Potential HPAI Shocks and Welfare Implications of Market Power in the U.S. Broiler Industry

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Abstract

Recent outbreaks of highly pathogenic avian influenza (HPAI) in Asia, Europe, and Africa have caused severe impacts on the broiler sector through production losses, trade restrictions and negative shocks to demand. This study develops a multimarket econometric model that is the basis of simulations to assess the spread and market implications of a potential HPAI outbreak in U.S. broiler industry. It takes into account market power that might exist within the livestock and meat sectors and endogenizes the optimal production condition on the model system. The results imply that the HPAI shocks affect prices at different marketing levels unequally and change the price margins along the supply chain with the existence of market power. The change in the price margin, although statistically significant, is quite small in absolute value.

Keywords: animal disease; broilers; HPAI; market power; meat market price margins;

POTENTIAL HPAI SHOCKS AND WELFARE IMPLICATIONS OF MARKET POWER IN THE U.S. BROILER INDUSTRY

1. Introduction

Highly pathogenic avian influenza (HPAI) has been recognized as a great concern for broiler production, wildlife conservation and public health. Between 2003 and August 2009, 62 countries reported HPAI cases in their domestic poultry or wildlife (Narrod 2009). The World Bank estimates that the HPAI disease could cost the world economy between US$800 billion dollars and US$3 trillion dollars during this six year period (Narrod 2009). HPAI is highly contagious and causes severe illness in poultry with high mortality; it can cause mortality rates of 90% or higher in domesticated poultry within 48 hours of infection (CDC). With concern for transmission to humans, outbreaks of HPAI have caused major changes in demand, led to an increase in costs to producers through additional input use, and caused price volatility which could in turn induce dramatic market instability. The United States exports more poultry product than any other country in the world. When export markets are taken into account, even a relatively small outbreak has the potential to cause large welfare loss, especially if trade is restricted. Although mainly affecting the broiler sector and egg sectors, an HPAI shock is expected to influence other related livestock sectors as well.

To understand the potential welfare effects of HPAI, we consider the transmission of HPAI shocks through various stages of the broiler supply chain and through other livestock and related agricultural markets. The impacts of shocks are determined by the behavior of market agents who are involved in the transactions. Price characterizes the linkages between markets. Food scares can have differential effects on downstream suppliers and upstream suppliers, i.e., the extent to which price adjustments may be asymmetric. As an example, both Sanjuán and Dawson (2003) and Lloyd et al. (2006) found that the retail price of beef decreased significantly less than farm level price in response to BSE outbreaks in the U.K., and resulted in a substantial increase in the farm-retail margin and widened the food crisis. Even though the causes of asymmetric price transmission are complicated and multidimensional, market power is potentially an important explanation for this differential. Under competitive conditions, shocks impact prices at each marketing level equally. “If market power exists then the spread between retail and producer supply prices behaves differently since price setting by the sector with market power will be reflected in the mark down that the firms can earn, and so affects the spread. ” (Lloyd et al. 2006).

Livestock, poultry and meat sectors are vertically integrated in the U.S. The linking of successive stages of production and marketing through ownership or contracting is widespread. For example, over 88 percent of the value of production in the broiler and egg industry are under ownership integration and contracts (MacDonald et al. 2004). Particularly, the processing industries become much more concentrated. Large processing establishments dominate production in all major meat sectors. In the year of 2005, the four largest meat processors processed 79%, 64% and 53% of purchases in cattle, hog and broiler industry, respectively (USDA 2009). Vertical integration between producing and processing activities in the meat industry results in reduced transaction costs, more uniform food products and gains in economic efficiency. However, this vertical integration generally increases market power as shown below, and could increase welfare loss from an HPAI outbreak. With the increased importance of vertical integration, local farmers have access to only a few buyers and may be forced to accept a reduced distribution of profit or increased risk. Transportation costs and product characteristics (such as perishability or quality deterioration) could limit the area over which products can be shipped (MacDonald et al. 2004). As MacDonald and colleagues (2004) indicate, contracts may extend market power by deterring entry by potential rivals, limiting price competition among existing rivals and facilitating discriminatory pricing.

In this paper we focus only on monopsony (buyer) market power, a situation which is traditionally more important in livestock and meat industries than monopoly (seller) power. The following questions are considered: Do the price effects of concentration vary across markets? How would the distribution of economic welfare differ across levels of market power among agents following an HPAI shock?

Many recent studies have conducted analyses on how Avian Influenza influences the economic outcomes of livestock and meat industries in the United States (Brown et al. 2007, Paarlberg et al. 2007, Djunaidi et al. 2007, and Fabiosa et al. 2007).However, these studies assume that the livestock and meat industries are competitive; none of these studies has accounted for market structure in modeling the price transmission of HPAI shocks. The principle objective of this research is to conduct an HPAI risk and cost analysis that accounts for potential market power within the whole meat supply chain. The paper is organized as follows: First, we review the literature. Second, we develop a theoretical model to examine the potential impacts of market power on the distribution of economic welfare following a food scare. Third, we conduct empirical analyses to measure the magnitude of market power for U.S. meat sectors. Fourth, we use an epidemiological-economic model to conduct simulation analyses on the spread and effects of a potential HPAI outbreak in the U.S. broiler industry. Lastly, we discuss conclusions and implications of our work.

2. Review of literature

Understanding market power implications in the food sectors is important. Following the work of Appelbaum (1982), a number of studies have examined market power in agricultural markets. The GIPSA/USDA study (1996) summarized the findings of previous studies on the effects of concentration in the red meat packing industry, the results on market power are "mixed" and not consistent across studies. With recent consolidation in the red meat sector, the newer studies may be more relevant. Several recent studies find evidence of market power in the beef and pork packing industry (Muth and Wohlgenant 1999; Quagrainie, et al., 2003). However, only a few studies have examined the broiler sector to see if buyers exert a significant amount of market power. Bernard and Willett (1996) analyzed asymmetric price relationships in the U.S. broiler industry at the regional and national levels. Vukina and Leegomonchai (2006) illustrated the poultry grower's hold-up problem. Their results showed moderate empirical evidence that under-investment by growers depends on the integrator's market power in the broiler industry production contract. Key and MacDonald (2008) suggest a "small but economically meaningful effect" of local monopsony power in the U.S. broiler industry using farm survey data.

There is a rich literature that investigates the farm-retail price margin and what factors influence price transmission. High concentration as well as increased vertical dependencies in agricultural sectors is evident in most developed countries. Suppliers may pass on only a small fraction of an input cost decrease to output price or, alternatively, pass all of input cost increases on to the output price (or both) when market power exists. Thus price signals are allowed to be passed up or down by market agents to capture welfare and profits for themselves relative to the competitive market (Azzam 1999, Meyer and von Cramon-

Taubadel 2004, Miller and Hayenga 2001, Lopez, Azzam and Liron-Espana 2002). For meatpacking industries, empirical studies indicated that concentration may limit competition and enable meatpacking firms to exert monopoly power and keep prices paid to producers low (Azzam 1997, Marion and Geithman 1995, Richards, Patterson and Acharya 2001).

In this study, a major effort is directed to the modeling and analysis of HPAI impacts on livestock industries when market power is taken into account. Hence, the estimation and measurement of market power is critical. A number of studies have explored the methods of estimating market power in food industries. The empirical implementation can be classified among several approaches. Our study uses an approach developed by Hyde and Jeffrey (1999). They developed a new technique for measuring market power in the Australian beef, lamb, and pork markets simultaneously by using a structural approach which allows estimation for more than one product.

