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Dynamics of Price Transmission in the Presence of a Major Food Safety Shock: Impact of H5N1 Avian Influenza on the Turkish Poultry Sector

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This article addresses the dynamic impact of the 2005 H5N1 avian influenza outbreak on the Turkish poultry sector. Contemporary time-series analyses with historical decomposition graphs are used to address differences in monthly price adjustments between market levels along the Turkish poultry supply channel. The empirical results show that price adjustments are asymmetric with respect to both speed and magnitude along the marketing channel. Results also reveal a differential impact of the exogenous shock on producers and retailers. The findings have critical efficiency and equity implications for the supply-chain participants.

Key Words: avian influenza, chicken, food safety shock, price transmission dynamics, supply chain, Turkey

JEL Classifications: Q11, Q13

In recent years, many highly publicized food safety scares have been reported worldwide. As a result, several interrelated issues, such as the impact of these events on human health, consumer safety concerns, the willingness of consumers to pay for food safety, and the impact of food safety shocks and subsequent consumer reaction on price adjustments across vertically linked markets, have received significant attention in the literature on food safety.

Widely discussed examples of recent cases of foodborne illnesses include contaminated meat products, infection by bacteria such as *Salmonella* and *Escherichia coli*, and contraction of Creutzfeld–Jakob disease after consuming beef infected with bovine spongiform encephalopathy (BSE). The consequences of such food safety scares include decreases in both the price and rate of consumption of meat products due to decrease in demand, recalls of meat products, culling of animals, and losses of export markets as a result of import bans. Where such incidents negatively affect consumer perception and confidence, the damage can extend to farm production systems and food supply chains and, in aggregate, to the whole food industry (Miles and Frewer; Verbeke).

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Losses due to safety incidents are significant. In the United States alone, productivity losses from such incidents are estimated to be worth $7 billion to $23 billion per year (Smith and Riethmuller). In the U.K., in 1996, it was estimated that with the BSE scare both producer and retail beef prices declined, beef consumption decreased by 40%, and losses of US$1.7 billion were realized (Lloyd et al.; Sanjuán and Dawson); in 2001, foot and mouth disease was responsible for the destruction of 6 million animals, at a cost of 5 billion euros to the public and 8 billion euros to the private sector (De Jonge et al.).

Another recent food scare, the outbreak of highly pathogenic avian influenza (HPAI), started in the Hong Kong Special Administrative Region in China in 1997, causing 18 reported cases of infection and resulting in six fatalities. In Hong Kong, cases of human infection ceased after the rapid destruction of the entire chicken population, but in February of 2003, two further human cases were confirmed in a family in Hong Kong. This was not a localized incident. From Southeast Asia the virus quickly spread to Central Asia, Europe, and Africa. During the 3 years after the incident, around 300 million poultry died or were destroyed; of the 170 people contracting the disease, 92 died, and economic losses in Asia alone were estimated at around US$10 billion (FAO; World Bank).

Avian influenza (AI) also struck Turkey, which bridges Asia and Europe and is on the migratory routes of many wild bird species (Yalçın). The first Turkish outbreak of the HPAI, H5N1 AI in humans, was observed in mid-October 2005 in northwestern Turkey, followed by a second outbreak toward the end of December 2005. On January 5, 2006, two human fatalities were reported. The World Health Organization (WHO) reported a total of 21 human cases of AI in Turkey and four deaths, in 2006 (World Bank).

Regarding research on AI, several studies have looked at the impacts of an outbreak on various sectors of the U.S. economy. Beach, Poulos, and Pattanayak examine the influence of poultry producers' policy decisions and measures to prevent and control AI disease. They address a wide range of issues from design of disease control measures, to potential income losses, to provision of public and private services and support. Djunaidi and Djunaidi use a spatial equilibrium analysis to investigate the effects of the disease on the U.S. poultry sector and the world poultry trade, where their study indicates significant negative effects on the world poultry trade. Paarlberg, Seitzinger, and Lee address the economic effects of regionalization of an avian flu outbreak in the United States. They look at different regionalization scenarios and show large consumer losses and declines in the returns to capital and management in the poultry and egg sectors resulting from an outbreak. They find—as expected—that regionalization dampens export and welfare losses. Brown et al. look at aggregate measures of an avian flu outbreak, such as farm income and consumer expenditure losses.

Food safety shocks, such as that resulting from AI, may be transmitted through marketing channels and affect price margins at the farm, wholesale, and retail levels. In this research, we investigate the impact of H5N1 AI on the Turkish poultry sector by focusing on the short-run dynamics of price adjustment and price transmission along the poultry-marketing channel. In particular, we focus on differential speeds of price adjustments through the poultry marketing channel rather than the speed of price increases and reductions.[1] As a consequence, differing market operation dynamics are seen to have welfare implications with respect to the efficiency and equity of the marketing system.

This paper is organized as follows. In section 2 we review the Turkish poultry sector and the impact of AI. In section 3, we provide a review of the literature on price transmission. In section 4, information about the empirical model used and the data used in this research are presented. Finally, in section

[1] Traditional definition of price asymmetry refers to a situation where producer price increase moves faster than do price reductions. See p. 1021 for more explanation.

5, we convey our interpretations of the results together with our concluding remarks.

Turkish Poultry Sector and the Impact of AI

In 2006, the annual value of the poultry sector in Turkey was estimated to be worth approximately US$3 billion and (including employment in related sectors) to employ around 500,000 people (Besd-Bir). During that year, approximately 300 million birds were traded commercially within Turkey, amounting to the production of about 1 million tons of poultry meat, or roughly 2% of world production. Production and per capita consumption numbers are presented in Table 1.

In 2005, 967,900 tons of poultry were consumed in Turkey, accounting for 1.4% of world consumption. The average per capita consumption of red meat (bovine, sheep, and goat) in Turkey was 8.93 kg in 2005, whereas the fish per capita consumption in the same year was 6.93 kg. In contrast, in 2006, per capita poultry consumption in Turkey was 13.8 kg. World per capita poultry consumption numbers were 12.2 kg/y both in 2003 and 2004, whereas the United States consumed 54 kg/y and the European Union-15 consumed 23 kg/y in 2004 (Executive Guide).

