United States Department of Agriculture

LDP-M-118-01

May 2004

Outlook

Electronic Outlook Report from the Economic Research Service

www.ers.usda.gov

Beef and Pork Values and Price Spreads Explained

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Abstract

Livestock and meat prices vary more in the short run than costs of production, processing, and marketing. ERS research shows that month-to-month changes in livestock and meat prices are driven by dynamic adjustment. It takes time for prices to adjust, and they tend to adjust more rapidly when they are increasing than when they are decreasing. When rates depend on direction, price adjustment is called asymmetric. The slow and asymmetric adjustment of prices does not appear to work against livestock producers. This report examines these price transmission issues and also explains price spread calculations and analyzes the relationship between marketing costs and livestock prices in the long run.

Keywords: Beef and pork price spreads, asymmetric price transmission, livestock prices, wholesale meat prices, retail meat prices.

Acknowledgments

This report was improved by comments from Keithly Jones, Suresh Persaud, Janet Perry, and Joy Harwood of the Economic Research Service, from Shayle Shagam of the World Agricultural Outlook Board, and from Dawn Thilmany of Colorado State University. The report also benefited from technical review by Dale Simms and production help from Juanita Tibbs.

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Introduction

This report examines a number of controversies surrounding price spreads for beef and pork. A price spread is the difference between the cost of an item at one stage of the marketing channel and a different stage. ERS collects prices at three different stages of the marketing chain for beef and pork: the farm, the packing plant (wholesale), and at the grocery store (retail). These three sets of prices are used to calculate farm, wholesale, and retail values for beef and pork. These three price levels allow the calculation of three price spreads: farm-wholesale, wholesale-retail, and farm-retail.

High and increasing price spreads often lead to controversy. Livestock producers often blame low livestock prices on high price spreads. Consumers blame high retail prices on high price spreads. Increasing price spreads can both inflate retail prices and deflate farm prices.

Sometimes analysts cite increasing amounts of value-added as a cause of rising price spreads. Consumers shifting demand toward more value-added products will result in lower percentages of the consumer food dollar being passed on to farmers. A higher demand for value-added products and a lower farm share of the consumer food dollar will not generally lead to decreases in farm prices. Analysts who cite increasing value-added as a factor in pork and beef price spreads misunderstand how these are calculated.

Price spreads fluctuate greatly from one month to the next. These short-term fluctuations are consistent with what economists call “dynamic price adjustment.” It takes time for prices to adjust to changes in economic conditions. With dynamic price adjustment, price spreads can be temporarily higher or lower than they “ought” to be. Price adjustment dynamics will tend to move prices so that price spreads go toward where they ought to be. One of the important factors that determines how farm and retail prices react to dynamic adjustment is a concept that economists call price discovery. In this case, price discovery is about which, if any, of the stages in the marketing system is most important in determining prices. In simple cases, one price reacts first and the others follow. In more complex cases, each price can simultaneously influence and be influenced by the others.

How Values and Spreads Are Calculated

The basic idea behind price spreads is simple. Consumers, for the most part, do not buy food directly from farmers. The price consumers pay for food is almost invariably higher than that received by farmers. The farm-to-retail price spread is the difference between what the consumer pays and what the farmer receives. From the consumer's point of view, the retail price is the most important. Changes in retail prices affect consumers directly. Producers are directly affected by the farm price. Why would either care about price spreads?

Producers expect two things out of a price-spread-reporting system. The first is help with marketing their products. The better their knowledge of what consumers want from meat, the better producers can meet consumer expectations. Retail prices or values are part of the information producers need to understand consumer demand. Price-spread calculations require the collection, calculation, and reporting of retail prices.

Producers also use price spreads to measure the efficiency and equity of the food marketing system. Producers are concerned about getting their fair share. Consumers are also concerned about the efficiency and equity of the food marketing system. All other things the same, consumers would prefer lower prices and producers higher prices. In mathematical terms, the price spread is the retail price minus the farm price. We can rearrange the price-spread equation and make it more useful for farmers or consumers. Consumers can view their price as the farm price plus spread. The consumer equation implies that higher price spreads cause higher retail prices. Farmers can see their price as the retail price minus spread. The farmer equation implies that higher price spreads cause lower farm prices. Price spreads can become lower if farm prices increase and/or retail prices decrease.

Turning the price-spread definition into a farm-price or retail-price equation is a mathematical exercise. In order for this exercise to correspond to something in reality, the price spread has to be something more than just the difference between the farm and retail price. It is. The price spread is the costs and profits of the marketing system that moves the farm product from the farm to the consumer and processes it to its final form. Innovative technologies can lower costs and, consequently, price spreads.

