Dynamic and Asymmetric Adjustment in Beef and Pork Prices

By
William F Hahn[1]
USDA-ERS

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[1] The views expressed in this paper are the author's and do not reflect official Economic Research Service positions.

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Abstract

Beef and pork prices at farm, wholesale and retail are examined for evidence of a dynamic and asymmetric price transmission using an endogenous switching model. Dynamic adjustment means that it take time for prices to adjust to changes in the market. Price transmission is asymmetric if the speed or completeness of price adjustment depends on the direction that the price or a related price is moving. Some of the previous research on price transmission in agricultural markets attempts to use market power abuses as an explanation of price-transmission asymmetry. Other research shows that price transmission asymmetry can arise in competitive markets and that competitive and anti-competitive issues can make prices adjust faster upwards or downwards.

By making stronger assumptions about the how live animal production relates to meat production and consumption and on the cost structure of packing and retailing, stronger statements about price transmission and potential market-power problems can be made. Incomplete or irreversible price transmission can be taken as evidence of market power issues given these stronger assumptions. However, these assumptions must be true or the tests will not be valid.

Two potential sources of incomplete-irreversible effects were included in the endogenous switching models. The only statistically significant evidence of incomplete price transmission is in the wholesale-to-retail transmission in pork. The estimates imply that the 89½% of wholesale price changes get passed to the retail price. In beef, price transmission was complete and pricing dynamics are symmetric.

Introduction

This research examines the relationship among the prices of beef and pork at the farm, wholesale, and retail levels for dynamic and asymmetric price transmission. In this context, “dynamic” price adjustment means that it can take time for prices to adjust at one level to changes in prices at different levels. An “asymmetric” price reaction is one where the speed or completeness of adjustment varies depending on whether prices are increasing or decreasing. This research is an extension of work previously done by the author. (Hahn 1990, 2004.) The data used in this study is published by the USDA's Economic Research Service on its website.[2]

Producers, consumers, and policy makers are concerned about prices in meat markets and the relationship between farm and retail prices. On August 15, 2009, The U.S. Department of Justice (DOJ) and The U.S. Department of Agriculture USDA) announced a jointly-sponsored series of 5 workshops to be held in 2010 "to explore competition issues in the agriculture industry." Producers have asked the Government to review their concerns regarding increased concentration and potential market power abuses in food processing and retailing. Much of the concern is focused on animal agriculture; the middle three workshops address poultry, dairy, and livestock respectively. The last of the workshops (December 8, 2010 in Washington DC) addresses "the discrepancies between the prices received by farmers and the prices paid by consumers". Economic theory shows that anti-competitive behavior in food marketing could cause some combination of lower farm prices and/or higher retail prices. Large gaps between farm and retail prices could be evidence of market power abuses.

Critiques of Asymmetric Price Transmission Research

There have been a large number of studies examining prices for dynamic and asymmetric price transmission. In 2004, Meyer and von Cramon-Taubadel wrote a critical survey article on asymmetric price transmission studies, most of which were done for agricultural markets. They noted that asymmetric price transmission was often assumed to be evidence of market power or other problems. One of their critiques of these studies is that many were statistical technique driven with little or no theoretical basis. However, those studies that attempted to build a theoretical case for asymmetric price transmission come to widely different conclusions about its

[2] The author also collects the raw data and calculates the Choice beef and pork price spreads data.

sources and the impact of these sources on the direction price-transmission asymmetry.

Some of the studies cited showed how market power can lead to asymmetric price transmission. Other economists have shown how dynamic and asymmetric price transmission could arise also in competitive markets. (The issues that cause dynamic and asymmetric adjustment in competitive markets could also affect uncompetitive markets.) To further muddy the issue, Meyer and von Cramon-Taubadel note that there is no consensus in the theoretical literature about what type of asymmetry one will get. There are cost and competition problems that will make prices increases faster than they decrease or vice versa.

