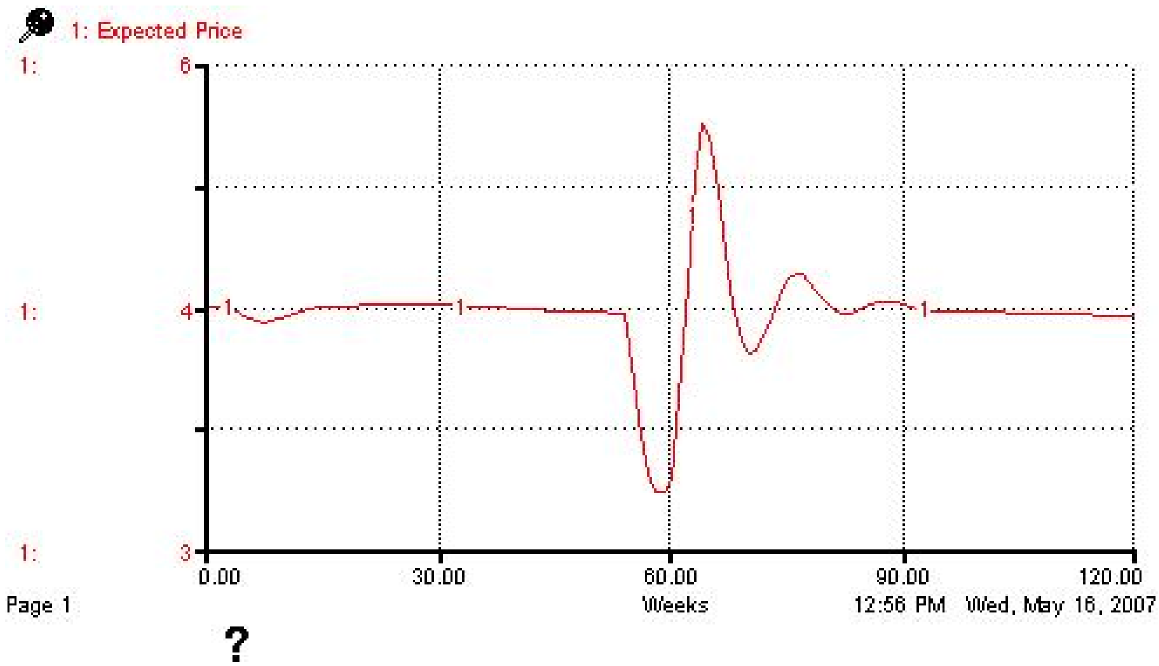
Evolution of disease under alternative assumptions about demand shocks



Note: Label "1" refers to a 50 percent drop in demand, 2: 37.5 percent; 3: 25 percent; 4: 12.5 percent; and 5: no change in demand.

Figure 7

Impacts of controlling a hypothetical animal disease outbreak through vaccination on prices, sales, inventories, and evolution of the disease itself (with demand shift)