The farm-to-wholesale and wholesale-to-retail spreads divide the total costs and profits between packers and grocery stores. Economic efficiency increases when costs and profits drop. In theory, changes in price spreads can help measure changes in the efficiency of the beef or pork marketing system. Both consumers and farmers can gain if the food marketing system becomes more efficient and price spreads drop. Lower price spreads can reflect both higher farm prices and lower consumer prices.

One of the problems with implementing a price-spread calculation is coming up with a definition for the farm and retail product. At the farm level, hogs and cattle come in a variety of sizes, ages, grades, and other factors that affect their price. Consumers also have a variety of outlets where they can buy meat, and can often buy multiple forms of this meat from the same outlet. The perfect price-spread system would calculate price spreads for all animal types and outlets, and give information on the relative importance of each of the marketing channels. The perfect price-spread system would require large amounts of data, computing resources, and human time, and consequently would be extremely expensive. The perfect price-spread system would also require data the government does not collect. For example, official statistics show only total domestic disappearance of meat, which means we do not know how much meat goes through stores and how much goes through food service, only the total going through both.

ERS provides two different "compromise" measures of meat price spreads. One compromise is to compare the "average" value of all hogs and cattle sold to the "average" value of pork or beef purchased in all forms from all outlets. The Food and Rural Economics Division of ERS calculates price spreads for meats and other foods using this method.[1] The major purpose of these price spreads is to calculate the farmer's share of the consumer food dollar. The consumer costs of meat are based on research that the Bureau of Labor

[1] See www.ers.usda.gov/Briefing/FoodPriceSpreads/

Statistics (BLS) uses to calculate the Consumer Price Index (CPI). The consumer market basket is based on periodic surveys of consumer purchases. Between surveys, price spreads are calculated using the assumption that the items consumers buy do not change.

ERS's Market and Trade Economics Division, on the other hand, calculates price spreads based on a standard animal, cut up in a standard way at the packing plant, and sold in standard form through the retail store.[2] These price spreads are the basis of this report. Focusing on a standard animal and marketing channel reduces the amount of data that has to be collected compared with that needed to calculate an "average" spread. Spreads based on average costs of beef and pork through all outlets change when the mix of outlets changes and when the margins in each outlet change. Increasing "average" spreads can be the result of increasing costs/profits, shifts to more costly channels, or both. Focusing on a single market channel allows one to attribute changing spreads to changes in economic performance in that channel. Given that one is focusing on a single channel, it would be helpful if that channel handles a relatively large volume of meat. Grocery stores are an important channel for meat sales, which is one reason that ERS calculates its retail value based on grocery-store prices.

Producers also use retail-price information in analyzing the end demand for their livestock. Focusing on a single channel and type of animal makes the retail values more consistent over time and easier to compare. The ERS standard marketing channel is a non-specialized or generic market. Those producers that are looking into market niches could always divert their animals into this "generic" channel. The ERS retail value represents a potential minimum value for more specialized producers.

The quality of animals that producers raise, and the cutting practices at the packing plant and the grocery store, evolve over time. ERS makes occasional changes in its standard animals and standard cuts to better reflect current practices. When the standard animals or cuts are changed, ERS recalculates the previous farm, wholesale, and retail values in an effort to make the historical data consistent with the new practices. The current standard beef animal (farm) price is the five-market, weighted average for a 35-65% Choice Steer as reported by USDA's Agricultural Marketing Service (AMS). The standard hog (farm) price is the AMS 51-52% base-lean-hog price. Some people have complained that these ERS standard animals are now substandard relative to the bulk of the market. However, the goal of this methodology is to compare price spreads for a consistent animal over time, not to compare price spreads for each period's most "representative" animal.

Wholesale values for beef and pork cuts are also published by AMS. ERS uses these wholesale values to make the wholesale composite values. The retail beef and pork cuts that ERS uses in the calculation of its retail composite prices are relatively low value-added cuts. All the beef cuts are fresh cuts sold through the meat case. The pork cuts are all fresh except for ham and bacon. Consumers purchase little fresh ham or bellies. (Bacon is cured and smoked pork bellies.) ERS changes in the standard retail value have been small. The current standard retail product has fewer bones and less fat than the standard product of the 1970s. The standard retail product has always been a relatively low-value-added mix of cuts sold through the retail meat case.

Before 1980, ERS collected data directly from cooperating retail stores. The ERS survey started with 20 chains; however, the number declined over time. The cooperators kept track of the prices of their cuts and the volume sold of those cuts, and provided ERS with sales-weighted average prices. Stores commonly change meat prices only weekly. When a store lowers the price of a cut, it will likely sell more of it. The sales-weighted price of an item was usually lower than the price averaged over weeks.