3. Theoretical framework

We first develop a theoretical model to illustrate the potential impacts of market power on the price margin and distribution of economic welfare following a food scare such as an HPAI outbreak. Following the assumption used in Schroeter and Azzam's study (1990), we assume "the existence of fully integrated firms spanning the farm-to-retail meat marketing channel and ignore all vertical relationships within the industry". This implies we do not decompose the farm-retail margin into farm-wholesale and wholesale-retail margins to identify if the exercise of market power occurs at the wholesale level or at the retail level. The model structure includes: producer supply, consumer demand on final product and retail supply. We assume that the final products produced by all firms are homogenous, and the industry technology is characterized by constant returns to scale. Furthermore, to concentrate the model on the implications of market power, we simply assume the input-output coefficient to be 1. The food shocks enter into the model by taking the form of exogenous demand and/or supply shifters.

The inverse producer's supply can be expressed as

$$p^0 = f\left(q, Z_s\right) \tag{1}$$

where p^0 is the price received by the producer, and q is producer supply. Z_s denotes the supply shifter caused by the food scare or outbreak.

The consumer's inverse demand for the retail product is

$$p = D\left(q, Z_d\right) \tag{2}$$

where p represents retail price. Z_d denotes the demand shifter caused by the food scare.

The representative firm's profit maximization can be expressed as

$$p + \lambda p'\left(q\right)q = C'\left(q\right) \tag{3}$$

where λ represents the level of market power, and the value of λ ranges from zero (perfect competition) to one (monopsony). Values for λ lying between zero and one imply the presence of an intermediate degree of market power. $C'\left(q\right)$ is the marginal cost of the firm and can be assumed to be a linear function of producer level price p^0 and marketing cost w.

$$C'\left(q\right) = p^0 + w \tag{4}$$

Let $\eta = \left(\partial q / \partial p\right)\left(p / q\right)$ which is less than zero denote the price elasticity of demand in the retail market. Then equation (3) can be rearranged as

$$p\left(1+\frac{\lambda}{\eta}\right)=p^{0}+w \tag{5}$$

In order to obtain the industry-level expression of equation (5), we need to aggregate among firms. The industry-level conjectural variation interpreter $\lambda_{industry}$ can be estimated as the weighted average of individual conjectural variation interpreter λ, with firms' market shares as weights. As in many studies of market power (e.g., Azzam and Pagoulatos; Lopez, Wann and Sexton), we simply assume that the market share of each firm on the final market is identical. Thus, the conjectural variation interpreter at the industry level is $\lambda_{industry}=\lambda$.

Using (1), (2) and (5), the endogenous variables $\left(q^{*}, p^{0*}, p^{*}\right)$ can be derived by implicit solutions. The price spread $r^{*}=p^{*}-p^{0*}$ can provide insight on how market power would change the impacts of the shocks. If market power exists, the exogenous shocks influence the prices at different supply chain stages to varying degrees. As a result, the price margin might be widened or narrowed depending on the demand elasticities as well as interactions of exogenous shifters. In the meantime, market power plays a role in determining the magnitude and distribution of welfare impacts. The producer's surplus $V^{*}=p^{*}q^{*}$ can be expressed as a function of the price elasticities vector η, marketing cost w and market power parameter λ. In general form, the impacts of a demand shock and a supply shock caused by HPAI can be provided by

$$\frac{dr^{*}}{dZ_{d}}=\frac{\partial p\left(\eta,w,\lambda\right)}{\partial Z_{d}}-\frac{\partial p^{0}\left(\eta,w,\lambda\right)}{\partial Z_{d}} \tag{6}$$

$$\frac{dr^{*}}{dZ_{s}}=\frac{\partial p\left(\eta,w,\lambda\right)}{\partial Z_{s}}-\frac{\partial p^{0}\left(\eta,w,\lambda\right)}{\partial Z_{s}} \tag{7}$$

and

$$\frac{dV^*}{dZ_d} = \frac{\partial p(\eta, w, \lambda)}{\partial Z_d} \cdot q(\eta, w, \lambda) - p(\eta, w, \lambda) \cdot \frac{\partial q(\eta, w, \lambda)}{\partial Z_d} \tag{8}$$

$$\frac{dV^*}{dZ_s} = \frac{\partial p(\eta, w, \lambda)}{\partial Z_s} \cdot q(\eta, w, \lambda) - p(\eta, w, \lambda) \cdot \frac{\partial q(\eta, w, \lambda)}{\partial Z_s} \tag{9}$$

respectively.

In the beef and pork industries, marketing contracts are the prevalent method of vertical coordination. The marketing contract mainly specifies delivered quantities, product specification, compensation and quality control (MacDonald et al. 2004). The farmer makes most of his or her decisions which include how much to produce and how to produce. Here p^0 is farm level price, i.e, steer price for the beef industry and barrow-gilt price for the pork industry.

Unlike the beef and pork industries, most farms in the broiler, egg and turkey industries are linked to an integrator through production contracts. In a production contract, the integrator is engaged in many of the farmer’s decisions like providing chicks, feed, veterinary services and retains ownership of important production inputs. In most cases, farmers invest only in production facilities according to the firm’s specifications and certain management strategies. Under production contracts, farmers are paid for farming services, not for the products. Therefore, here, the producer’s price p^0 is the wholesale level price instead of the farm level price. The impacts of market power will be transmitted along the whole supply chain and result in a different new market equilibrium compared with perfect competition.

4. Empirical analysis

4.1. Measurement of market power

To examine the impacts of market structure on economic outcomes in the food sector following an HPAI scare, it is important to measure the market power that might exist for each product within the livestock and meat sectors. Our study draws upon the method of Hyde and Jeffrey (1999) who simultaneously estimated an Almost Ideal Demand System (AIDS) model for Australia's retail meat sectors, a market power parameter and a marginal cost function for each product. This approach is more efficient than examining each good in isolation because "it makes use of information obtained from demand theory, such as price homogeneity restriction" (Hyde and Jeffrey 1999). Due to the substitution between meat products on the demand side, the prices of all meat products are included in the demand functions for each meat product. This enables us to capture substitution between meat products by consumers in response to relative price changes, which is important for examining the net impacts on one specific market. We modify Hyde and Jeffrey's model by analyzing market power in the whole supply chain instead of at the retail level only. In our study, the model estimates simultaneously the demand of major meat products: chicken, pork, beef, turkey and egg.

The demand component recognizes that in the very short run, meat production is essentially fixed, and thus price determination is at the retail level. The demand component also recognizes that the consumers' adjustment to changes in relative prices and income is not instantaneous, and consumers of the five meat products have preferences that are weakly separable.

The AIDS model includes expenditure share equations for the meat-poultry products that are related to the logarithm of total expenditure and the logarithms of relative prices. The model can be written as follows:

$$s_i = \alpha_i + \sum_{j=1}^{5} \gamma_{ij} \ln p_j + \beta_i \ln\left(X / P \right) \quad (10)$$

where s_i represent the share of commodity i, p_j denotes the retail price of good j, X is the total expenditure on the five meat products, and P is price index which is defined as:

$$\ln P = \alpha_0 + \sum_{i=1}^{5} \ln p_i + \left(1/2\right) \sum_i \sum_j \gamma_{ij} \ln p_i \ln p_j \quad (11)$$

The AIDS model satisfies the aggregation restriction $\sum_{i=1}^{5} \alpha_i = 1$, $\sum_{i=1}^{5} \beta_i = 0$, and homogeneity, $\sum_{j=1}^{5} \gamma_{ij} = 0$, and symmetry, $\gamma_{ij} = \gamma_{ji}$,which can be imposed with parametric restrictions automatically.