Within 2 weeks of the outbreak in 2005, the impact of AI on the Turkish poultry market was such that consumption of poultry (roughly 1.2 kg per capita per month before the crisis) dropped by 50%. Retail poultry prices fell almost by 20% and the market capitalization of publicly traded Turkish poultry firms dropped by over 30% in the first week after the crisis (EU; Sarnıç; Turkstat). Demand for eggs fell 20% (from 12 eggs per capita per month) and retail egg prices dropped by 22% (EU; Turkstat). As a result, the poultry and egg sectors incurred losses estimated roughly at US$0.9 million per day during the October–December 2005 period (Besd-Bir; EU).

The AI outbreak also significantly affected poultry prices. In November 2005, real retail and wholesale poultry prices reached their lowest levels since the beginning of 2003. In November 2005, during the crisis, real wholesale broiler prices in Turkey dropped to 1.52 YTL/kg (new Turkish currency per kilogram) (the mean value between January 2003 and September 2006 was 2.18 YTL/kg and the lowest value earlier was 1.62 YTL/kg in February 2005), but soon after, especially after TV ads and newspaper announcements by the state authorities and poultry producers, demand increased, and prices rose to 2.22 YTL/kg in April 2006 (on average, US$1 was equal to 1.35 YTL in 2005 and 1.41 YTL in 2006) (Turkstat). Broiler prices for the period January 2003–September 2006 are presented in Figure 1 (see section 4 for the description of the data set). As seen in Figure 1, there was another period of falling poultry prices between November 2004 and April 2005. This fall was related to consumer response to the news that chickens were being fed excessive amounts of antibiotics and that consumption of overmedicated birds would result in health hazards.

After the outbreak, more than 13 million spent hens (almost one third of the national

Table 1. Poultry Production and Per Capita Consumption in Turkey

Year	Broiler Production (tons)	Turkey Production (tons)	Other Poultry Meat (tons)	Total Production (tons)	Exports and Imports (tons)	Population 1,000	Consumption per Person (kg/y)
2000	662,096	23,265	67,021	752,382	−1,854	67,896	11.05
2001	592,567	38,991	41,813	673,371	−12,416	68,838	9.6
2002	620,581	24,582	60,043	705,206	−6,909	69,770	10.01
2003	768,012	34,078	51,255	853,345	−9,175	70,692	11.94
2004	941,000	50,000	54,555	1,045,555	−11,711	71,610	14.44
2005	957,416	53,530	52,850	1,063,795	−30,922	72,520	14.24
2006	945,779	45,750	40,250	1,031,779	−17,832	73,423	13.81

Source: Besd-Bir.

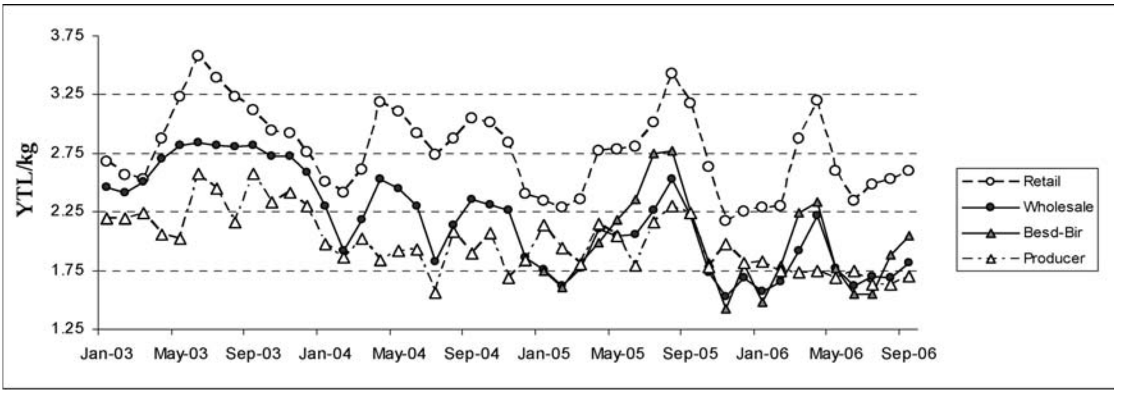


Figure 1. Real Poultry Prices in Turkey 2003:01–2006:09 (Besd-Bir, 2005:01–2006:09) Sources: Turkstat, Besd-Bir, and authors' calculations

population of egg-laying hens) were culled. The financial impact of AI in Turkey is estimated at around US$93 million; US$20 million due to decreased production, and US$73 million due to price decreases. In addition, culling, compensation of farmers, and related outlays cost an additional US$23 million (Yalçın).

Regarding the impact of the food safety shock on sales volumes, quarterly data obtained from Besd-Bir (Beyaz Et Sanayicileri ve Damızlıkçılar Birligi—The Poultry Meat Producers and Breeders Association) on sales of broiler chickens is presented in Figure 2. From Figure 2, the seasonal nature of Turkish broiler production is clearly observable. In addition, the remarkable impact of the 2005 AI incidence on the broiler industry may be seen as, during the first quarter of 2006, production dropped to the lowest levels in the 2004–2007 time periods. Whereas in 2006 first-quarter sales amounted to 174,310 tons, this was 25,000 tons lower than sales in 2004, and 55,000 tons fewer than sales in 2005.