High costs and loss of cooperators led to a change in ERS procedures. Since 1980, ERS has used retail prices reported by the Bureau of Labor Statistics (BLS). BLS data are collected from more outlets than the old ERS data and from a statistical sample of outlets versus self-selected cooperating stores. The self-selected stores ERS used prior to 1980 may have been different from stores in general, and this might have induced some degree of unknown bias in the retail prices. However, BLS collects only prices from stores, not sales volume on the individual cuts. It can not change the weights on its averages to reflect changes in sales volume associated with changes in retail prices.

[2] See www.ers.usda.gov/briefing/foodpricespreads/meatpricespreads/

This omission led to some concern that using BLS retail prices leads ERS to overstate the retail values for beef and pork. The Livestock Mandatory Reporting Act of 1999 required that USDA "compile and publish at least monthly (weekly, if practicable) information on retail prices for representative food products made from beef, pork, chicken, turkey, veal, or lamb." In response, ERS began to buy commercially available retail-scanner data, which are compiled and published on the web. These data have sales-weighted average prices for beef and pork cuts, which are generally, but not consistently, lower than BLS prices.

Grocery stores are not required to provide scanner data to ERS, so these data come from a self-selected sample of stores. These stores may have either consistently higher or lower prices than the average supermarket. As with the pre-1980 ERS data, the self-selected sample could induce some unknown bias in the reported average prices.

ERS continues to use the BLS data in calculating price spreads, also mandated in 1999's Livestock Mandatory Reporting Act. Sticking with the BLS data also makes current estimates consistent with those from the 1980s and 1990s.

The retail value used in price spread calculations is the average price per pound of all the cuts an animal produces. In other words, the retail value is the average cost per pound rebuilding the animal with meat parts only from the grocery store. Animals are not entirely meat. The further up the marketing chain an animal goes, the more weight it loses due to the removal of bone and fat trimming, hides, hair, offal, and the like. For example, a 1,000-pound steer produces 417 pounds of retail meat cuts, 110 pounds of edible fat, 38 pounds of variety meats, 80 pounds of hide, 40 pounds of blood, 175 pounds of inedible fats, and 140 pounds of liquids lost during processing (shrinkage).

To make the price comparisons easier, ERS transforms the farm and wholesale prices to a retail-weight equivalent. The live animal value is the cost of the amount of live animal it takes to produce 1 pound of retail meat. The ERS conversion factors are 2.4 pounds of live, Choice steer to produce a pound of "standard" retail beef; and 1.869 pounds of 51-52 % lean hog to produce a pound of "standard" pork. Some bone and fat trimmings are removed in converting wholesale cuts to retail cuts, so wholesale prices also must be adjusted to a retail-weight basis. The ERS standard conversion is 1.14 pounds of wholesale beef per pound of retail beef, and 1.04 pounds of wholesale pork per pound of retail pork.

Table 1 shows January 2003 price spread figures for beef and pork and includes two farm values and a byproduct value. Many animal parts that are not meat (hides/skins, tallow/lard, bone meal, and edible/inedible offal) have value. ERS does not track the value of these byproducts past the packer level. Most of these products are used as intermediate inputs in the production of other goods, and tracking their contribution to the final products demanded by consumers is not feasible. Still, the byproducts have value, and this value is used to calculate the byproduct allowance and net farm values in table 1.

The total sales that an animal generates for a packer are the value of its meat and byproducts. ERS calculates the percentage of the animal's value generated by byproducts. Call that percentage "x." The byproduct allowance is "x" times the gross farm value. The net farm value is the gross farm value minus the byproduct allowance. You could also calculate the net farm value by multiplying the gross farm value by the percentage of the animal's value that is meat, 1-x. For example, in January 2003, the byproducts represented 10 percent of a steer's total wholesale value. The byproduct value for beef in January 2003 is 9 percent of the gross farm value while the net farm value is 91 percent of the gross farm value. The wholesale-to-retail spread is the difference between the wholesale value and the retail value. The farm-to-wholesale spread is the difference between the wholesale value and the net farm

Table 1—Recent values and spreads for beef and pork

		Values					Spreads		
Species	Month	Retail	Wholesale	Gross farm	Byproduct	Net farm	Total	Wholesale-retail	Farm-wholesale
Beef	Jan-03	339.7	200.4	187.1	18.8	168.3	171.4	139.3	32.1
Pork	Jan-03	258.2	101.9	64.3	3.5	60.8	197.4	156.3	41.1

value. The total spread is the sum of the farm-wholesale and wholesale-retail spreads, which can also be calculated by subtracting the net farm value from the retail value.

Price Spreads Versus Gross Margins

ERS has historically stressed that it is calculating price spreads and not gross margins. Gross margins and price spreads are related, and increases in gross margins are likely to cause increases in price spreads. A gross margin is the difference between the purchase and selling price of a product. The farm-to-retail price spread is the difference between the value of an animal at the farm and its value at the grocery store. The price spread looks suspiciously like a gross margin. What makes them different?