In order to examine the potential impacts of market power on price reaction elasticities, the "integrated" firm's profit maximization conditions are considered to be endogenous in the demand system. One of the favorable characteristics of the AIDS model is that it is plausible to incorporate theoretical restrictions on the system.

Recall the firm's maximization problem

$$p_i + \lambda_i p_i^{'}\left(q_i \right) q_i = C_i^{'}\left(q_i \right) \quad (12)$$

where $\lambda_i \in \left[0,1\right]$ is the parameter that captures market power (conjectural variation). That is, in a competitive market, we expect λ_i is equal to zero.

$C_i^{'}(q_i)$ is the marginal cost of product i. Differing from Hyde and Jeffrey's study, in this study p_i^0 and w denote producer price and marketing cost along the whole supply chain, respectively.

$$C_i^{'}(q_i) = a_i + b_i p_i^0 + d_i w \tag{13}$$

By substituting (13) and $p_i^{'}(q_i)$ derived from the AIDS model into (12), the first order condition can be rewritten as

$$p_i = \left[a_i + b_i p_i^0 + d_i w - \frac{\lambda_i s_i}{q_i} \sum_{j \neq i} \frac{p_j q_j}{\gamma_{ij} - \beta_i s_j} \right] \times \left(1 - \frac{\lambda_i}{1 - \gamma_{ii} / s_i + \beta_i} \right)^{-1} \tag{14}$$

Then the AIDS model is estimated using a double logarithmic demand system by imposing parameter restrictions and the profit maximization restriction (14). The market power parameter λ_i can be obtained. The magnitude of price asymmetry depends not only on the level of market power but also on the demand elasticities. The data used in the demand system are obtained from USDA/ERS and NASS. The estimation in this study is based on 96 quarterly observations that cover quarterly periods 1981:1 - 2004:4. Table 1 provides the regression results.

Table 1 lists coefficients of statistical inference. Most parameters are statistically significant at the 5% level or less. These findings indicate the estimated market power index λ is statistically significant for the beef, pork and chicken sectors, which indicates that market power exists in these industries to some extent. The results also show that the overall concentration at the national level is quite small in terms of magnitude.

Table 1. Model estimates

Parameter	Estimate	Parameter	Estimate	Parameter	Estimate
α_1	-0.0012	γ_{44}	-0.0096	d_1	0.0163***
α_2	0.1432***	γ_{45}	0.0000***	d_2	0.0021***
α_3	1.0152***	γ_{55}	0.0393***	d_3	0.0014**
α_4	-0.0016***	β_1	0.1269***	d_4	0.0000***
α_5	-0.1557***	β_2	0.0256***	d_5	0.0001***
γ_{11}	0.0903***	β_3	-0.2123***	a_0	0.0000
γ_{12}	-0.0527***	β_4	0.0054***	λ_1	0.0342***
γ_{13}	-0.0161***	a_1	-0.0060***	λ_2	0.0499***
γ_{14}	0.0378***	a_2	-0.0010***	λ_3	0.1607***
γ_{15}	-0.0594***	a_3	-0.0007	λ_4	-0.0015
γ_{22}	0.0981***	a_4	0.0001*	λ_5	0.00004
γ_{23}	-0.0089***	a_5	0.0033*		
γ_{24}	-0.0373***	b_1	0.00001		
γ_{25}	0.0009***	b_2	0.0000		
γ_{33}	-0.0033	b_3	0.00002**		
γ_{34}	0.0091***	b_4	0.00000		
γ_{35}	0.0192***	b_5	0.00008*		

Note: *** 1% significance level; ** 5% significance; * 10% significance level
1-beef; 2-pork; 3-poultry; 4-turkey; 5-egg

4.2. Economic impacts of HPAI under market power

4.2.1. Economic model

An epidemiological-economic model is developed to simulate the spread and effects of the disease in the poultry and other meat sectors. This approach differs from the study of Lloyd et al. (2006) which adopted a vector autoregressive (VAR) model to verify the influences of BSE disease on the farm-retail margin. Instead, here, a state-transition model of the transmission of Avian Influenza developed by Lawrence Livermore National Laboratory (LLNL) was used along with an economic model. The epidemiological model was developed to incorporate the dynamics of influenza A virus infection with birds and estimate the effect of different risk profiles on the final disease prevalence and infection rate. (Please refer to Fabiosa et al. for further details and references.) The economic model developed by the Center for Agricultural and Rural Development (CARD) at Iowa State University uses parameters generated by the epidemiological model to validate the potential effects of shocks associated with the disease on prices along the supply chain, domestic consumption, export, production and ending stock under different scenarios.

The CARD model is a multimarket partial equilibrium model and provides a complete depiction of key biological and economic relationships within five livestock and meat industries. The modeling effort updates previous work described in Jensen et al. (1989), and Buhr and Hayenga (1994). The model revisions accommodate updated results from re-estimated market models, added livestock sectors, and new technical production parameters. The model allows for components envisioned in the simulations of an Avian Influenza outbreak in the broiler and egg industries. The current extended model system includes five meat sectors: broiler and chicken meat; turkey and turkey meat; layer and eggs; beef cattle and beef; and hog and pork. Each market in the model is assumed to be national in scope, and has a single national equilibrium price.

The structure of the model includes live animal supply, meat supply, meat demand, and price margin components. The econometric specification provides an abstraction of a complex system and aids in synthesizing information and causal relationships into a comprehensible form. Aggregate demand and supply can be partitioned to equations that define the behavioral relationship between quantities and price and other event factors. The specification of the five supply sectors is based on a partial adjustment-adaptive expectations framework and is driven by the feed cost variable, output price and expected output on particular stages. The processes include biological restrictions inherent in livestock production, the appropriate lags to capture time periods required in production, technical parameters, and accounting identities to ensure consistency in the stock as well as flow variables. Relevant trade flows for the products involved are also modeled. In a word, the supply components of the models are determined by the biological relationships in the production process as well as on the economic considerations of meat producers.

Under the assumption that supply is fixed in the short run (less than one quarter), the meat demand system is estimated by an Almost Ideal Demand System (AIDS) which includes expenditure share equations for the all meat products. The linkage takes the assumption that consumers adjust their purchasing behaviors based on relative retail meat prices and the cross-commodity effects originate on the demand side. The marginal specifications provide a price linkage from the farm market to the retail market. The potential existence of market power and the optimal production condition for each sector are not included in the CARD model. In this study, we update the estimation of the AIDS demand system by accounting for market power and its impacts on economic outcomes.

The model has a simultaneous econometric framework where market equilibrium price and quantity for the five livestock sectors are jointly determined. Economic activity is initiated by the breeding decisions of livestock producers, and these are linked recursively to all other variables of the model system and simultaneously interact to determine each other's value. The supply and demand sides of each model are linked by market clearing conditions. Current prices influence future production and current consumption decisions. For this analysis, input markets are assumed to be exogenous. When the scenarios introduce a shock, responses captured through elasticities on the endogenous variables will shift the demand or supply curve, and thus induce price movements. Thereafter supply recovers gradually and a stable supply path can be obtained again. A new equilibrium is achieved in which supply and demand are in balance. While a shock on the broiler industry may have an initial impact on the industry itself, the interdependencies between the industries and the supply chain integration ensure that the others are also affected to some extent. The influences of the shocks are different because of the differences in the endogenous variables' elasticities and in the relative variability of the series for the endogenous variables. The effects of market power involve adjustments on demand elasticities, which influence equilibrium prices and quantities, as well as the distribution of social cost through market relationships.