Meyer and von Cramon-Taubadel also discuss their own work demonstrating conditions where price transmission asymmetry is only apparent and not real. Much of the applied price-transmission work is based on pure time series modeling. That is, prices are related to one another only and not to supply and demand conditions. Price changes could be driven by supply and demand shifts. Asymmetric movements in either supply relative to demand or vice versa could produce apparent asymmetry in price interactions. They noted that the EU beef market had suffered a series of food-safety incidents in the 1990s, decreasing beef demand. This pattern of shocks could lead one to believe that retail price decreases were being transmitted more fully to farm prices than retail price increases.

Meyer and von Cramon-Taubadel also mention issues with unit roots in the data underlying the empirical analysis. Unit roots can affect the distribution of statistical hypothesis tests. Most of the applied tests for asymmetry are based on asymptotic distribution theory. Unit roots in the data can lead to violations of the asymptotic conditions on which tests' distributions are based.

Dealing with the Critiques in the Applied Model

The statistical model that I estimate is based on my 2004 model, which has been modified to deal with some specific critiques Meyer and von Cramon-Taubadel raised about asymmetric price transmission studies in general.

First, I am going to attempt to deal with the "spurious asymmetry" problem by including supply, demand, and marketing-cost shifters in the model as well as current and lagged prices. The 2004 model included these factors in its specification; this new version includes an expanded set of exogenous variables.

It is well known that unit roots can cause problems with tests in small samples; however, their large-sample effects are mixed. Sims, Stock and Watson demonstrated that many hypothesis tests on cointegrated systems are asymptotically normal- chi-square or something close to that. Even if the data do not have unit roots; the model presented here is also non-linear and will be estimated using a multi-stage, method of moments/instrumental variable approach. All of these features can make the small-sample properties of tests much different than the asymptotic ones. Usually non-linear estimates and their tests have fatter tails in small samples than they do asymptotically. To test various hypotheses about the data, I will first use the standard chi-square tests. If the test passes the chi-square, I will accept it. Those hypotheses that are rejected by chi-square tests may be evaluated using Monte-Carlo techniques.

Speaking of unit roots, I modified the 2004 structure to allow for unit roots in price transmission, either in the setting of over-all price levels or in the differences between prices at different levels. Other than their impacts on tests, I am not concerned with unit roots effects on my estimates. Sims, Stock, and Watson's results show that models with unit roots are generically consistent, even if unit root restrictions are not imposed. Another implication of their proof is that one can have mixed-root systems; for example, farm prices could be stable while wholesale and retail prices both have unit roots.

Much of the public concern with meat price interactions is concern about the possible abuse of market power. Given Meyer and von Cramon-Taubadel's critique of the theory, is there anything one can determine about market power from price interactions? I am going to argue that by adding some additional assumptions, stronger statements about price transmission and potential market-power problems can be made. However, these assumptions must be true or my tests will not be valid.

The Choice beef and pork price spreads published by ERS are based on the assumption that the standard animal yields a standard amount of wholesale and retail meat, the fixed-proportion assumption. (See Hahn 2004 for a discussion of meat price spread procedures and assumptions) These fixed-proportion assumptions are used to transform cattle, hog and wholesale meat prices into a price-per-retail-weight equivalent. The statistical model is based on the assumptions that the meat is processed by a fixed proportions technology and the ERS estimates of the fixed proportions are correct. I also assume that the long-run differences between farm prices, wholesale prices, and retail prices are independent of the volume of meat processed.

My explicit assumptions also embody some implicit ones; I am aware of two[3] that I will make explicit. I have included a number of exogenous variables that are implicitly assumed to be adequate to explain the shifts in demand, supply, and marketing costs. If this is not true I could be inducing "apparent" as opposed to real problems in price transmission. Second, the model is based on the idea that differences between farm and wholesale and wholesale and retail prices reflect farm-to-packer and packer-to-retailer gross margins. I have a lengthy discussion of

[3] I am not trying to hold anything back here; there could be some of which I am unaware.

the relationship if any between price spreads and gross margins in the 2004 report.

I specified the 2004 model so that it required the fixed-proportions and spreads-independent-of-volume restrictions to hold when markets were fully adjusted. If I relax the restrictions on the model, I can test for partial- irreversible price transmission between levels. By "partial" I mean that price changes at one level are only partially transferred to other levels; say the farm price changes by 1 cent, marketing costs do not change, but the retail price only changes by 0.6 cents (after full adjustment). By "irreversible" I mean cases where price adjustment is asymmetric in the long run; for example, farm prices go up by 1cent, retail prices (eventually) go up by 1 cent. Farm prices go down by 1 cent, retail prices do not change.