Let us start by examining the farm-to-wholesale spread. The farm value is based on a specific type and quality of animal. The ERS standard steer or hog is not the only type of animal that packers slaughter. Each type of animal has its own value at the farm and produces a different mix of wholesale products. Every animal that a packer buys could have a different farm-to-wholesale spread. In the best-case scenario, the ERS farm-to-wholesale price spread represents the average gross margin for its standard animal.

The ERS farm-to-wholesale price spread is unlikely to match average packer margins on livestock exactly. Different animals will have different gross margins. However, we expect that all the possible gross margins move together, so that increases and decreases in the farm-to-wholesale price spread closely follow packers' overall gross margins. The price spread may be higher or lower than packers' total gross margins; still, ERS price spreads and packer gross margins are likely to be highly correlated.

The relationship between grocery stores' gross margins and the wholesale-to-retail price spread is likely to be weaker than that between packers' gross margins and the farm-to-wholesale price spread. The wholesale value is the value for which a packer can sell the standard animal's meat. A packer that buys a standard animal is going to want to sell all its meat and byproducts. The retail value is the value of that animal's meat in the grocery store. However, grocery stores do not buy whole animals. They buy selected cuts of the animal. There is no government data on the mix of cuts that stores sell. The consensus is that grocery stores tend to sell mostly medium-priced cuts of beef and pork, while foodservice firms tend to sell either low-priced cuts (fast food) or premium cuts. We expect that ERS wholesale-retail price spreads would likely move in the same direction as grocery store gross margins.

Some people have raised questions about the shift toward "case-ready" meats and what that implies for price-spread calculations. Stores have traditionally purchased wholesale cuts that need further processing before sale to consumers. Case-ready cuts arrive in the store ready to put directly in the meat case. The ERS wholesale pork composite is based on primal pork cuts and the wholesale beef cuts are subprimal cuts. These primal and subprimal cuts are large pieces of meat that grocery-store butchers trim, cut, and package for retail sale. Packers and other intermediaries are now trimming, cutting, and packaging large volumes of these retail cuts for sale to stores. A store that uses case-ready meat no longer has to process meat itself. Its employees simply take delivery and stock packages in the meat case. Those stores that buy case-ready meats are essentially subcontracting out their meat processing.

One may also consider the ERS wholesale-retail price spread as the packer-cuts to retail-cuts price spread. Rather than measuring the efficiency of grocery stores in turning wholesale meat into retail meat, it measures the efficiency of grocery stores and their subcontractors in turning wholesale meat into retail meat. If case-ready meat has significant cost advantages, it can lead to improved efficiency of the meat marketing system and lower wholesale-retail spreads.

Case-ready meat could grow to such an extent that it dominates the market, largely eliminating sales of primal and subprimal cuts. If this happens, ERS will have to switch its price spread methodology to a wholesale-case-ready-to-retail price spread. Something like this happened to the ERS methodology in the late 1970s. Stores used to buy beef by the half or quarter carcass. Meatpacking companies developed boxed beef in which the carcasses were broken down to (largely boneless) subprimal cuts. As boxed beef grew to dominate the market, the ERS standard wholesale beef switched from a carcass to a mix of boxed-beef cuts.

ERS's retail values are often used by industry analysts to measure the value of beef and pork to consumers. For example, analysts sometimes multiply the total amount of pork consumed by the pork value, and call that figure "expenditures on pork." The ERS retail value (and the BLS cut-prices underlying it) are based on retail market prices. Not all meat is bought through grocery stores; meat bought in food service is generally more expensive than the same cut bought at retail. In addition, the ERS retail value does not include the value-added meat products that stores sell. The ERS retail value does not include cooked and processed meats sold through the service deli or the meat included in processed foods. Multiplying ERS retail values by consumption will understate total consumer expenditures on meat.

While the ERS retail composite is a poor measure of the price that consumers pay for beef in general, is it a good measure of what consumers pay for beef in the grocery store meat case? Probably not. As noted above, the ERS composites are based on the value of the whole animal at the store. If stores buy relatively more of the expensive parts of the animal, the ERS composite will understate what consumers pay at grocery stores. If stores buy more of the relatively cheap parts of the animal, then the ERS composite will overstate what consumers pay. It is generally believed that grocery stores sell relatively more of the lower-priced cuts. Further, in the case of beef, the standard animal—the Choice, Yield Grade 2-3 steer—is a higher quality animal. Select or ungraded beef cuts generally sell for less than Choice.

One reason that analysts use ERS retail values as a measure of "price" is to help separate the value of the meat from the other ingredients and services embedded in value-added products and food service. Most value-added and foodservice items are a mix of meat and other foods. For example, eating a hamburger increases one's beef consumption, as well as bread and condiment consumption. One way of valuing the hamburger's ingredients to a consumer is to use the retail cost of the ingredients. The service value is the difference between the ingredient costs and total price of the hamburger.