4.2.2. Scenarios

Following Fabiosa et al. (2007), the simulated market scenarios are classified according to the length and severity of the outbreak, number of birds removed from the market, percentage reduction in domestic and export demand for poultry products, duration of the demand shock, assumptions on diversion, and use of product destined for export markets. Since it is challenging to know in advance the range of an outbreak, this study examines three possible scenarios of the extent of HPAI on broilers and layers: high, medium and low. The epidemiological model generates data on infection rates and effects on national broiler production required by the economic model. An infection rate of 0.2% and duration of 90 days are generated for the low shock scenario. Infection rate and duration for medium and high shock scenarios are 0.4% and 180 days, 0.7% and 270 days, respectively. There is depopulation of pullets, chicks hatched and slaughter ready birds, applied in equal percentages to each sector spread out during the period of the outbreak.

On the domestic demand side, consumers are assumed to respond to an AI outbreak by decreasing purchase of chicken during the quarter when the outbreak happens. The decreasing level is 5%, 8% and 14% for low, medium and high scenarios, respectively. For the high scenario, the consumption decreases by 10% on the quarter following the outbreak, while there is no decline on the following quarters for the low and medium scenarios.

For export, we assume exports would be 50%, 25% and 10% below normal levels for the high, medium and low scenarios, and shocks on export market fade gradually and are gone after 135, 270, and 405 days, respectively. Disposition of product destined for export is also specified. If none of the retained product is "diverted" to secondary or alternative markets (e.g., pet food, or rendered product), any product that is not exported would be consumed in the U.S. or added to ending stocks (cold storage). For each of the three scenarios (low, medium, and high), three levels of export diversion, 0%, 50%, and 100%, are considered. The assumptions underlying the scenarios for disease outbreaks for egg layers can be described similarly. The assumptions of each scenario are summarized in Table A-1 (see Appendix).

4.2.3. Empirical results

The data used in the economic model include time-series data on the levels of production, price, consumption, exports, and stock for the period between the year of 1981 and 2004. The model is also calibrated by dynamic simulation over the same periods. Through calibration, the baseline-solved value of the endogenous variables equals the actual value. The baseline projections are developed in the first quarter of 2000 and cover the period 2000.1-2004.2. Effects of alternative scenarios are measured relative to this period. The firm-level production impacts and market-level changes in equilibrium prices and output are evaluated. Table A-2 and Figure A-1~A-7 (in the Appendix) provide simulation results of the broiler sector for the base line and the high-range shock with 0% export diversion under the environment of market power. The first four quarters of the scenarios are listed individually in the table and the remaining quarters are averaged annually since the impacts of external shocks become smaller. The results from other cases and other sectors are not listed here because of space limitations.

The simulation results indicate that if HPAI is introduced (model shock occurs in 2000.1) into the U.S., restrictions imposed on chicken exports, even when combined with bird mortality and production impacts will result in excess supply in the domestic market. Consequently, the HPAI domestic market price of poultry products is lower than before because producers are not able to adjust production decisions in the very short run. From Table A-2, a 50% decrease in export results in approximately a 35% decrease in the retail chicken price. After trade restrictions are removed and export markets can begin to recover, the simulation reveals chicken prices recover above the level without an HPAI shock. Producers respond to the reduction of poultry prices by operating on a lower production function. But the long run impact of the HPAI shock on production is generally quite small. Only a larger demand or supply shock results in long run production decreasing by more than one percent from the baseline scenario. Producers are able to recover after the shock and sometimes achieve higher production than before the shock. As the retail price decreases, the ending stocks and per capita consumption of chicken increase due to the decrease in retail price.

The HPAI shocks also affect the other meat markets to some extent. For example, the HPAI outbreak has a negative demand shock on poultry. At the same time, the increase in chicken supply dominates market response and market prices decrease. The fall in poultry prices has a negative effect on demand for other meat products and leads to decreases in the prices in other meat markets. The magnitude of the substitution effect depends on substitution elasticities among these meat products and the degree of market power.

Table A-4 (in the Appendix) presents the simulation results of chicken's total value under the environment of market power in comparison to a situation with perfect competition $(\lambda = 0)$. We find the absolute value of the change in chicken's total value is higher with the existence of market power. That is, market power is more likely to lead to a greater change in the producer's surplus and deepen the effects of HPAI.

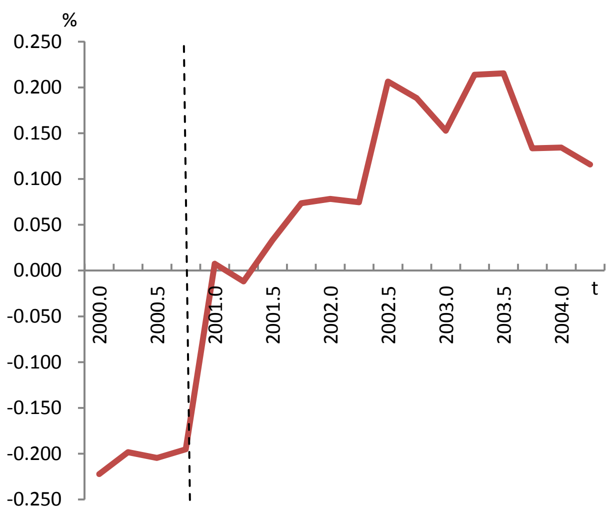

Figure 1. Percentage change in chicken's total value (with and without market power)

However, as can be seen in Figure 1, the difference between the two scenarios is small and it amounts to no more than 0.2% change compared to perfect competition. The vertical dashed line in the figure identifies the periods with trade restrictions and without restrictions (when the trade restrictions are relaxed).

The changing patterns of the egg sector are similar to those observed in the poultry sector except that per-capita consumption of eggs decreases from the beginning. Simulation results are summarized in Table A-3 and Figures A-8~A-14 (in the Appendix). For the egg sector, there are almost no differences between the simulations in case of perfect competition and market power. This is not surprising because we found no market power in that industry.

Although the existence of market power has varying impacts on different meat products, in poultry markets, producers are paid for farming services instead of products. We analyze if there is a change in the price margin at the retail level relative to the wholesale level in the presence of the HPAI shock.

Without the existence of market power, the demand and supply shocks play no role in determining the price margin. Correspondingly, if market power does exist, then the demand or/and the supply shifter will influence the wholesale and retail prices to varying degrees and thus change the price margin. The econometric analyses of Lloyd et al. (2006) show that the price margin is positively affected by the demand shifter and negatively affected by the supply shifter. Whether and how an HPAI outbreak would change the price margin depends on which effect is dominant. We denote by p_{i0} and p_{i1} the baseline (no shock) and forecasted (with shock) poultry prices, where i indicates the wholesale $(i = w)$ and retail $(i = r)$ levels. Then we can obtain the change of the forecasted price margin and the baseline price margin

$(p_{r1-}p_{w1})-(p_{r0-}p_{w0})$. Table A-5 (in the Appendix) and Figures 2 and 3 show the change in the poultry price margin resulting from an HPAI outbreak.