ERS Price Spread Data

ERS meat price spreads are based on 4 sets of values-prices: the byproduct allowance, the gross-farm value, the wholesale value, and the retail value. The models that I estimate are 4-equation models designed to explain these 4 values. The Choice beef and pork price models are separately estimated. I test hypotheses by comparing the results of more-restricted models against more-general ones. The model structures are generic to both species.

All four prices are measured in dollars per pound of retail cut. The retail values are designed to measure the cost of buying back all an animal's meat parts at the grocery store. The gross farm values are the prices of either a steer or hog transformed into cents per pound of retail cuts. Wholesale values are based on the prices packers get for their Choice beef or pork, again adjusted based on the retail yields of these cuts. In addition to meat, animals produce a range of edible and inedible byproducts: hides/skins, tallow/lard, bones, etc. The byproduct allowance is a measure of the value of these byproducts.

I made some minor modifications to one part of the ERS data to make it more consistent with a gross-margins relationship. To estimate the byproduct allowance, we calculate the value of the animal's meat and its byproducts as sold by the packer. Currently for Choice steers our calculations show that around 11% of the animal's value is in its byproducts, the rest is in its meat. (The share varies constantly as meat and byproduct prices change.) The byproduct value is then calculated by multiplying the gross-farm vale, GFV, by the ratio of packers' sales of byproducts divided by total sales. If 11% of the packers sales come from byproducts and 89% comes from beef, we make a byproduct credit by multiplying GFV by 11% and 89% of the GRV is assigned to the Net Farm value. The byproduct adjustment is meant to divide up the live animal's value; it will understate the value of byproduct sales to the packer. For this study, I "inflated" the byproduct value back up to match the value of byproducts to the packer; something I did not do in 2004.

The applied model

My data set for this study has monthly ERS meat price spread data starting in 1970 and ending with December 2009. Actual estimation starts with 1971 data; I use the first year of observations to deal with lags in the model. The model itself is an extension of the Wolffram-Houck-Ward approach, an approach invented by Wolffram and subsequently modified by Houck, then Ward. My innovation to this procedure was to embed the approach in an endogenous switching framework. Wolffram-Houck-Ward- endogenous-switching models use signed differences in the prices. For example:

$$(1)\quad y^{+}_{t,i} = \begin{cases} y_{t,i} - y_{t-1,i} & \text{if } y_{t,i} > y_{t-1,i} \\ 0 & \text{if } y_{t,i} \le y_{t-1,i} \end{cases}$$

$$(2)\quad y^{-}_{t,i} = \begin{cases} 0 & \text{if } y_{t,i} > y_{t-1,i} \\ y_{t,i} - y_{t-1,i} & \text{if } y_{t,i} \le y_{t-1,i} \end{cases}$$

In my model, prices are denoted by y. The subscript "t" stands for a specific month and the subscript "i" is a specific price. I used 3-letter codes for the prices in the model-estimation files[4]: BYP, GFV, WHL, and RET, for byproduct, gross-farm value, wholesale value, and retail value. I use these signed differences and lagged prices in the model. In order to account for irreversible effects, I also created a series of Wolffram variables, called "w". The W are generated by the following equation:

$$(3)\ w_{t,i}^{?} = w_{t-1,i}^{?} + y_{t,i}^{?}$$

In (3) the "?" is a wildcard that is either – or +. The w are cumulated signed changes in the prices. The 2004 model did not have w variables.

With 4 endogenous variables, I need 4 equations in the model; these are identified using 4-letter codes. Two equations are the price-spread-definition equations: F2WS is the farm-to-wholesale-spread equation and W2RS is the wholesale-to-retail-spread equation. The other two determine the general price level for meat and the byproduct value: MEAT and DROP[5].