Given the size of its poultry market, Turkey's international trade in poultry products is relatively minor. Exports of poultry meat (mostly broiler and turkey) in 2006 amounted to 39,810 tons with a value of US$28.1 million. During the same year, imports amounted to only 170 tons with a value of US$0.1 million (Besd-Bir). Domestic

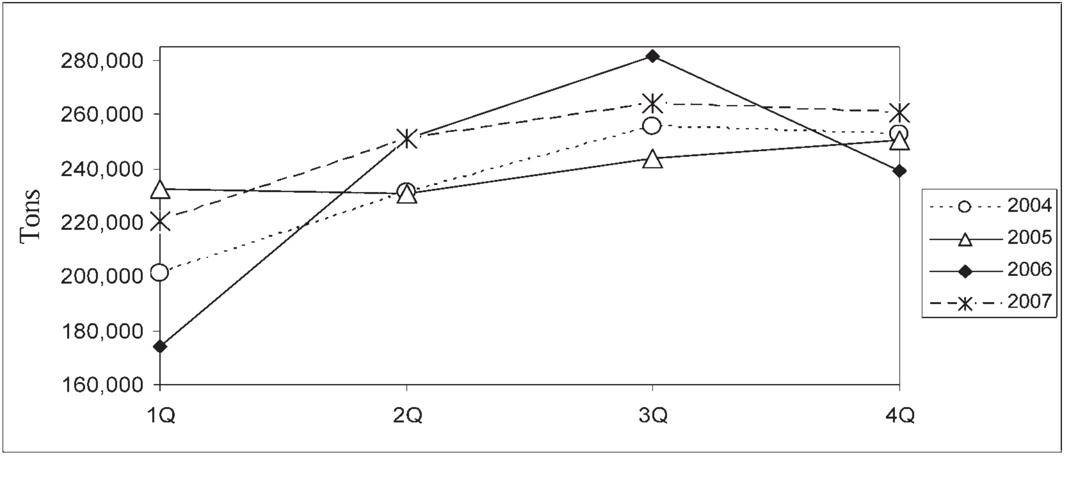


Figure 2. Quarterly Broiler Meat Production in Turkey, 2004–2007 Source: Besd-Bir

demand for poultry products is almost entirely provided for by domestic production.

According to the 2007 projections of the State Planning Organization (SPO) of Turkey, by 2010 demand for poultry meat in Turkey is expected to reach 1.3 million tons, with a per person consumption of 18 kg/y, and 1.6 million tons and 20 kg/y per person by 2013 (SPO).

Regarding the structure of the poultry market in Turkey, the majority of meat is supplied by modern enterprises and the industry is dominated by vertically integrated firms that have their own breeder units, feed mills, slaughterhouses, veterinary products, and even provide financial credits to farmers on contract. Commercial broiler and turkey production amounts to 93% of total production, whereas around 3% of production is composed of rural, backyard poultry operations (Yalçın). The integrated broiler firms are organized under the "Besd-Bir" association, which has 41 member firms and collectively shares of about 90% of total commercial poultry production in Turkey.

Review of the Price Transmission Literature[2]

The number of research articles on market integration and price transmission is extensive. Early literature in this area typically focuses on farm–retail spreads to analyze rapid producer price changes and their impacts on consumers. The early models are primarily linear equilibrium models applied to perfectly competitive markets. An important example of this literature is the work of Gardner, who investigates the factors influencing the prices of marketing services and price transmission between farm and retail sectors. He focuses on the source of exogenous shocks on the supply and demand functions. Heien, on the other hand, uses dynamic analysis to address short-run disequilibrium price adjustments.

In early price determination theory, producer price changes determine retail price changes and price transmission proceeds downward along the supply chain: meaning that the direction of causality runs from producer to retail (Tiffin and Dawson). However, the results of studies applied to different commodities in different countries are mixed. For example, Tiffin and Dawson find that lamb prices in the U.K. lamb market are determined in the retail market and then passed upward along the supply chain, i.e., the direction of causality flows upstream from retailers to producers. Others find that retail market shocks are, for the most part, confined to retail markets, but farm markets adjust to shocks in wholesale markets (Goodwin and Harper; Goodwin and Holt). Yet, Ben-Kaabia, Gill, and Boshnjaku find that both supply and demand shocks are passed along in full. It is now reasonable to hypothesize that, at least in the long run, all prices in the marketing channel are jointly and simultaneously determined.

Although short-run price behavior is thereby better understood and explained, the longer-term movements of margins are not fully understood (Tiffin and Dawson). Price transmission can be asymmetric when the speeds of price adjustments across the marketing chain differ, and the price reacts differently at one level of the supply channel to a price change at another level. Price asymmetry can exist with respect to magnitude or speed, or a combination of the two. von Cramon-Taubadel argues that in the case of magnitude the long-run elasticities of price transmission are different, because input price rises are moved more completely to output price than are corresponding input price reductions. In the case of speed, short-term elasticities differ because at the time of the input price rise, the output price responds immediately, whereas the reaction to an input decrease takes far longer.[3]

There are many notable developments in price transmission theory in the area of market efficiency and imperfect competition (e.g.,

[2] This section draws on Saghaian.

[3] For a detailed explanation and graphical examples of these issues see Meyer and von Cramon-Taubadel, pp. 582–586.

Azzam and Pagoulatos; Holloway; Hyde and Perloff, among others). Luoma, Luoto, and Taipale argue that market power is the most likely explanation for asymmetric price transmission in the long run. However, the empirical evidence supporting this hypothesis is mixed (e.g., Pelzman). The fact that price dynamics may differ under competitive and noncompetitive market conditions can lead to market inefficiency. McCorriston, Morgan, and Rayner have demonstrated the role of oligopolistic power in determining price transmission elasticity after a supply shock. Other studies have supported the hypothesis that market concentration and imperfect competition can be the cause of asymmetric price transmission (Lloyd et al.; Miller and Hayenga).

Market power can also affect price transmission in opposing ways. In imperfectly competitive markets, retailers may keep price levels relatively fixed for long periods, or oligopolies may react more quickly to declining margins by utilizing their market power (Jumah). Their goal is to maintain market shares, keeping long-run rather than short-run profits in mind. Lloyd et al. also address the hypothesis that market power changes the margins between retail and farm prices.