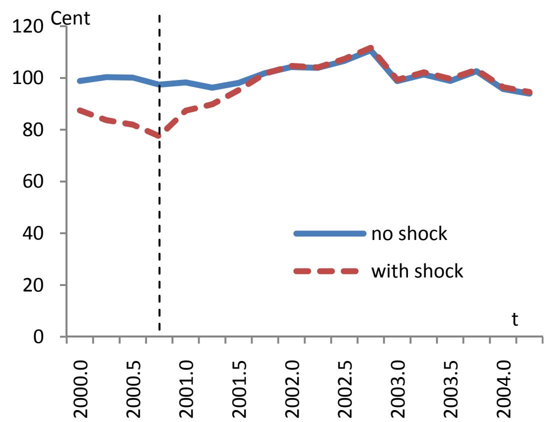

Figure 2. Wholesale - Retail poultry price margin

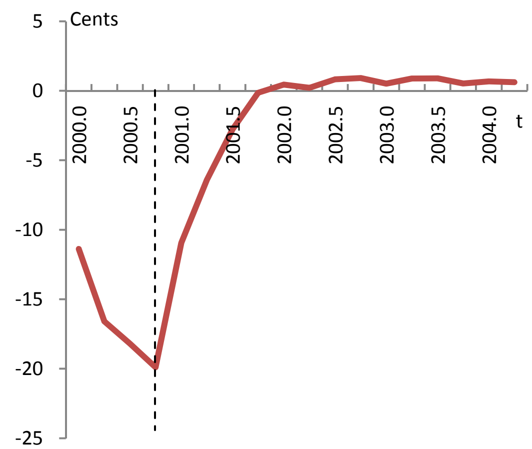

Figure 3. Change in Wholesale - Retail poultry price margin

The results illustrated in Figures 2 and 3 suggest that the wholesale-retail margin of poultry products decreases for the first eight quarters following the shock. Recall that immediately after the outbreak of HPAI, the large scale export ban (supply shifter) leads to excess supply in the domestic market. Due to the lag structure of the supply functions, decreased exports are associated with a retail price decrease that is more than the wholesale price decrease, and thus narrows the price margin. At the same time, the concern over HPAI among consumers (demand shifter) also contributes to a lower retail price. With the existence of market power, the extent to which price adjustments occur is asymmetric. The wholesale level price decreases more than retail level price, and the demand shock has the effect of widening the price margin. The decrease in the price margin in this period suggests that the impacts of the supply shock dominate.

After the trade restriction is removed, the impact of the supply shock diminishes. On the demand side, the retail price rebounds with the recovery of poultry consumption. The wholesale level price response is lower than the retail price response. The impact of the demand shifter is greater than that of the supply shifter. Therefore, from the ninth quarter after the outbreak, the wholesale-retail price margin starts to increase and becomes wider. The results are consistent with the empirical findings of Bernard and Willett (1996) who indicated that the national retail price of poultry products showed upward asymmetry from the wholesale to retail level. Because the magnitude of market power is relatively low in the poultry market, we find the change in the price margin is quite small in absolute value and remains nearly constant in the long run.

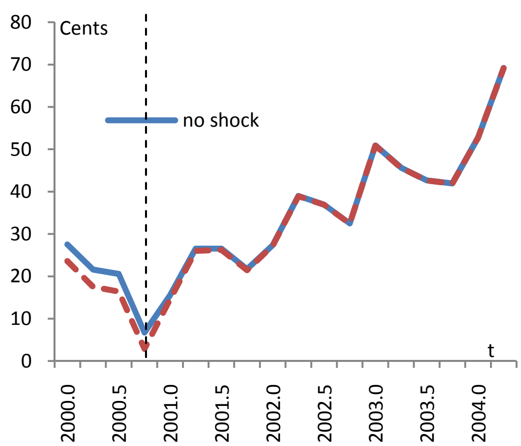

Figure 4. Wholesale - Retail egg price margin

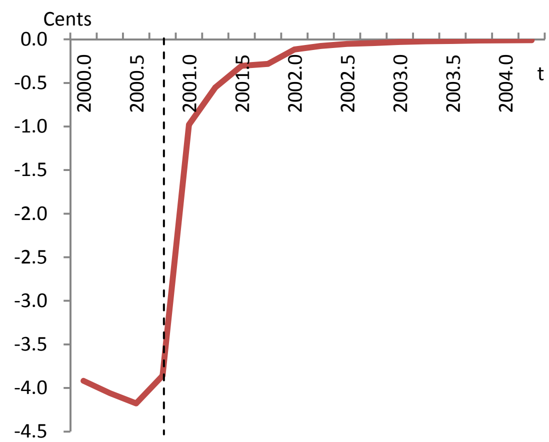

Figure 5. Change in Wholesale - Retail egg price margin

The changes in the egg price margin resulting from the HPAI shock are shown in Table A-6 (in the Appendix) and Figures 4 and 5. The results indicate that the supply shock leads the price margin to decrease immediately after the outbreak of HPAI. Since there is no evidence of market power in the egg sector, the price margin is not affected by HPAI after the trade restriction is removed.

5. Conclusions

This study is motivated by an interest in determining the effects of a potential HPAI outbreak on the U.S. meat and poultry sectors and an effort to understand the influence of market structure on the U.S. meat sectors following the potential shock in the broiler sector. A simulation approach is used to analyze the responses of producers and consumers on a potential HPAI scare in a market setting. Specifically, this study recognizes that suppliers in the meat industry may exert market power to make adjustments that affect the market environment in which they operate. The results suggest that the poultry retail price margin relative to the wholesale level of poultry products becomes smaller immediately after an HPAI outbreak (or shock) and then becomes wider with the recovery of poultry consumption. However, the results show that the magnitude of market power is relatively low in the poultry markets. Further work could be done to analyze the potential impacts of market power by relaxing the assumption that total expenditure on all meat products is fixed. Moreover, sensitivity of these simulation results could be extended to examine the effects at a regional level. Additionally, a model with more time granularity (smaller time steps than one quarter) would be of interest to better describe and understand the price volatility that might occur with a shock such as HPAI.

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APPENDIX

Table A-1. Assumptions used in scenario analysis

Broiler scenarios

Range	Outbreak duration (days)	Broilers infected	Fraction broiler industry infected	Fraction of broiler industry affected by export bans exported	Export ban duration (days)	Consumer demand shift during outbreak	Consumer demand shift, in quarter following outbreak
low	90	2,500,000	0.2%	10%	135	5%	0%
med	180	5,000,000	0.4%	25%	270	8%	0%
high	270	10,000,000	0.7%	50%	405	14%	10%

Layer scenarios

Range	Outbreak duration (days)	Layers infected	Fraction layer industry infected	Fraction of broiler industry affected by export bans exported	Export ban duration (days)	Consumer demand shift during outbreak	Consumer demand shift, in quarter following outbreak
low	90	1,475,060	0.5%	10%	135	5%	0%
med	180	14,750,600	5.0%	10%	270	8%	0%
high	270	29,500,000	10.0%	10%	405	14%	10%

Table A-2. Broiler sector simulation results for the high-range scenario (baseline and 0% export diversion)