I build the endogenous switching model by starting with the simplest structure possible and adding features. The example equation chosen here is the W2RS. If there are no asymmetries or dynamic in determining the wholesale-to-retail spread, i.e. the wholesale-to-retail spread adjusts instantly, I would write W2RS as:

$$(4)\ y_{t,RET} - y_{t,WHL} = X_t \beta_{W2RS} + u_{t,W2RS}$$

In (4) the X_t is a vector of exogenous variables, β_{W2RS} a set of estimated coefficients and $u_{t,W2RS}$ a random error term. Tables 1 and 2 list the endogenous variables by their index names, identify their sources, and identify which variables show up in which equations. The exogenous variables include functions of quantities of beef and pork produced each month; these quantities are excluded from the W2RS and F2WS equations.

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[4] I estimated the model using the mathematical programming software GAMS.
[5] Most of beef's byproduct credit is calculated from the "byproduct drop value" as calculated and reported by USDA's Agricultural Marketing Service.

To transform (4) into a dynamic and asymmetric equation, add lags and signed price changes. The form I used in 2004 is something like:

$$\begin{aligned}
&\textstyle\sum_{i=0}^{1} a^{+}_{W2RS,RET,i} \cdot y^{+}_{t-i,RET} + a^{-}_{W2RS,RET,i} \cdot y^{-}_{t-i,RET} \\
(5)\quad &+ \textstyle\sum_{i=0}^{1} a^{+}_{W2RS,WHL,i} \cdot y^{+}_{t-i,WHL} + a^{-}_{W2RS,WHL,i} \cdot y^{-}_{t-i,WHL} \\
&y_{t-2,RET} - y_{t-2,WHL} = X_t \beta_{W2RS} + u_{t,W2RS}
\end{aligned}$$

In (5) the "a" are endogenous variable coefficients. I use current and lagged signed changes and twice-lagged in the wholesale and retail prices. (5) is basically a twice-lagged model. In 2004 I only used one lag, current signed changes and once-lagged prices. The equation is symmetric if the a^+ and a^- terms for each price-lag pair are the same. When we have full adjustment all the y^+ and y^- are 0, which makes the y_{t-2} equal to the y_t and (5) is essentially (4). In full adjustment, both (4) and (5) imply that the retail price is the wholesale price plus some spread.

The structure of (5) requires that the twice-lagged retail price has a positive effect on the left-hand side of the equation while the twice-lagged wholesale price has a negative effect. I also impose these sign restrictions on the current signed changes. Lagged, signed changes have free signs. I impose these sign constraints (and similar ones on the other equations) for two reasons. First, the sign constraints help insure that price adjustment makes intuitive sense. The second has to do with the model's structure as an endogenous switching model. This model is a set of set of simultaneous equations. Simultaneous equations have identification conditions, endogenous switching models also have *coherency* condition. The model is coherent if there is one and only one solution for its current endogenous variables given the lagged endogenous, exogenous, and error terms. Gourieroux, Laffont, and Monfort discuss coherency and the requirements it imposes on endogenous switching model coefficients in general cases. My previous works discuss how to impose these restrictions in these specific types of models.

Two modifications allow the model to have irreversible-incomplete price transmission and unit roots. To model irreversible effects in the W2RS equation, I add third-lags of the Wolffram variables for WHL & RET and set of coefficients for each. I test these coefficients to see if I have either incomplete or irreversible price transmission.

To allow for unit roots, I introduce an estimated parameter for the twice-lagged prices, called $a_{W2RS,2}$. This coefficient multiplies the twice-lagged retail price and its negative multiplies the twice-lagged wholesale price[6]. If $a_{W2RS,2}$ is 0 then there is a unit root in the wholesale-retail spread. If there is a unit root, the right-hand-side of the modified version of (5) now determines how the wholesale-retail spread grows or shrinks over time rather than the full-adjustment price spread.

Note that if an equation has a unit root and asymmetries in the current and lagged price changes there will be irreversible effects even if the w-variables have 0 coefficients. In the unit-root case, some part of any change in this month's price spread is going to persist indefinitely. The difference between increases and decreases on the price spread equations give us irreversible price effects. In order to rule out irreversible price transmission effects I have to have 0-coefficients on the Wolffram variables and no unit roots in the W2RS or unit roots in W2RS and symmetric price transmission. Unit roots and symmetric price transmission could product incomplete price transmission.