Price Spreads or Gross Margins in Theory

The demand for livestock is derived from the demand for meat. Knowing retail prices and price spreads from farm to retail gives us a clearer picture of what factors drive the demand for livestock. Economists use price spreads as a measure of gross margins, or at the very least, an indicator of trends in gross margins. The following discussion assumes that price spreads and gross margins are the same thing. As noted above, gross margins and price spreads are not in fact the same thing, but they are likely to be related. Gross margins represent the profits and costs of the food marketing system. Increasing economic efficiency leads to lower gross margins, by either lowering costs or reducing profits. Since high gross margins imply high price spreads, for the purpose of theory, it makes little difference whether spreads are gross margins or indicators of gross margins. The following discussion is nontechnical. Technical proofs are in the Appendix.

The discussion of how margins affect livestock and meat prices is based on the economic concept of derived demand. In economics, "demand" usually refers to the relationship between what consumers want to buy, their incomes, and the prices they have to pay. Livestock and wholesale meat are used to make consumer products. The demand for livestock and meat is derived from the consumer demand for meat and meat products.

No discussion of economic theory is complete without assumptions. One assumption is that the technology of transforming livestock into meat has a very simple form, the form inherent in ERS price spread procedures. ERS price spread procedures are based on the assumption that there is a fixed yield of meat from each kind of animal. We also assume that the longrun price spread is independent of the volume of livestock processed. If we keep the assumption of fixed proportions, then derived demand and price spreads are intimately related. Under these assumptions, the price of livestock is the price of meat minus the price spread. Higher price spreads translate into lower prices for livestock.

How much does an increase in gross margins decrease livestock prices? It is hard to say. Two factors make measuring this effect difficult. The first is producers' supply response. Higher margins would tend to decrease livestock prices. Lower livestock prices discourage livestock production. Lower livestock and meat production leads to higher prices to consumers. The longrun effect of higher marketing margins is less production (than there would be with lower margins) and some combination of lower farm prices and higher retail prices.

The second complicating factor is that ERS price spreads are farm-to-supermarket price spreads. The supermarket is just one of the outlets for beef and pork. If supermarkets were the only outlets for beef or pork, then a 1-cent rise in margins would translate to a 1-cent decline in the derived demand for livestock. From that point, the supply adjustments begin to affect the market. However, because there are other outlets for beef and pork, particularly food service and export, a 1-cent increase in spread will translate to a less-than-1-cent decrease in the retail-weight derived demand for livestock. Higher price spreads from wholesale to the supermarket will raise supermarket prices. Higher supermarket prices mean less demand for meat from supermarkets and make other outlets more competitive for the consumer's food dollar. A 1-cent increase in the wholesale-to-retail spread will decrease derived demand for livestock by less than 1 cent.

One of the problems caused by focusing only on farm-to-retail spreads for meat is that it ignores the other sources of derived demand. In theory, we should keep track of all the sources of derived demand. Official government statistics allow us to estimate exports. U.S. Government measures of domestic meat demand track the meat that leaves meatpackers and warehouses for domestic consumers but do not account for the type of outlet that buys it.

The effect of an increase in the farm-to-retail spread on the farm price is larger when grocery stores have a larger share of total meat markets. Over time, export and foodservice markets have become more important outlets for U.S. beef and pork. Wholesale-to-retail price spreads probably have less effect on longrun livestock prices than they did in the past. On the other hand, packing plants are by far the largest users of slaughter animals, the other major use of slaughter animals being the export market. A 1-cent increase in the farm-to-wholesale spread is likely to translate into a 1-

cent decline (or something very close to that) in the derived demand for livestock.

The theoretical effects of the wholesale-retail margin on the derived demand for livestock are also based on the assumption that only the wholesale-retail margin changes—and the margins in the other parts of the marketing channel do not. One can discuss this case in theory; in real life, it is, however, extremely unlikely that only the grocery store margin would change and the others not. For instance, grocery stores and restaurants may be buying some of the same nonmeat inputs. Increases in the costs of common inputs will increase costs in all the marketing channels, so that higher grocery store margins would be associated with higher margins in the rest of the marketing channel. Inflation generally raises the cost of all items, so that inflation-driven increases in wholesale-retail gross margins might be associated with inflation-driven increases in other outlets' margins. If a 1-cent increase in the grocery channel's margin implies a 1-cent increase in all the other marketing channels' margins, then derived demand will decline by 1 cent. If a 1-cent increase in the grocery store margin implies different increases in the other channels, then derived demand could drop by more or less than 1 cent.