To investigate the dynamics of price transmission along the Turkish poultry supply chain, we use a vector error correction (VEC) model along with directed acyclic and historical decomposition graphs. The use of the VEC model allows estimation of the short-run speed of adjustment for the price series, and it also preserves long-run relationships among the variables. Cointegration of prices in distinct markets provides an indication of price transmission and market integration. Its convergence property is consistent with the hypothesis that arbitrage binds prices into long-run relations. Last, the use of historical decomposition identifies the short-run dynamic effects of the market shock on prices, and aids in providing a visual explanation of the impact of AI outbreak on the price series in the neighborhood of the event.

Data, Econometric Model Development, and Empirical Results

The data used in this study were officially collected and publicly announced by the Turkish Statistical Institute (Turkstat). Monthly time-series chicken price spreads were assembled for the period January 2003 to September 2006 for farm prices $\{P_{\mathrm{ft}}\}$, wholesale prices $\{P_{\mathrm{wt}}\}$, and retail prices $\{P_{\mathrm{rt}}\}$. Whereas prices received by farmers are published by the Department of Agricultural and Environmental Statistics, the wholesale and retail prices are published by the Department of National Accounts and Economic Indicators (both departments are divisions within Turkstat). All prices are in YTL/kg.

Turkstat does not publish standard price series on meat products. Data on retail prices are based on whole chicken meat, and real prices are calculated by deflating the series with the consumer price index. Producer (farmer) prices are based on broiler meat, and real prices are calculated by deflating the series with the agriculture, hunting, forestry producer price index. Data on producer prices were not collected before 2003, which is why the three series we use start with the year 2003. Wholesale prices for the years 2003 and 2004 are calculated from wholesale price data on poultry meat. Unfortunately, Turkstat ceased collecting wholesale price data on several items starting in 2005, and, instead, only reports producer prices from that date on. Hence, for the years 2005 and 2006 we had two options: Using wholesale broiler price data provided by Besd-Bir collected from individual firms, or recalculating producer prices by using data on whole chicken meat collected by Turkstat. These two series are found to be highly correlated (with a correlation coefficient of 0.92). To arrive at consistent data sources we prefer to use and recalculate Turkstat's data. The real prices for this series are calculated by deflating the series with the wholesale price index. All four series including Besd-Bir wholesale prices are presented in Figure 1 and the descriptive statistics of the price series used are provided in Table 2.

Table 2. Descriptive Statistics of the Price Series[a]

	Farm	Wholesale	Retail
Mean	1.99	2.18	2.77
Median	1.98	2.21	2.78
Maximum	2.58	2.84	3.58
Minimum	1.56	1.52	2.17
Std. Dev.	0.26	0.41	0.35
Skewness	0.47	0.09	0.26
Kurtosis	2.43	1.75	2.24
Observations	45	45	45

[a] Calculations are based on monthly observations of prices in YTL per kilogram (YTL/kg) for the period January 2003 to September 2006.

Commenting on the use of the data, although the beginning date of the H5N1 AI scare is known, there is no way to know exactly how long the impact of the safety scare on consumers' perception of chicken safety will last. In this research, we concentrate on the short-run dynamics of price adjustment and price transmission at different market levels in a time-interval neighborhood around the H5N1 AI shock specified by the historical decomposition graphs, though price transmission patterns could be different before and after the food safety scare. Also, there is the possibility of the presence of structural changes resulting from the food safety shock, especially in the long run. However, the monthly data available for empirical analysis provide only 45 observations, which is a rather short time period. In addition, the AI crisis happened in the middle of that period.

Given the nature of the underlying data series, we follow closely the contemporary nonstationary time-series modeling. First, the temporal properties of the three price series are analyzed using augmented Dickey–Fuller (ADF) tests. The null hypothesis is that the series are nonstationary in their levels. Traditionally, definition of price asymmetry refers to a situation where producer price increase moves faster and more completely to consumers than do price reductions (Bakucs and Ferto; Pelzman). In such cases, the standard Dickey–Fuller unit root tests, also used in this study, are improperly specified and inefficient in detecting cointegration relationship (Enders and Granger). In this research, we focus on the different speeds of price adjustment along the Turkish poultry farm, wholesale, and retail markets that affect price margins.

Second, Johansen's cointegration tests are used to determine whether a long-run relationship exists among the three price series in the system. Whenever the series are integrated and cointegrated, a VEC model is appropriate to characterize the multivariate relationships among the variables (Engle and Granger).

Next, we estimate a VEC model and conduct hypothesis testing within this framework. The VEC model uses both short-term dynamics as well as long-term information. Following that, we utilize directed acyclic graphs to investigate causal patterns among the variables. Directed graphs allow errors among the endogenous variables to be incorporated into the forecasted effects of the poultry market shock over time. Finally, the historical decomposition of farm-, wholesale-, and retail-level price series aids in explaining the behavior of chicken prices due to the H5N1 AI shock.

Consistent with the literature, we use an ADF test to determine the order of integration of each price series. For example, in the retail price series $\{P_{rt}\}$, the usual ADF test statistic is obtained from the α_1 parameter in the regression model $\Delta P_{rt} = \alpha_0 + \alpha_1 P_{rt-1} + \sum_{j=1}^{n} \beta_j \Delta P_{rt-j} + \upsilon_t$, where H_0: $\alpha_1 = 0$ is tested against H_1: $\alpha_1 < 0$ with P_{rt} representing the natural logarithm of observed retail prices.

We started with an overspecified ADF regression where n, the number of lags, was relatively large and then used a battery of lag length diagnostic tests to refine the specification for each univariate series to reach $n = 4$ (Enders). The upper portion of Table 3 summarizes the ADF test results for each variable, whereas the lower portion catalogues the results for the first difference of each price series. Given a MacKinnon 10% critical value, we failed to reject the null hypothesis of a unit root for these variables with two terms, a constant and a trend. Each series was then first differenced and the ADF regressions were re-estimated with a constant but no trend. In

Table 3. Augmented Dickey–Fuller (ADF) Test Results

Statistic/ Diagnostic	Test Results for Variables in Levels		
	P_{ft}	P_{wt}	P_{rt}
ADF test[a]	3.25	2.40	4.50*
F-test	10.56*	3.50	13.62*
Durbin–Watson	2.31	1.85	1.84
	Test Results after First Differencing Variables		
	P_{ft}	P_{wt}	P_{rt}
ADF test[a]	8.08*	5.81*	5.83*
F-test	62.14*	18.57*	17.08*
Durbin–Watson	2.12	2.12	1.99

[a] In absolute value and compared with MacKinnon, Haug, and Michelis critical values.
* 1% significance level.