I would expect that the use of exogenous variables ought to reduce the chances of finding unit roots in the data. It could be the case that inflation could induce some apparent unit roots. After the w & y variables were created, they were deflated using the consumer price index, CPI. The nominal variables in the "X' are also deflated. I assume that people are switching their behavior based on changes in nominal prices.

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[6] In the 2004 model, the coefficients on the lagged variables helped to identify the equation. I used over-all size restrictions on the current-price change terms to identify this and the other three equations in this study.

The structure of the F2WS is similar, except that it includes three endogenous variables and their lags-differences: BYP, GFV, and WHL. The farm-to-wholesale price spread is WHL+BYP-GFV. The DROP and MEAT equations were designed to allow for flexible specification of price discovery. Much of the price transmission research based on the on Wolffram approach required that one price or set of prices followed another price or set of prices. One of the reasons for using endogenous switching models in the first place is to be able to test for leader-follower type behavior within the context of the asymmetric model. Three of my prices-products have meat in them, the live animal, wholesale and retail. Two of the prices-products have byproducts in them, live animals and the byproduct value. The DROP equation has BYP and GFV in it lags and signed differences. The MEAT equation has all 4 prices in it. In order to improve its identification, I require its currents & lagged endogenous-variable coefficients to be orthogonal to the other three equations'.

Although the MEAT and DROP equations are tested for irreversible effects I would contend that irreversible effects in these equations cannot be evidence of market power abuses. Market power abuse would lead to wider margins in the marketing channel. I would consider irreversible price level effects to be evidence of irreversible shifts in supply and/or demand. These are likely to be spurious asymmetries.

Estimation Procedures

Endogenous switching models are non-linear models and have to be estimated with non-linear techniques. In my previous research I estimated these models using full-information-maximum likelihood, FIML, estimation assuming that the errors are normally distributed. FIML is the most efficient estimation technique if all your assumptions are correct. If your assumption about the error distribution is incorrect, FIML can be badly biased. Instrumental variable estimation (IVE) is more robust, but less efficient if the errors are normally distributed. I used a generalized-method-of-moments inspired version of IVE; it is not "general" as I assume that the instruments and equation errors are truly independent[7].

Prior to estimating this model, I did a Monte-Carlo study of a simple, single equation endogenous switching model estimated using normal FIML and IVE with normally and non-normally distributed errors. IVE worked under all types of error structures. FIML worked well for normally distributed errors and was not dreadful if the errors were non-normal but symmetric, although IVE seemed better. FIML was badly biased when the error distribution was not symmetric. I estimated versions of the 4-equation models using both FIML and IVE and the two sets of estimates were vastly different; suggesting to me that the errors are not normally distributed.

Table 1 lists which of its exogenous variables were used as instruments. All the exogenous variables in Table 2 are instruments. I did not use lagged prices or Wolfram variables as instruments. The equation error terms are likely to be auto-correlated and lagged prices would violate the conditions for the instruments. All the models are estimated in three steps. In step 1, I estimate the least-restricted models without correcting for the covariance of the errors or the potential autoregression. I take the first-stage errors and estimate a third-order vector-autoregressive (VAR) model. I fix the VAR and inverse covariance matrix in the third stage. I would loop through the errors again using the third-stage errors and repeat the third stage on least-constrained models. I would then run the constrained models using the free-model VAR and covariance matrix, comparing the objective function. The difference in the constrained and less-constrained objective is asymptotically chi-square.

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[7] The MEAT & DROP equations both have current changes in beef and pork production in them. These quantities could be jointly endogenous with prices, another reason to go with IVE.

Test results and Implications

The Wolffram variables were tested first. These were statistically insignificant for all the equations except for those in pork's W2RS. These coefficients were also statistically significant under Monte Carlo analysis. Further testing of the Wolffram coefficients showed that only the RET terms were significant and that these are symmetric. The symmetry of the Wolffram terms implies that pork's wholesale-retail price transmission is reversible.