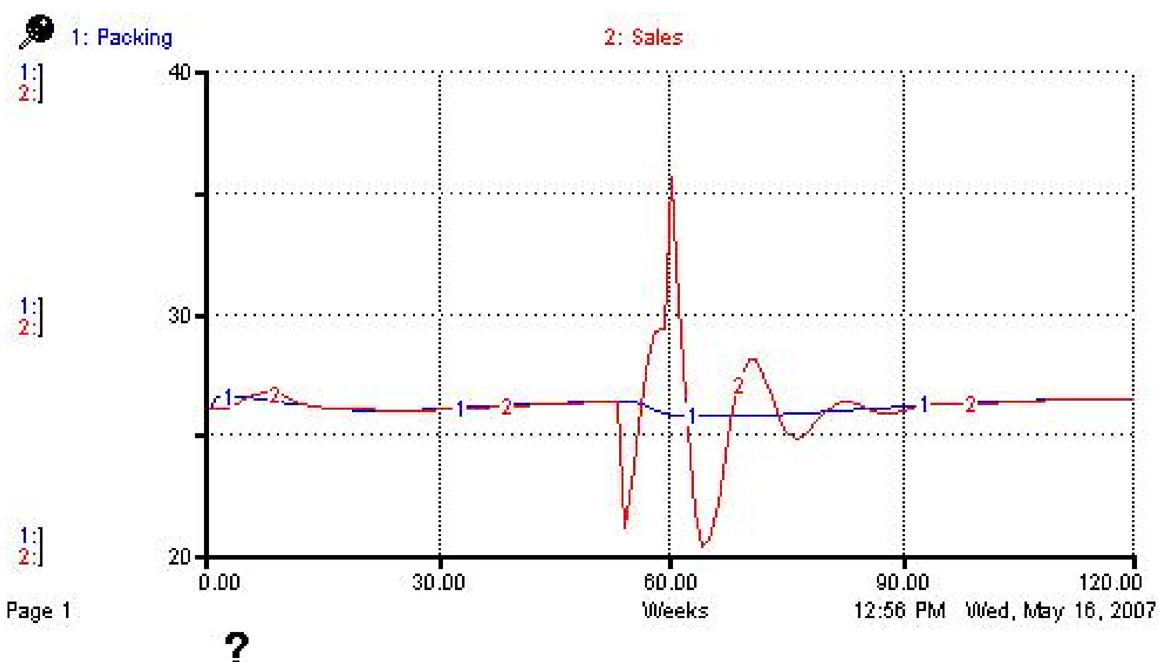
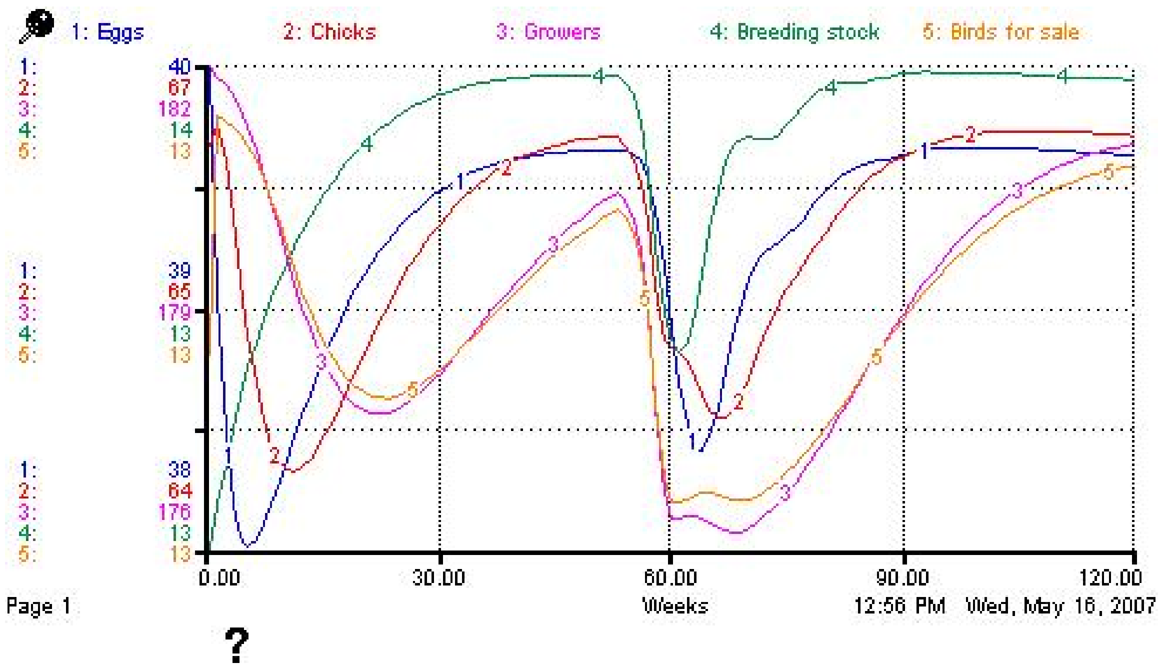