Table 4. Johansen Cointegration Test Results

Null Hypothesis[a]	Trace Statistics	Probability Value[b]	Eigenvalue
$r = 0$*	39.25	0.003	0.44
$r \leq 1$*	4.55	0.069	0.25
$r \leq 2$	2.22	0.136	0.05

[a] r is the cointegrating rank.
[b] MacKinnon, Haug, and Michelis *P*-values.
* Denotes rejection of the hypothesis at the 10% level.

each case, we rejected the null hypothesis of a unit root at the 1% level of significance.[4]

Johansen's Cointegration Tests and the VEC Model

Following Enders, when the series are $I(1)$ processes, the possibility of equilibrium is examined by Johansen's cointegration test. Whenever we deal with variables that have unit root but their linear combination does not, there is a relationship between these variables regarding cointegration and that relationship is represented by the cointegrating vector. Hence, if the variables are cointegrated, their linear combination will be stationary. Using the E-Views (2004) software package, we use the Johansen's test, which is a likelihood ratio (LR) test, designed to determine the number of cointegrating vectors in the system. By using the test, 'the cointegrating rank r' is derived. Theoretically, the rank r can be at most one less than the number of endogenous variables in the model. The LR test in our analysis determines if two cointegrating vectors exist between the three endogenous price series. The results of tests conducted are reported in Table 4.

We follow Johansen's testing procedures to specify a cointegration model. Each cointegrating equation contains an intercept and a slope coefficient. At the 10% level of significance, for the trace test, which is one of Johansen's cointegration tests (Johansen and Juselius),[5] we reject the null hypotheses that $r = 0$ and $r \leq 1$, but we failed to reject the null hypothesis that the cointegrating rank of the system is at most two. These results suggest that there are two long-run equilibrium relationships between the three price series. The cointegrating vectors are used to address empirically short-run economic reactions and the speed of adjustments, trends, and long-run equilibria.

A more contemporary approach to quantifying the relationship between $I(1)$ series is to construct a VEC model. The ADF test results suggest that a VEC model is more appropriate than a vector autoregression model to characterize the multivariate relationships among the three price series (Engle and Granger). This is because the way to write the system that captures all the relationships and avoids unit roots is the VEC model; the error correction comes from the cointegrating rela-

[4] These stationarity tests are the same as checking the series for the order of integration to see if their mean and variance change and are not constant over time. When the series are integrated of order one, the series then will be checked for long-run equilibrium or cointegration.

[5] The name comes from the fact that the test statistic involved is the trace, or the sum of the diagonal elements of a diagonal matrix of generalized eigenvalues.

tionship. The VEC model incorporates cointegration to capture information contained in the series' long-run stochastic trend, and reflects the fact that the variables are $I(1)$ and must be differenced. In this model, the first difference of each price series is represented as a function of its own lagged values, the lagged values of the other variables, and cointegrating equations. The specification of the VEC model used to conduct the analysis is as follows:

$$\Delta P_t = \alpha_0 + \sum_{i=1}^{k-1} \Gamma_i \Delta P_{t-i} + \Pi P_{t-k} + \varepsilon_t$$

where ΔP_t is a (3×1) matrix (ΔP_{1t}, ΔP_{2t}, and ΔP_{3t} represent the three price series) with k denoting the number of lags; α_0 is a (3×1) vector of intercept terms; the $\Gamma_i \Delta P_{t-i}$ terms reflect the short-run relationships among elements of the P_t matrix, and the Π matrix captures the long-run relationship among the variables.[6]

The stability of the dynamic VEC model is an important issue that needs to be addressed. We have to ensure that the dynamic model is stable and the adjustment paths converge to the long-run equilibrium as time passes. The VEC model is stable if all the characteristic roots have modulus less than one and lie inside the unit circle. If the model is unstable, the empirical results are not valid and long-run steady-state equilibrium does not exist. For our data set, the results show that the dynamic model is stable and all the characteristic roots are within the unit circle. As expected, we found no evidence of first-order autocorrelation at the 5% level of significance using the Durbin–Watson bounds test. The R^2 values indicate that the models explained between 24 and 46% of the variation in the natural logarithms of the price series.

[6] When the Π matrix is less than full rank, it can be decomposed into two $p \times r$ matrices, α and β, where $\Pi = \alpha\beta'$. The matrix β contains the cointegrating vectors that represent the underlying long-run relationship and the α matrix describes the speed of adjustment to the exogenous shock at which each variable moves back to its long-run equilibrium after a temporary shock or departure from it (Johansen and Juselius; Schmidt).

Table 5. Empirical Estimates of Speeds of Adjustment

Variable	ΔP_{ft}	ΔP_{wt}	ΔP_{rt}
Speeds of adjustment	−0.59*	0.17	−0.77*
R^2	0.33	0.24	0.46

* 1% significance level.

Dynamic Speeds of Adjustment to the Food Safety Shock

The VEC model analysis of dynamic adjustments permits this study to provide a precise measure of the speeds of price transmission. The empirical estimates of the speeds of adjustment are summarized in the top portion of Table 5. The speeds of adjustment for the farm and retail price series were statistically significant at the 1% level. The speed of adjustment for the wholesale prices was not statistically significant. The speeds of adjustment have the expected negative sign because of the overreaction of prices in the short run in response to an exogenous shock. The dynamic speed of adjustment for the retail prices was higher (0.77), in absolute value, than farm prices (0.59), an indication of asymmetric price transmission with respect to speed. This is an interesting result suggesting that with the safety shock, retail prices adjust more quickly and are more flexible than farm prices to restoration in the long-run equilibrium.