Another potential source of irreversible or incomplete price transmission is a unit root in either or both of the F2WS and W2RS equations. All the tests were very large, and I decided not to pursue Monte Carlo analysis. I then tested equations and variables for symmetry. An equation is symmetric if all pairs of a^+ and a^- coefficients are the same. While I was testing for asymmetry, I decided to check the equations for adjustment speed. One extreme case of asymmetric adjustment is when an equation implies instant adjustment; that happens if the coefficients of its current and lagged changes are the same as the coefficients on its twice-lagged levels.

Each beef equation symmetry test and all groups of beef equation symmetry tests were statistically insignificant. All the tests of instant adjustment in beef are rejected. Pork has instant-symmetric adjustment in the DROP equation and symmetric adjustment in F2WS. The combination of instant DROP and symmetric F2WS is also not statistically significant.

My previous research has found statistically significant asymmetry in both beef and pork prices. The 2004 analysis used much of the same data and specification that I use here. It could be the case that the statistical significance is the result of using FIML when the errors are not normally distributed.

Coefficient estimates for the final models are presented in tables 3 and 4. These estimates are based on a fourth step in the estimation procedure. In this step, I put the lagged prices into the set of instruments and estimated the VAR autoregression simultaneously along with the rest of the models' coefficients.

What do these estimates imply about price transmission in beef and pork markets? Beef has no asymmetric adjustment, and price adjustment is complete over the longer term. Pork has evidence of asymmetric adjustment between wholesale and retail prices. The coefficient on the third lag of the retail price is 0.226; combining this with the estimate for the lagged wholesale-to-retail spread coefficient, 1.909; implies that when fully adjusted only 89.4% of the wholesale price change is passed on the retail price. This could be taken as evidence of non-competitive price of pork to consumers.

It is somewhat surprising that beef and pork wholesale-retail price interactions are so different, given that the same firms, supermarkets, are the source of both meats' retail prices. Explaining this difference could be difficult. Another problem with the estimated models are that they fit the data poorly compared to the 2004 models.

Web resources for the DOJ-USDA Workshops and Data

The press release announcing the workshops can be found on the USDA Office of Communications website as Release No. No. 0368.09, August 5, 2009.
http://www.usda.gov/wps/portal/!ut/p/_s.7_0_A/7_0_1OB/.cmd/ad/.ar/sa.retrievecontent/.c/6_2_1UH/.ce/7_2_5JM/.p/5_2_4TQ/.d/3/_th/J_2_9D/_s.7_0_A/7_0_1OB?PC_7_2_5JM_contentid=2009%2F08%2F0368.xml&PC_7_2_5JM_parentnav=LATEST_RELEASES&PC_7_2_5JM_navid=NEWS_REL

Details on the workshops can be found on the Department of Justice, Antitrust Division website
http://www.justice.gov/atr/public/workshops/ag2010/index.htm

USDA-ERS meat price spread data can be accessed at
http://www.ers.usda.gov/Data/MeatPriceSpreads/

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Table 1—exogenous variables that are not pure functions of time

<table>
<tr><th rowspan="2">Index name</th><th rowspan="2">Explanation</th><th rowspan="2">Source</th><th colspan="2">In equation?[1]</th><th rowspan="2">Instrument treatment</th></tr>
<tr><th>F2WS</th><th>W2RS</th></tr>
<tr><td>wageRET</td><td>hourly earnings retail trade</td><td rowspan="9">Bureau of Labor Statistics</td><td></td><td>x</td><td rowspan="9">Current through 4 lags of these variables are instruments</td></tr>
<tr><td>wagePAK</td><td>hourly earnings meat packing</td><td>x</td><td></td></tr>
<tr><td>ppiBox</td><td>PPI Boxes</td><td>x</td><td>x</td></tr>
<tr><td>ppiNRG</td><td>PPI Fuels and related products and power</td><td>x</td><td>x</td></tr>
<tr><td>ppiFuel</td><td>PPI fuels & lubricants</td><td>x</td><td>x</td></tr>
<tr><td>cpiBird</td><td>CPI poultry</td><td colspan="2" rowspan="3">these three are only used as instruments</td></tr>
<tr><td>cpiFish</td><td>CPI fish & seafood</td></tr>
<tr><td>cpiMilk</td><td>CPI dairy & related</td></tr>
<tr><td>cpiFuel</td><td>CPI motor fuel</td><td>x</td><td>x</td></tr>
<tr><td>D0upQB</td><td rowspan="8">D0up, D0dn are current increase and decrease, W1up, W1dn are lagged Wolffram variables. QB and QP are logarithms of beef and pork production.</td><td rowspan="8">USDA National Agricultural Statistics Service Data</td><td colspan="2" rowspan="8">the quantities are excluded from both of the spread equations</td><td rowspan="8">The second & third lags of the differences are used as instruments. There may be simultaneity between current quantities & prices.</td></tr>
<tr><td>W1upQB</td></tr>
<tr><td>D0dnQB</td></tr>
<tr><td>W1dnQB</td></tr>
<tr><td>D0upQP</td></tr>
<tr><td>W1upQP</td></tr>
<tr><td>D0dnQP</td></tr>
<tr><td>W1dnQP</td></tr>
</table>