Broilers	unit	2000.00	2000.25	2000.50	2000.75	2001	2002	2003	2004
Baseline									
Per Capita Consumption	Retail lb	23.46	23.85	22.99	22.68	23.42	24.86	25.40	26.34
Export	Thousand lbs	1135383.7	1189349.8	1275979.6	1317640.6	1388821.1	1201783.1	1230003.2	1014866.8
Ending Stock	Thousand lbs	795596.0	811422.0	815723.0	810293.0	682990.5	798225.3	662037.5	604163.5
Wholesale Price	$/cwt	54.58	55.70	56.81	57.56	59.11	55.52	61.96	76.25
Retail Price	$/lb	1.53	1.56	1.57	1.55	1.58	1.62	1.62	1.71
Production	Thousand lbs	7603368.0	7754304.0	7593955.0	7543544.0	7816452.2	8059930.5	8187249.0	8343283.0
Total Value (Retail Price*Production)	Thousand $	11662761	12095972	11919678	11688814	12327614	13044947	13290221	14275113
Scenario (high 0 xd)									
Per Capita Consumption	Retail lb	25.35	24.96	23.63	23.77	23.22	24.79	25.45	26.34
Export	Thousand lbs	583927.6	609507.0	651291.2	670485.5	1299213.4	1201115.4	1229662.0	1014419.2
Ending Stock	Thousand lbs	813722.2	825608.7	827587.7	820476.6	682612.1	797899.9	661874.5	604000.0
Wholesale Price	$/cwt	11.62	22.60	30.48	38.41	67.26	57.16	62.41	77.11
Retail Price	$/lb	0.99	1.06	1.12	1.16	1.61	1.64	1.63	1.73
Production	Thousand lbs	7585902.1	7472632.4	7140643.7	7191648.7	7608896.0	8040145.5	8200621.4	8342146.0
Total Value (Retail Price*Production)	Thousand $	7513701	7946950	8029144	8335680	12234584	13192615	13405573	14398132
Change of Total Value	Thousand $	-4149059	-4149022	-3890534	-3353134	-93030	147668	115353	123019

Table A-3. Layer sector simulation results for the high-range scenario (baseline and 0% export diversion)

Layers	unit	2000.00	2000.25	2000.50	2000.75	2001	2002	2003	2004
Baseline									
Per Capita Consumption	Dozen	5.96	5.75	5.77	6.16	5.97	5.96	6.02	5.93
Export	Thousand Dozen	41037.93	37366.58	44717.83	48023.82	47485.22	43496.10	36490.88	30773.74
Ending Stock	Thousand Dozen	10626.42	10711.47	10952.16	11367.50	11466.21	9702.35	13208.43	14238.04
Wholesale Price	Cents/ dozen	68.07	66.05	68.80	86.05	70.35	69.24	79.16	89.45
Retail Price	$/ dozen	0.96	0.88	0.89	0.93	0.93	1.03	1.24	1.50
Production	Millions	1760166.7	1748833.3	1758166.7	1793833.3	1796895.8	1817645.8	1824104.2	1833083.3
Total Value (Retail Price*Production)	Thousand $	140226611	127713412	130934579	138723111	139140794	156402277	189405025	229696243
Scenario (high 0 xd)									
Per Capita Consumption	Dozen	5.70	5.27	5.17	5.70	5.84	5.96	6.02	5.93
Export	Thousand Dozen	38087.3	34240.4	40645.4	43549.1	46726.2	43478.5	36490.8	30774.3
Ending Stock	Thousand Dozen	10682.9	10754.4	10979.1	11388.1	11448.3	9701.4	13208.4	14238.1
Wholesale Price	Cents/ dozen	54.59	60.89	66.95	84.97	75.73	69.58	79.18	89.46
Retail Price	$/ dozen	0.78	0.78	0.83	0.88	0.98	1.03	1.24	1.50
Production	Millions	1685061.7	1614044.7	1589358.3	1664304.7	1758676.5	1815651.2	1824092.5	1833121.9
Total Value (Retail Price*Production)	Thousand $	109807854	105479551	110381395	121848890	143109572	156633343	189406040	229688108
Change of Total Value	Thousand $	-30418757	-22233861	-20553184	-16874221	3968778	231067	1015	-8135

Table A-4. Chicken's total value (with and without market power)

Year	Total Value (Thousand $) (A)	Total Value (Thousand $) (B)	Difference (Thousand $) (B-A)	Percentage change (%) ((B-A)/A*100)
2000.00	7530444.3	7513701.5	-16742.8	-0.222
2000.25	7962746.9	7946950.1	-15796.9	-0.198
2000.50	8045606.1	8029143.6	-16462.4	-0.205
2000.75	8351977.2	8335680.2	-16297.1	-0.195
2001.00	11233413.0	11234249.3	836.3	0.007
2001.25	12030931.7	12029508.8	-1422.9	-0.012
2001.50	12739123.9	12743343.1	4219.2	0.033
2001.75	12944686.4	12954209.3	9522.9	0.074
2002.00	12681005.2	12690917.7	9912.6	0.078
2002.25	13167207.6	13177024.0	9816.4	0.075
2002.50	13671533.5	13699751.7	28218.2	0.206
2002.75	13172967.7	13197754.3	24786.7	0.188
2003.00	12400530.9	12419457.9	18927.0	0.153
2003.25	13505642.8	13534522.5	28879.7	0.214
2003.50	13830233.4	13860031.7	29798.3	0.215
2003.75	13811804.1	13830231.7	18427.7	0.133
2004.00	13969827.6	13988586.4	18758.8	0.134
2004.25	14795833.7	14812960.9	17127.2	0.116

Note: A-without Market Power; B-with Market Power

Table A-5. Wholesale price, retail price and price margin before and after shocks (unit: cents/lb)-poultry

Year	p_{w0}	p_{r0}	p_{w1}	p_{r1}	$p_{w1}-p_{w0}$	$p_{r1}-p_{r0}$	$p_{r0}-p_{w0}$	$p_{r1}-p_{w1}$	$(p_{r1}-p_{w1})-(p_{r0}-p_{w0})$
2000.00	54.58	153.39	11.62	99.05	-42.96	-54.34	98.81	87.42	-11.38
2000.25	55.70	155.99	22.66	106.35	-33.05	-49.64	100.29	83.69	-16.60
2000.50	56.81	156.96	30.48	112.44	-26.33	-44.52	100.15	81.96	-18.19
2000.75	57.56	154.95	38.41	115.91	-19.14	-39.04	97.39	77.49	-19.90
2001.00	57.76	156.06	69.91	157.26	12.15	1.21	98.29	87.35	-10.94
2001.25	59.25	155.46	65.66	155.46	6.41	0.00	96.21	89.81	-6.41
2001.50	61.09	159.15	67.84	163.12	6.75	3.98	98.06	95.29	-2.78
2001.75	58.35	160.19	65.62	167.32	7.28	7.13	101.84	101.70	-0.14
2002.00	55.98	160.16	58.64	163.26	2.66	3.10	104.18	104.62	0.44
2002.25	56.11	160.00	55.56	159.66	-0.55	-0.34	103.89	104.10	0.21
2002.50	56.28	162.81	59.65	167.01	3.37	4.20	106.53	107.36	0.83
2002.75	53.71	164.43	54.78	166.41	1.07	1.98	110.72	111.63	0.91
2003.00	60.32	159.06	59.55	158.79	-0.77	-0.27	98.74	99.25	0.51
2003.25	59.59	160.88	61.86	164.03	2.27	3.15	101.29	102.17	0.88
2003.50	63.36	162.17	64.24	163.94	0.88	1.77	98.81	99.70	0.89
2003.75	64.58	167.20	63.98	167.12	-0.60	-0.08	102.62	103.14	0.52
2004.00	73.19	168.95	74.49	170.92	1.31	1.97	95.76	96.43	0.67
2004.25	79.31	173.24	79.72	174.27	0.41	1.02	93.93	94.54	0.61