This result is also important for policy makers and agribusinesses and has clear implications for the efficiency and equity of the Turkish poultry marketing system. It indicates that the speeds of price adjustment are not the same in different markets. Prices in the retail market adjust more quickly than prices at the farm level in response to the safety shock. Since retail prices decrease faster than farm prices, the burden of the H5N1 virus shock is initially borne more heavily by retailers than farmers and as a result, the farm–retail price margins initially shrank. However, in the long run, retail prices also recovered faster, and farmers had longer periods of depressed prices.

Regarding potential impacts of AI, a shock is hypothesized to affect negatively consumers' perceptions of chicken quality and is anticipated to cause spot chicken prices to decrease. It also leads to the anticipation of price decreases in the futures market. If we assume perfect competitive market conditions, such as an auction market with perfect information and no adjustment costs or explicit contracts, then prices should be flexible and adjust quickly and fully in response to the H5N1 virus scare; the shock, as expected, induces an immediate decrease in spot prices.

In terms of efficiency, prices are transmitted fully and completely given efficient market conditions. The fact that price dynamics differ might point to noncompetitive market conditions that can lead to market inefficiencies. It is important to note that our analysis cannot directly test for imperfect competition and does not explicitly address imperfect competition. Future research and modeling efforts are required to address this hypothesis directly and appropriately.

Karp and Perloff have shown that the dynamic behavior of oligopolies is relatively more competitive than collusive. Our results show the retail chicken prices to be relatively more 'flexible' in contrast to the farm-level prices. This could be due to factors such as the role of contracts (Bordo). For example, futures contracts could make farm-level prices less responsive to system shocks. Overall, prices of most homogeneous commodities that are traded in auction markets adjust instantaneously in response to exogenous shocks.

For the causes of price asymmetry, some explanations given in the literature are products of heterogeneity, long-term contracts, and adjustment or menu costs (e.g., Goodwin and Holt; Zachariasse and Bunte). As explained above, long-term contracts could play a role in how prices respond to exogenous shocks, and may explain the differential speeds of price adjustments along the Turkish poultry marketing channel. Originally, Hicks' and Okun's works showed that prices in some sectors of the economy were sticky while prices in other sectors were flexible. They argue that the prices of most goods and services are not free to respond to changes in demand in the short run. This is due to imperfect information, the costs of changing prices, explicit contracts, etc. Most of the prices of manufacturers and services, and, in general, heterogeneous goods, fall under this category.

Causality and Directed Graphs

We use the covariance matrix of the VEC model to investigate the causal relationship among the variables by directed acyclic graphs (Bessler and Akleman; Saghaian, Hasan, and Reed), and use directed graphs to determine the causal structure behind the correlation in innovations.[7] A directed graph is a picture representing the causal flow among a set of variables called nodes. Vectors are used to represent causal directions so that a vector from node A to node B indicates that variable *A* causes variable *B*. A connecting line without an arrowhead indicates that the two variables are connected by information flow, but we cannot say which one causes the other. A directed graph has a set of nodes or vertices (variables) and a set of directed lines (edges) between those vertices; it is a portrait of causal relationships among those variables. An algorithm is utilized that first assigns undirected lines to all the nodes (variables) and then removes adjacent edges when partial correlations are not statistically significant and determines causal flow directions for the remaining edges on the basis of the partial correlations of the residuals (Spirtes, Glymour, and Scheines).[8] The causal modeling software used is a set of computa-

[7] The TETRAD software uses a theory of causation to model the causal mechanisms that lie behind statistical dependencies. It uses Monte Carlo facilities in the search for path models and constructs a Bayes network from the sample data. Joint distributions allow calculation of conditional distributions, which in turn make prediction possible. For details, explanations, and proofs of asymptotic correctness of the search modules see Sprites, Glymour, and Scheines.

[8] A vector between two variables is meant explicitly to indicate the direction of the causal process generated from statistical properties of the sample. Undirected lines represent unspecified causal connections between error terms.

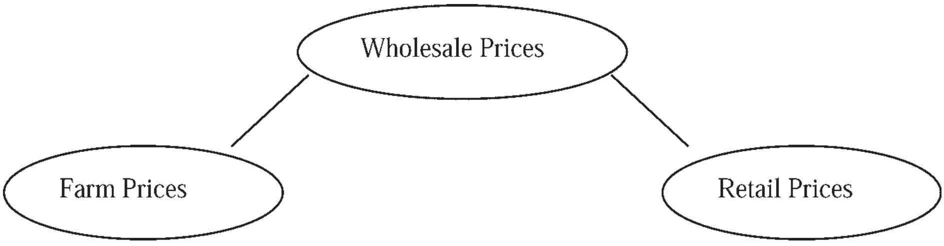


Figure 3. Causal Structure on Innovations from the Chicken Price Series (5% Level)

tional tools to help with such inferences and can handle linear structural equation models, which are used in economics and other social sciences, as well as discrete Bayesian networks used in artificial intelligence.

The TETRAD IV software (Spirtes et al.) is used to generate the causal patterns among the price series. Figure 3 presents the causal structure of the three price series on innovations from the three variables generated by the TETRAD software at the 5% significance level. The results show that innovations in farm and wholesale, and in wholesale and retail price variables affect residuals in one another (i.e., there is a connecting line, but there are no arrows to indicate the direction of causality). According to the TETRAD software, this is a case where a line between *A* and *B* indicates that either *A* is a cause of *B*, or *B* is a cause of *A*, or there is a common latent cause of *A* and *B*, or some combination of these, but the direction of causality is not known given the nature of residuals at hand. Also, there exists no residual relationship between farm and retail prices; the relationship between farm and retail price residuals is through wholesale prices. The reason for the lack of direction of causality among the three price series could be explained by the vertically integrated nature of the Turkish poultry sector. In this case, farm and wholesale prices are internal transfer prices rather than market-driven competitive prices that would be more responsive to causal market forces.