[1] The DROP & MEAT equations have all the exogenous variables

Table 2—exogenous variables that are pure functions of time (and are also instruments)

x0	x1	intercept & trend
Cos1	Sin1	seasonal variables: cosine& sine making 1,2, & 3 turns per year
Cos2	Sin2	
Cos3	Sin3	
Cost1	Sint1	seasonal variables: cosines & sine making 1,2, & 3 turns per year times trends
Cost2	Sint2	
Cost3	Sint3	
TCos1	TSin1	I used harmonic terms to add flexibility to the trends. Tcos & Tsin are cosine & sine making 1/2, 1, 2 or 3 revolutions in 40 years
TCos2	TSin2	
TCos3	TSin3	
TCos4	TSin4	

Table 3—endogenous variable coefficients[1]

			difference & lag treatments				
			current		lagged		twice-lagged
meat	equation	variable	increase	decrease	increase	decrease	
Beef[2]	F2WS	BYP	0.499	0.499	-0.101	-0.101	0.652
		GFV	-1.082	-1.082	0.064	0.064	-0.652
		WHL	1.257	1.257	-0.189	-0.189	0.652
	W2RS	WHL	-0.640	-0.640	-0.894	-0.894	-0.330
		RET	1.261	1.261	0.674	0.674	0.330
	DROP	BYP	0.460	0.460	-0.351	-0.351	1.018
		GFV	0.888	0.888	1.120	1.120	1.029
	MEAT	BYP	-1.626	-1.626	-1.015	-1.015	-0.173
		GFV			0.392	0.392	0.080
		WHL	0.597	0.597	-0.082	-0.082	
		RET	0.006	0.006	0.345	0.345	0.413
Pork	F2WS[2]	BYP			4.707	4.707	0.632
		GFV	-1.118	-1.118	-1.585	-1.585	-0.632
		WHL	1.323	1.323	0.736	0.736	0.632
	W2RS	WHL	-0.676	-0.626	-1.561	-1.691	-1.909
		RET	0.952	1.498	1.695	2.224	1.909
	DROP[3]	BYP	1.000	1.000	1.000	1.000	1.000
	MEAT	BYP		-1.011	1.342	-0.331	
		GFV	1.458	1.422	1.833	0.663	1.046
		WHL	0.064	0.910	-0.274	1.909	0.927
		RET			0.622	0.777	1.256

[1]Blank cells are 0 by exclusion or sign restrictions. Special highlighting denotes symmetric or instant-adjustment equations.

[2] All the beef equations and pork's F2WS are symmetric

[3] Pork's DROP equation implies instant adjustment

Table 4—exogenous variable estimates[1,2]