What effect has the growth of the foodservice and export markets had on the derived demand for livestock? As these outlets become more important, their gross margins have a larger effect on the livestock price. Consumers shifting their meat consumption from retail stores, a lower-margin source, to food service, a higher-margin source, may or may not depress livestock prices. Cattle or hog prices will be depressed if consumers buy less beef and pork when they replace at-home food preparation with away-from-home foods. If they increase meat consumption as they shift toward food service, derived demand for livestock—and livestock prices—will increase.

Price spreads are highly volatile, varying greatly month to month. This volatility is difficult to reconcile with the derived demand and livestock supply explanation for price interactions. Therefore, economists explain this volatility with price adjustment dynamics, wherein it takes time for prices to adjust to changes in the market. If prices at different parts of the market adjust at different rates, then price spreads will be volatile.

In a market with dynamic adjustment, price spreads can be temporarily either too high or too low. Suppose that current price spreads are too high. Adjustment dynamics will tend to move prices to narrow the price spreads. Price spreads narrow if farm prices rise or retail prices fall. High price spreads now may actually be a leading indicator that farm prices are likely to increase in the near term.

What Do 30-Plus Years of Beef and Pork Values and Spreads Say About the Market?

Figures 1 and 2 show monthly gross farm, wholesale, and retail values for beef and pork. All the values for all the meats fluctuate from month to month, but the general trend in nominal prices has been upward. While ERS price spreads are meant to capture the value of a "standard" animal over time, inflation makes comparing 1970s values with more current ones difficult. The animals remain more or less the same, but the value of money changes. Figures 3 and 4 show the same set of values corrected for inflation using the Consumer Price Index, or CPI. The general trend after correcting for inflation is downward. The prices that consumers pay for beef and pork have increased less rapidly than inflation. In other words, the real cost of beef and pork is declining. Economists assume that this downward trend in real prices over the long run shows that the beef and pork production/marketing systems are becoming more efficient.

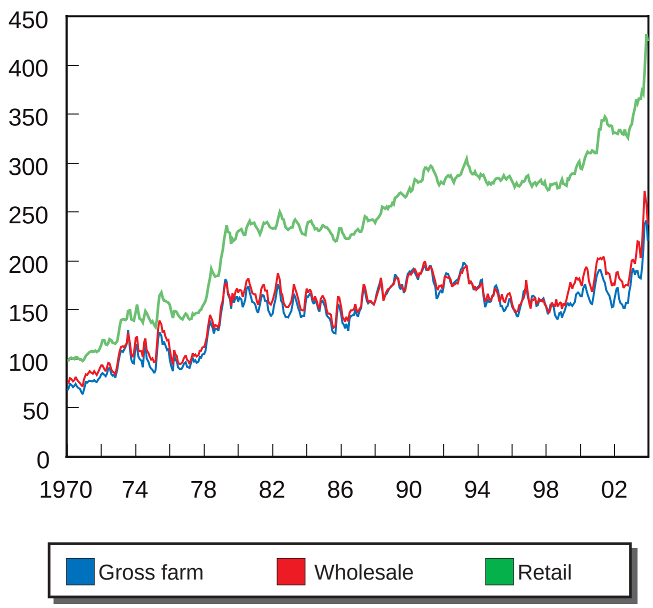
What do price spreads show about changes in the efficiency of the packer and retail segments of the meat marketing system? Figures 5-8 show the price spreads for beef and pork before and after correcting for inflation. The general trends in the noncorrected price spreads are the same for beef and pork. The total spreads and the wholesale-retail spreads are increasing over time. The farm-to-wholesale spreads fluctuate, with a slight upward trend. Because noncorrected farm-to-wholesale spreads have shown small growth, the inflation-corrected farm-to-wholesale spreads trended downward until the mid-1990s. After that time, both farm-to-wholesale price spreads have trended upward. The wholesale-to-retail spreads for both beef and pork have trended upward, even after correcting for inflation. The declines in the inflation-corrected farm-to-wholesale spreads largely offset the increase in the wholesale-to-retail spreads. Therefore, the total price spreads show a weak upward trend when corrected for inflation.

The discussion to this point has focused on the meat marketing system. Much of the decline (relative to inflation) in livestock and meat prices has been driven by technology changes in agricultural production. Research shows that U.S. livestock farms have become increasingly productive over time (Ahearn et al.; Gale and Kilkenny; USDA-NASS). This increasing productivity explains part of the longrun decline in inflation-adjusted livestock prices. Producers are willing and