Historical Decomposition Graphs

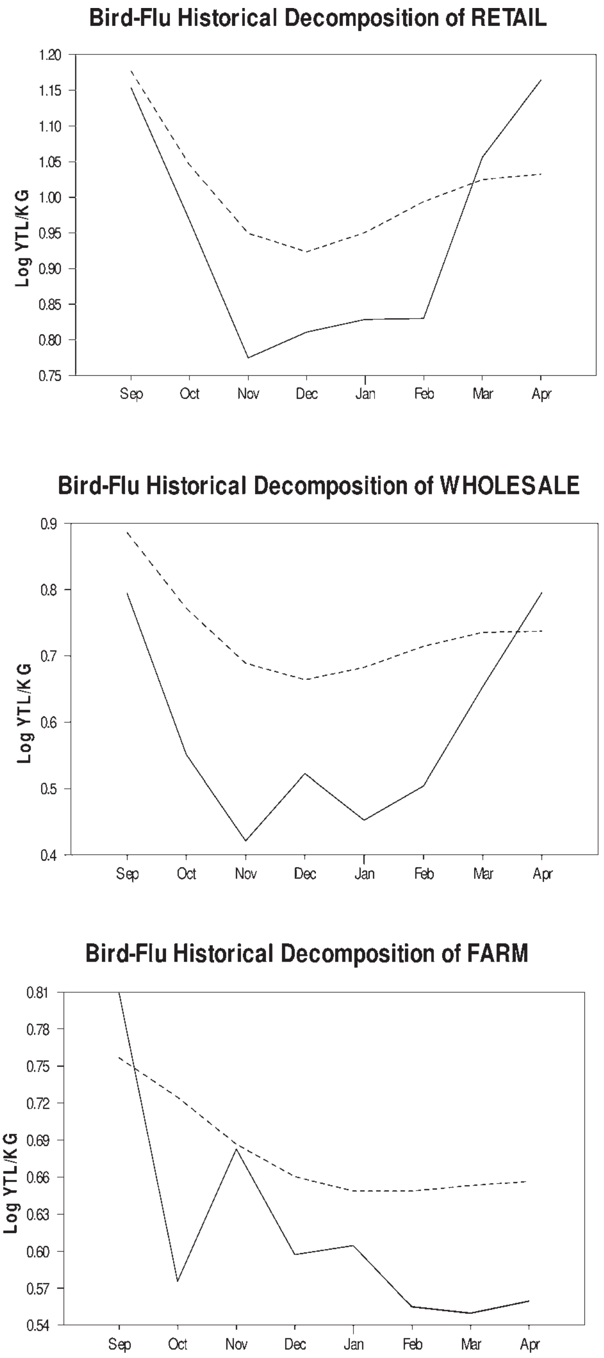
Earlier, we derived that the speeds of price adjustment along the Turkish chicken supply varied in response to the H5N1 virus scare. The next important step is to measure the magnitude of price transmission due to the food safety shock, which can be handled by historical decomposition graphs. Historical decompositions on the basis of causal patterns decompose the price series of the structural VEC model to determine the impact of the safety shock on prices in a neighborhood (time interval) of the safety scare (Chopra and Bessler; Saghaian, Maynard, and Reed). Historical decomposition graphs are based upon partitioning of the moving average series into two parts (Fackler and McMillin; RATS):

$$P_{t+j} = \sum_{s=0}^{j-1} \psi_s U_{t+j-s} + \left[X_{t+j}\beta + \sum_{s=j}^{\infty} \psi_s U_{t+j-s} \right]$$

where P_{t+j} is the multivariate stochastic process, U is its multivariate noise process, X is the deterministic part of P_{t+j}, and s is counter for the number of time periods.[9]

Figure 4 shows the historical decomposition graphs of the three price series for a 4-month horizon from RATS software. The solid line is the actual price, which includes the

[9] The first sum represents that part of P_{t+j} due to innovations (shocks) that drive the joint behavior of chicken prices for period $t + 1$ to $t + j$, the horizon of interest, and the second is the forecast of price series on the basis of information available at time t, the date of an event—that is, how prices would have evolved if there had been no shocks (RATS). The noise process is included in both parts, but for two different time periods. It drives the moving average for the two partitions, one for the process that incorporates the shock, and another for the purpose of forecast estimates.



Actual price including the *H5N1 Avian Influenza* shock:__________
Forecast price before the event: ------------

Figure 4. H5N1 Avian Influenza Impact on Turkish Retail, Wholesale, and Farm Prices in Log Form from September 2005 to April 2006

impact of the H5N1 shock and the dashed line is the predicted price excluding the effects of any shock. The dynamic impacts of shocks can spread over many time periods or dissipate quickly. However, we do not focus on prices very far into the future because we are more interested in the contemporaneous nature of their impacts. Further, it is likely that other effects would normally occur after a few weeks or months to cloud their impacts. For this study, we have emphasized a 7-month time period for forecasting and testing the impact of the H5N1 virus shock while utilizing all the observations.

The H5N1 virus was discovered in October, 2005. Before this date, the actual farm, wholesale, and retail prices (solid lines) and their forecast prices (dashed lines) followed each other closely with minor differences that are commonly expected between the actual price and its forecast. However, the series began to depart significantly in October 2005. Historical decomposition of the retail prices, which includes the impact of the shock, show that the wide departure of actual retail prices occurred in October and reached its maximum by the beginning of November 2005. It is estimated that retail prices dropped by 38% in November 2005, compared with the prices in September 2005. In November 2005, the estimated magnitude of the actual retail prices with the impact of the food safety scare were 18% lower than the forecast prices without the shock.