exogenous variable	Meat and equation							
	Beef				*Pork*			
	F2WS	***W2RS***	***DROP***	***MEAT***	***F2WS***	***W2RS***	***DROP***	***MEAT***
D0upQB			-0.5884	-0.3656			0.0146	0.0041
W1upQB			-0.6254	-0.2285			-0.0933	-1.0594
D0dnQB			0.0986	0.1000			-0.1534	-1.1325
W1dnQB			0.1496	0.0736			-0.1951	-1.0115
D0upQP			0.6985	0.4032			-0.0507	-0.2541
W1upQP			0.8204	0.3788			0.0179	0.0319
D0dnQP			-0.3122	-0.2219			0.1448	0.9347
W1dnQP			-0.4825	-0.2548			0.1886	1.1025
wageRET		-0.0139	0.5397	0.1589		0.0724	-0.0104	-0.1442
wagePAK	-0.0305		-0.3074	-0.1322	-0.0176		-0.0136	-0.1889
ppiBox	0.0047	0.0002	-0.0110	-0.0025	-0.0042	0.0086	0.0028	0.0936
ppiNRG	0.0085	0.0027	0.0957	0.0211	-0.0254	-0.0426	0.0111	0.1543
ppiFuel	-0.0134	-0.0066	-0.1112	-0.0261	0.0249	0.0292	-0.0140	-0.2165
cpiFuel	0.0015	-0.0048	-0.0053	0.0017	0.0078	0.0169	-0.0017	0.0083

[1] Blank cells are 0 because of equation restrictions

[2] All the prices, the "y" were divided by the average, deflated, wholesale price for the sample period. They can be interpreted as elasticities.

Table 4—exogenous variable estimates, *continued*

	Meat and equation							
	Beef				***Pork***			
exogenous variable	***F2WS***	***W2RS***	***DROP***	***MEAT***	***F2WS***	***W2RS***	***DROP***	***MEAT***
x0	-2.0320	-5.0592	0.8182	-0.3224	1.2735	5.8483	-0.9092	-16.4401
x1	4.5518	11.1387	-2.6998	-0.4645	-2.4494	-11.6352	2.3297	38.2113
Cos1	0.0022	0.0063	0.0031	0.0054	-0.0028	0.0113	-0.0057	-0.0674
Cos2	0.0059	0.0065	0.0257	0.0206	-0.0206	0.0236	0.0029	0.1388
Cos3	0.0053	-0.0052	0.0246	0.0109	0.0184	-0.0056	-0.0016	0.0057
Cost1	-0.0157	-0.0150	-0.0052	-0.0061	0.0021	-0.0013	-0.0055	-0.0084
Cost2	-0.0090	-0.0061	-0.0170	-0.0200	0.0200	-0.0251	-0.0027	-0.1535
Cost3	0.0059	0.0091	-0.0171	0.0001	-0.0107	-0.0061	-0.0001	-0.0044
Sin1	0.0048	-0.0016	0.0352	0.0156	-0.0260	0.0048	-0.0060	-0.0695
Sin2	-0.0055	0.0031	0.0206	0.0062	-0.0269	0.0110	-0.0009	-0.0217
Sin3	0.0156	0.0077	-0.0103	0.0093	-0.0051	0.0032	0.0008	0.0548
Sint1	-0.0104	0.0009	-0.0480	-0.0199	0.0176	-0.0061	0.0049	0.0936
Sint2	0.0042	-0.0052	-0.0462	-0.0166	0.0237	-0.0131	0.0019	0.0024
Sint3	-0.0130	-0.0169	-0.0062	-0.0152	0.0058	-0.0005	0.0026	-0.0055
TCos1	2.5875	5.1361	-0.6936	0.7225	-1.2143	-5.3909	0.9133	15.8093
TCos2	-0.0006	0.1153	-0.0596	-0.0386	0.1500	-0.3235	0.0166	0.5611
TCos3	-0.0248	0.0113	-0.0068	-0.0159	0.0154	-0.0546	-0.0008	0.0666
TCos4	-0.0086	0.0074	-0.0124	-0.0136	0.0000	-0.0246	-0.0007	0.0186
TSin1	-0.1555	0.2632	-0.2365	-0.2795	0.2646	-0.7478	0.0814	1.8265
TSin2	-0.5480	-1.0339	0.1262	-0.1936	0.2744	1.0556	-0.1713	-2.9981
TSin3	-0.0672	-0.0984	0.0098	-0.0290	0.0409	0.0764	-0.0143	-0.2475
TSin4	-0.0215	-0.0246	-0.0097	-0.0158	0.0130	0.0139	-0.0004	-0.0264