Figure 1

Beef values

Cents per pound, retail weights

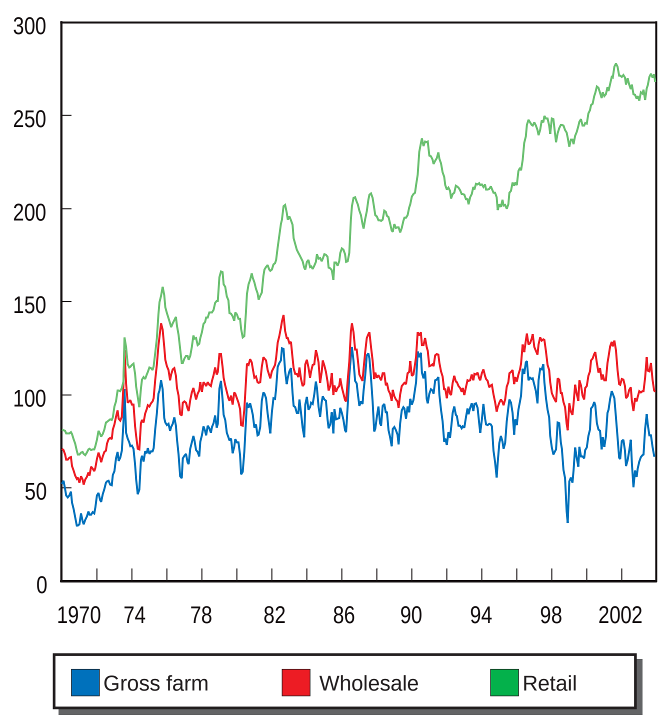


Source: ERS.

Figure 2

Pork values

Cents per pound, retail weights

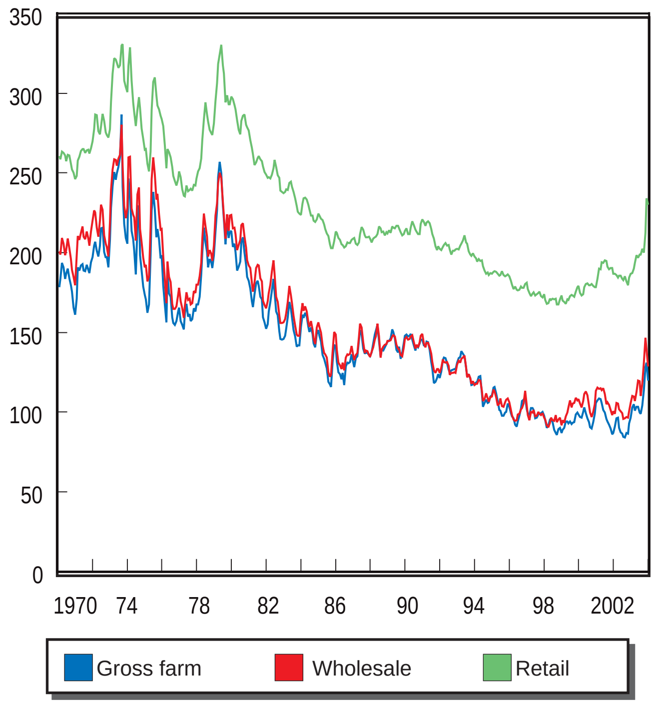


Source: ERS.

Figure 3

Beef values deflated by the CPI

Cents per pound, retail weight

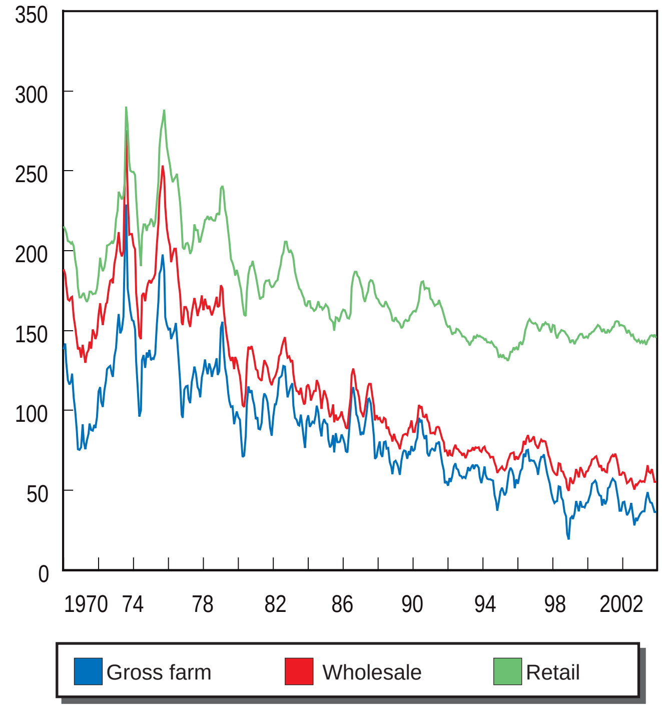


Source: ERS.