Table A-6. Wholesale price, retail price and price margin before and after shocks (unit: cents/lb)-layer

Year	p_{w0}	p_{r0}	p_{w1}	p_{r1}	$p_{w1}-p_{w0}$	$p_{r1}-p_{r0}$	$p_{r0}-p_{w0}$	$p_{r1}-p_{w1}$	$(p_{r1}-p_{w1})-(p_{r0}-p_{w0})$
2000.00	68.07	95.60	54.59	78.20	-13.48	-17.40	27.53	23.61	-3.92
2000.25	66.05	87.63	60.89	78.42	-5.15	-9.21	21.59	17.53	-4.06
2000.50	68.80	89.37	66.95	83.34	-1.85	-6.03	20.57	16.39	-4.18
2000.75	86.05	92.80	84.97	87.86	-1.08	-4.94	6.75	2.89	-3.86
2001.00	79.14	94.67	90.80	105.35	11.66	10.68	15.53	14.55	-0.98
2001.25	67.73	94.30	73.45	99.47	5.72	5.17	26.57	26.01	-0.55
2001.50	63.70	90.23	66.36	92.59	2.66	2.36	26.54	26.23	-0.30
2001.75	70.82	92.53	72.32	93.75	1.50	1.21	21.71	21.43	-0.28
2002.00	71.68	99.07	72.39	99.66	0.71	0.59	27.38	27.27	-0.12
2002.25	61.65	100.63	62.01	100.91	0.36	0.28	38.98	38.91	-0.08
2002.50	66.32	103.27	66.50	103.40	0.18	0.13	36.95	36.90	-0.05
2002.75	77.33	109.83	77.43	109.89	0.10	0.06	32.51	32.46	-0.04
2003.00	68.19	119.10	68.24	119.12	0.05	0.02	50.91	50.88	-0.03
2003.25	65.66	111.30	65.69	111.30	0.02	0.00	45.64	45.61	-0.02
2003.50	80.14	122.80	80.15	122.79	0.01	-0.01	42.66	42.64	-0.02
2003.75	102.63	144.57	102.64	144.56	0.00	-0.01	41.93	41.92	-0.01
2004.00	106.61	159.37	106.61	159.36	0.00	-0.01	52.76	52.75	-0.01
2004.25	72.30	141.50	72.30	141.49	0.00	-0.01	69.20	69.19	-0.01