Figure 7, continued



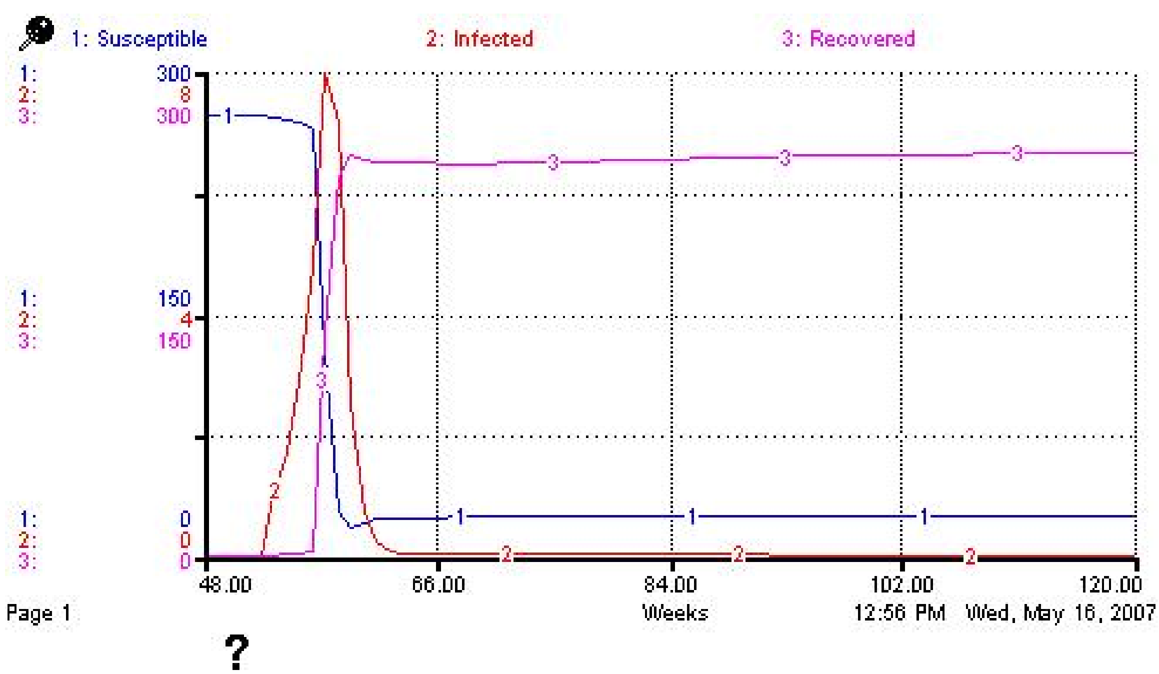
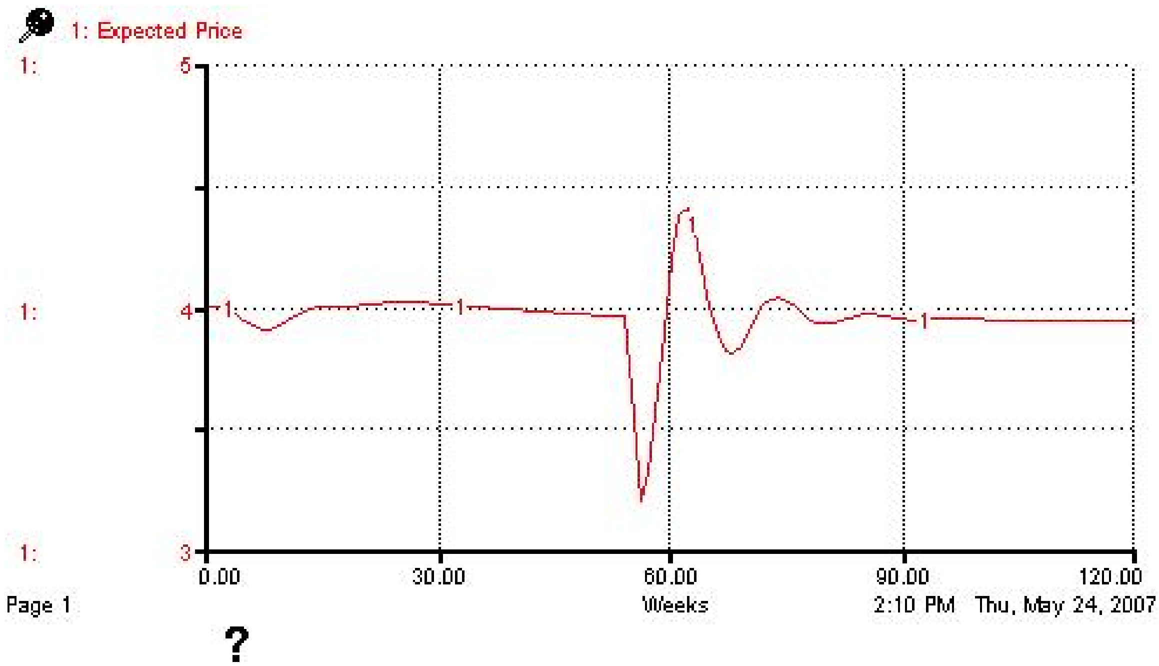
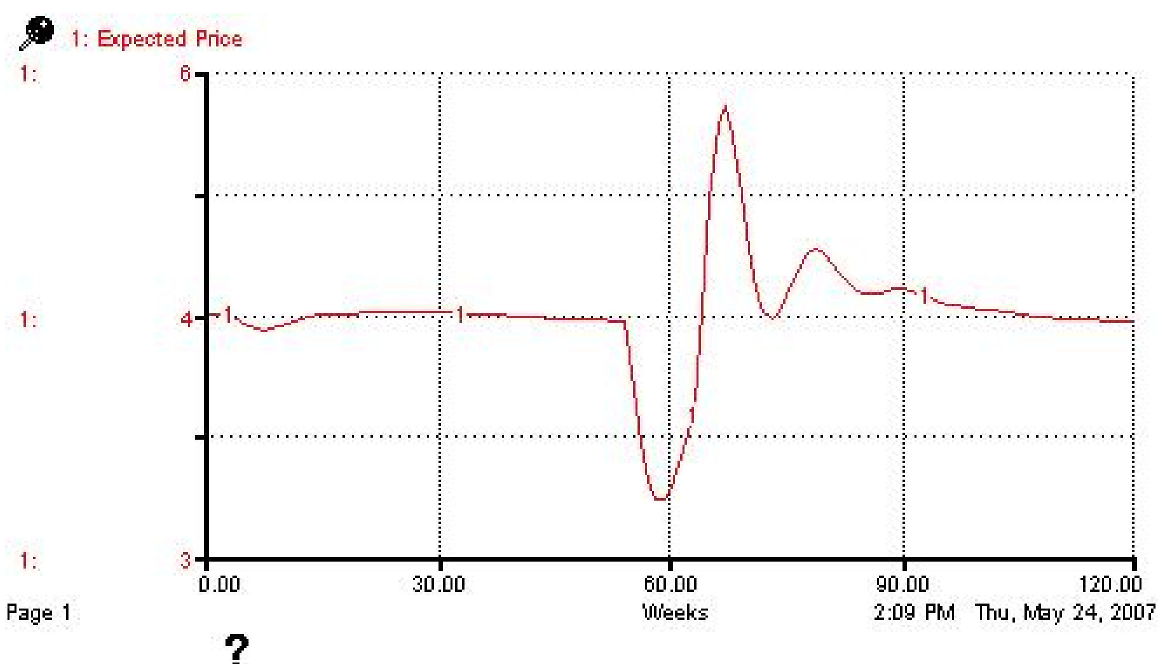


Figure 8

Price impacts of controlling a hypothetical animal disease outbreak through vaccination in an early and delayed vaccination campaign



(a) Impacts on price from an early vaccination program (e.g., one week after detection)



(b) Impacts on price from an delayed vaccination program (e.g., 7 weeks after detection)

NOTES

[1] Of course, there will be a market for each type of stock (e.g., chicks, growers) that would further necessitate modeling demand and price movements for different stocks and how they influenced breeding decisions.

[2] Additional sensitivity analysis and model simulations will be presented at the 2007 AAEA conference.