Meanwhile, the sharp fall in wholesale prices during the same time period was estimated to be about 38%, indicating that retail and wholesale prices were mimicking each other closely. However, the difference between the actual (solid line) and the forecast wholesale prices (dashed line) at the beginning of November 2005 was estimated to be about 28%. In contrast, the negative impact of the AI shock on the farm prices during October 2005 is estimated to be only about 20%. These results, consistent with the results for rates of adjustment, show that the impacts of the chicken safety scare on producers and retailers differ significantly. The impact of the shock on retail and wholesale prices is almost double the impact on the producer prices, a clear indication of an asymmetric price effect with respect to magnitude. These results indicate that in the short run, an exogenous food safety scare on the Turkish poultry sector affected wholesalers and retailers much more severely than producers.

Interestingly, between October and November of 2005, producer prices recovered up to a point where the actual and forecast prices were the same in November, but producer prices continued to decrease for the next few months with the ongoing media coverage of the bird flu and the news of fatalities. The wholesale and retail prices were also shown to increase by December with a 1-month lag and level off again, but during February and March, they had completely recovered and sharply increased by April 2006. There are several reasons for this behavior: first, the result is related to the preferences and habits of Turkish consumers. Demand for poultry meat usually increases in early spring in Turkey with increased outdoor activities and picnicking/grilling. The second reason is that there was a suppressed demand for poultry during the crisis and once the crisis was over, demand for poultry meat increased while companies had allegedly destroyed chicks they owned and canceled the contracts they had signed with growers, constraining supplies. Also, during the crisis, because of excess financial pressures, several smaller producers went bankrupt and exited the market (Yalçın, personal communication).

Overall, the historical decomposition results showed, as expected, that discovery of the H5N1 virus affected chicken prices negatively, but the magnitude of price effects were substantially different for the price series, resulting in a widening of the price differences. Also, the effect of the shock on the wholesale and retail price series in December shows a lag of approximately 1 month. Since the H5N1 virus discovery was covered by the media and electronic news outlets rather quickly, the estimated 1-month lag for the safety impact along the supply channel may reflect the role of contracts and the fact that in the research we are dealing with monthly data series, rather than reflecting problems with the flow of information through the chain.

These results, consistent with our previous results regarding the differential speeds of adjustment, point to differing price transmission in the Turkish poultry-marketing channel. Lloyd et al., who investigated the impact of food scares in the U.K. meat market, suggest that market power could influence the retail–farm margin. Their results found market inefficiency in the opposite direction, supporting the hypothesis that market power caused the margin between retail and farm prices to widen after a food safety scare. Our results showed that farm prices had a lower speed of adjustment and fell less than retail prices because of the AI shock. It seems the difference is due to the fact that the Turkish poultry sector is vertically integrated to a high degree, and retailers might have kept long-run rather than short-run profits in mind when accepting shrinking margins. In contrast, in the U.K., meat markets consist of market concentration related to size (i.e., horizontal integration), rather than vertical integration, leading to wider margins. More research explicitly incorporating appropriate imperfect competitive analysis is required to address the oligopolistic and oligopsonistic market behavior in the Turkish poultry sector.

Summary and Concluding Remarks

In this article, we investigated how the discovery, in late 2005, of the H5N1 virus in the Turkish poultry sector affected farm-, wholesale-, and retail-level chicken price series along the Turkish chicken supply channel. We applied time-series cointegration techniques, VEC, directed graphs, and historical decomposition to monthly Turkish chicken price series. The objective was to investigate the following hypotheses.

First, the results of the cointegrated VEC model showed that retail prices were more flexible than farm prices, and the short-run speed of adjustment at the retail level was faster than the one at the farm level. More than 80% of poultry growers in Turkey sign contracts with large firms, and around 90% of broilers are produced under contract (Çınar; Çobanoğlu, Konak, and Boztürk). This explains why farm-level prices are less flexible. With contracts, prices are sticky and cannot be adjusted over the duration of the contract.

Hahn, investigating the U.S. meat markets, argues that month-to-month meat price changes are due to dynamic adjustments; he shows that livestock and meat prices vary more in the short run than do operational costs. Mathews, Jr. et al. argue that wholesale prices are more variable than retail prices in the U.S. beef sector. They further state that it often seems that retail prices follow producer prices and mimic the ups and downs of producer prices with lags of a month or more. Our results confirm this assertion only to a degree. We used monthly data as well, and historical decomposition graphs showed the lag to be about 1 month for part of the time period investigated.

Second, the historical decomposition results corroborated those of the VEC model and dynamic speeds of adjustment, showing that the burden of the H5N1 virus shock on prices was distributed unevenly, with the wholesale and retail levels taking most of the burden of the negative price shock, falling by almost twice as much compared with the fall in the farm prices. The historical decomposition graphs showed that retail and wholesale prices initially decreased more than farm prices; later these prices recovered quickly, but farm prices did not. Again, contracting might be the key factor to explaining these results. Although we cannot not say much about the impact on profits explicitly, the results showed that margins diminished in the short run, which could lead to lower profits at the retail level. In the long run, because of the sluggishness of farm-level price recovery, the profits at the farm level could have suffered.

Looking at the historical decomposition graphs, we see that for the producer prices, toward the end of the analysis, in March 2006, actual prices were far lower than forecast, and remained at that level for some time, whereas forecast wholesale and retail prices were equal to actual prices in March 2006 and later increased. This is not the case with farm prices, which moved lower and remained at those depressed levels.

Also, looking at the farm and wholesale prices, we see that for the period November 2005–March 2006, the farm prices were above the wholesale prices, meaning that wholesalers were making losses during the period. It seems that producer losses were prolonged, possibly due to lack of concentration or organization on their part. Azzam and Anderson, who reviewed the literature on the meatpacking industry in the United States, concluded that increased concentration might be due to the economies of size rather than noncompetitive behavior; packers' market power did not increase with greater concentration.

The results showed that differing price adjustments exist in the Turkish poultry marketing channel. The differential effects of the discovery of the H5N1 virus on supply channels between farm and wholesale, and wholesale and retail, consequently distort distribution of income in the industry. There are many factors that could contribute to this; for example, the role of contracts. However, other factors such as product heterogeneity, market inefficiency, imperfect competition, and market power could also lead to differential price adjustments in the supply chain. Further research is needed to address these issues.

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