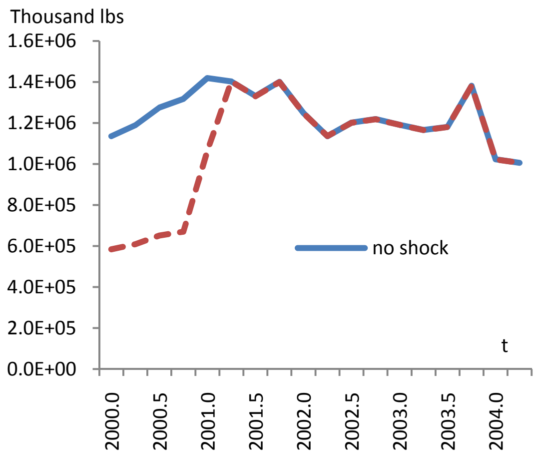

Figure A-1. Young chicken exports

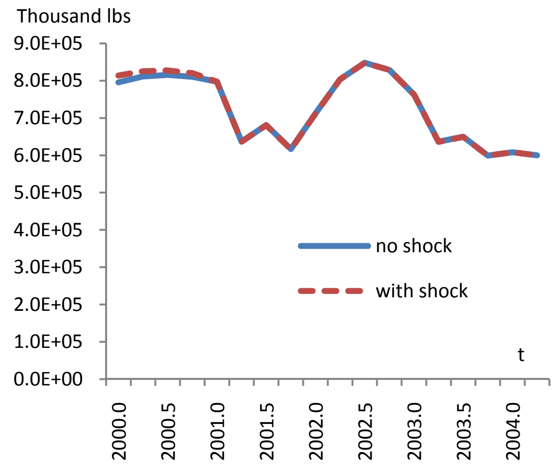

Figure A-2. Young chicken ending stock

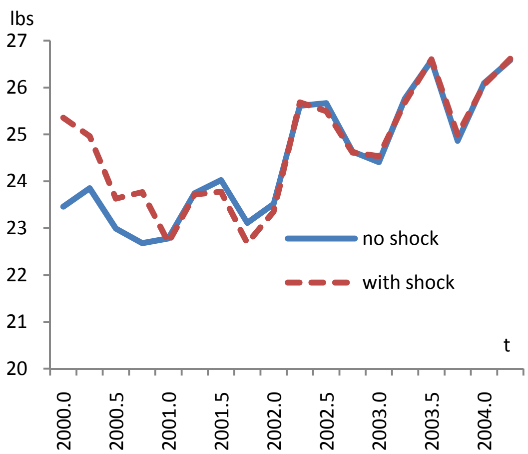

Figure A-3. Per capital chicken consumption

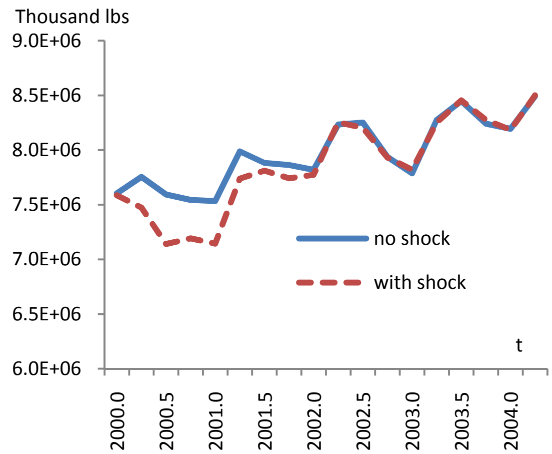

Figure A-4. Young chicken production

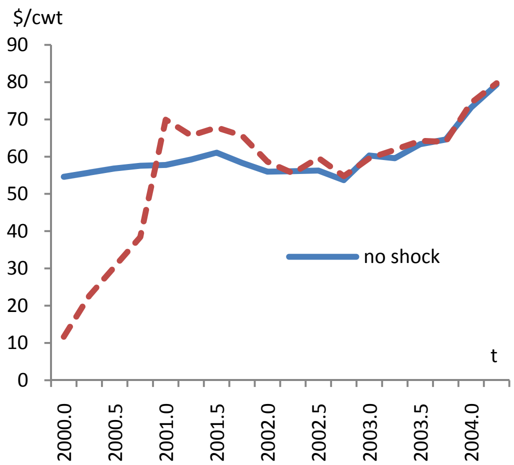

Figure A-5. Wholesale chicken price

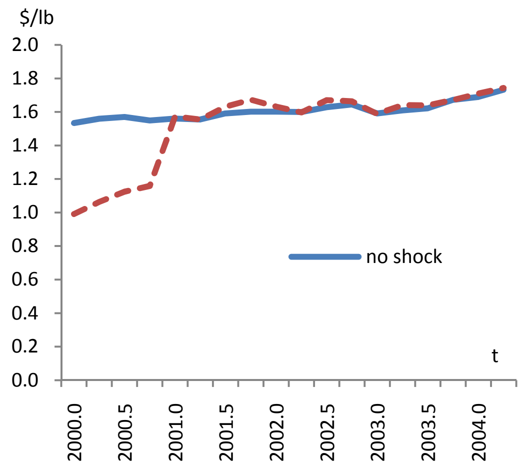

Figure A-6. Retail chicken price

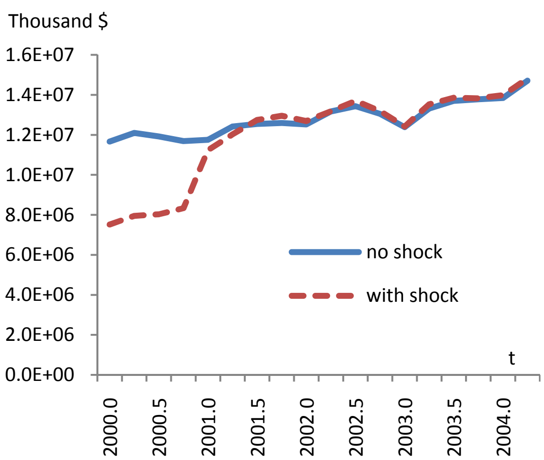

Figure A-7. Total chicken value

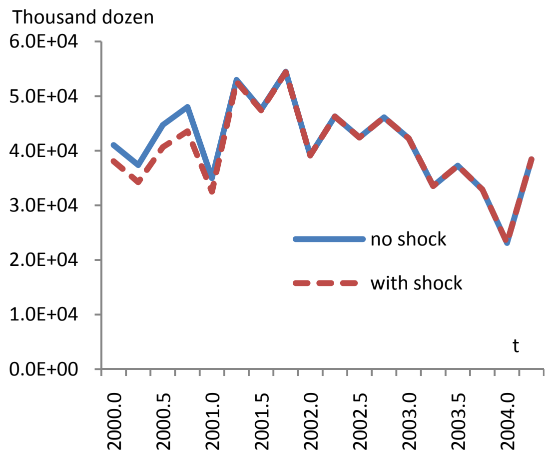

Figure A-8. Egg exports

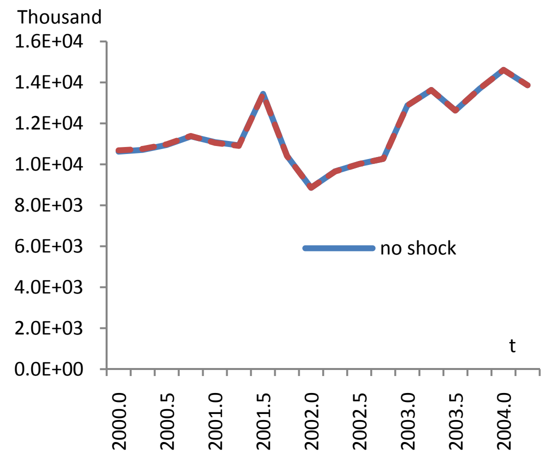

Figure A-9. Egg ending stock

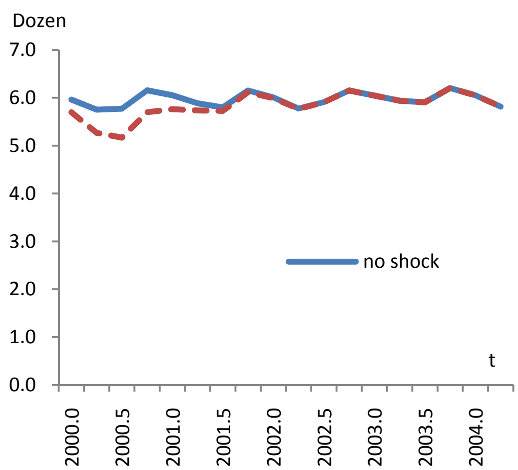

Figure A-10. Per capita egg consumption

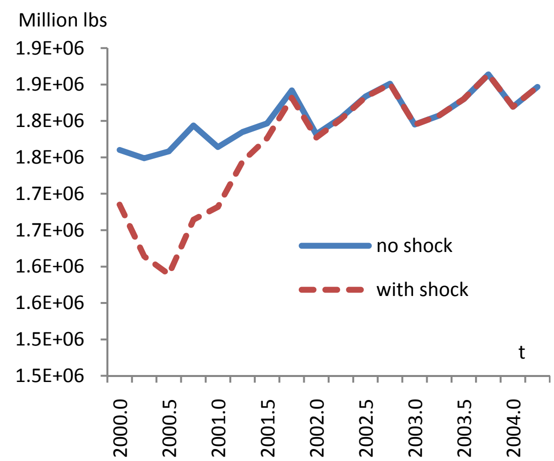

Figure A-11. Egg production

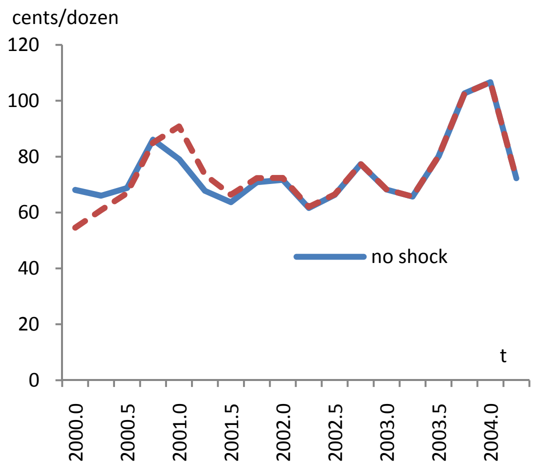

Figure A-12. Wholesale egg price

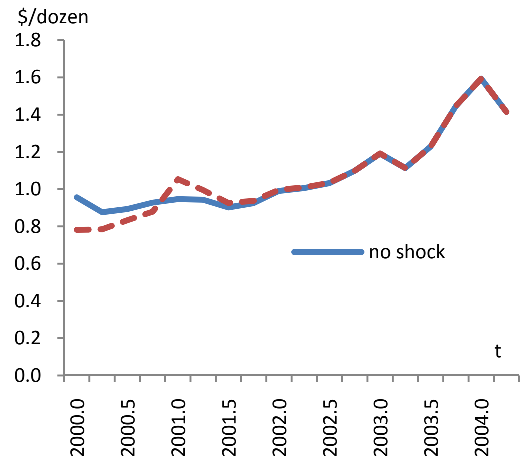

Figure A-13. Retail egg price

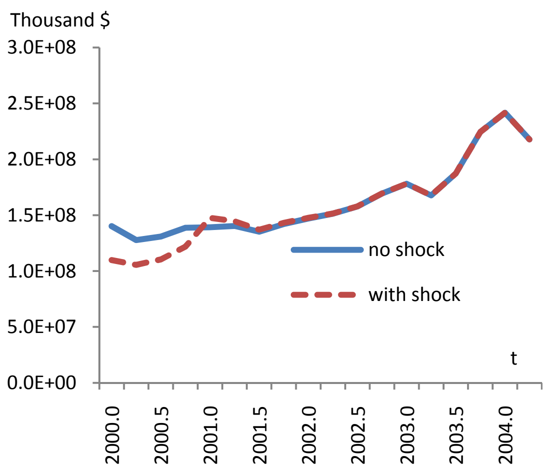

Figure A-14. Total egg value