Figure 4

Pork values deflated by the CPI

Cents per pound, retail weight

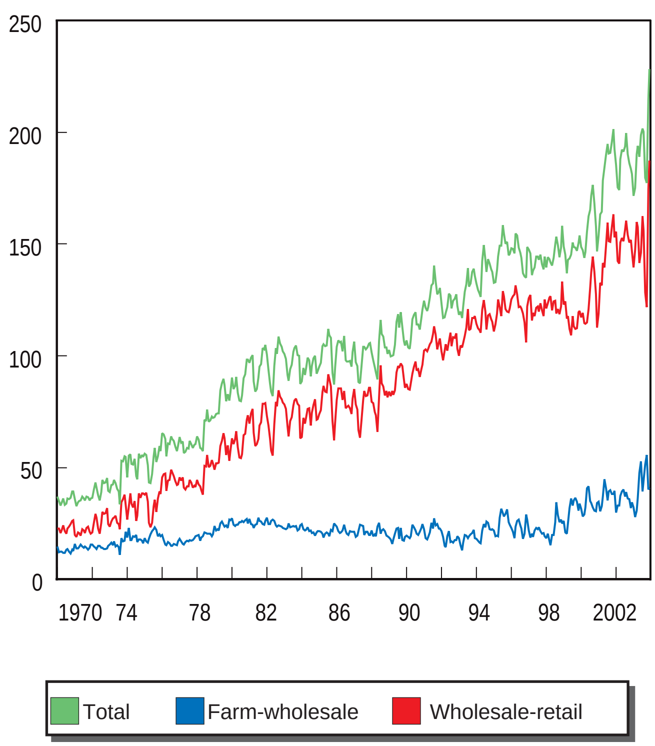


Source: ERS.

Figure 5

Beef price spreads

Cents per retail pound

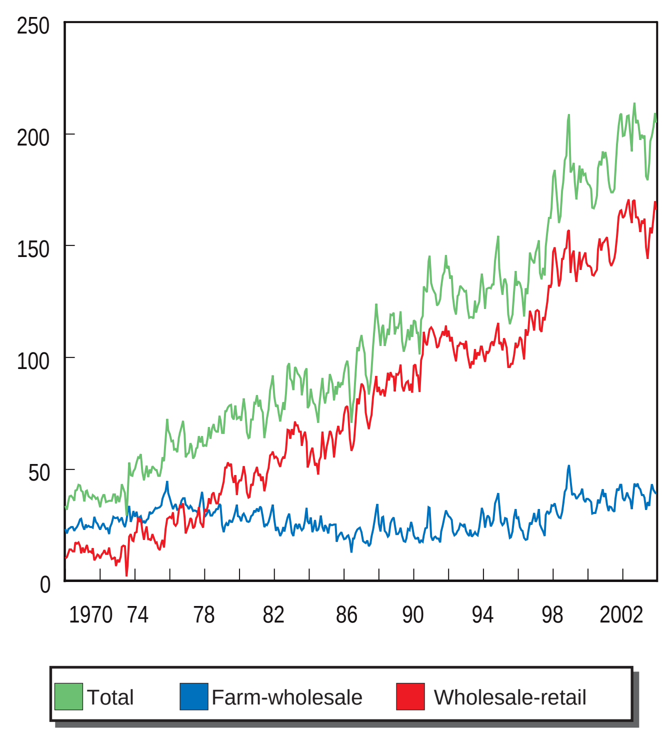


Source: ERS.

Figure 6

Pork price spreads

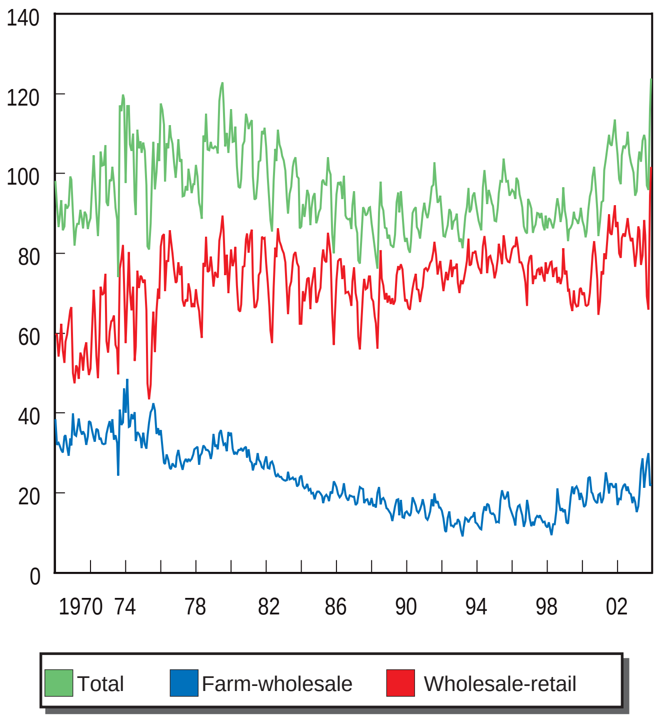
Cents per retail pound



Source: ERS.

Figure 7

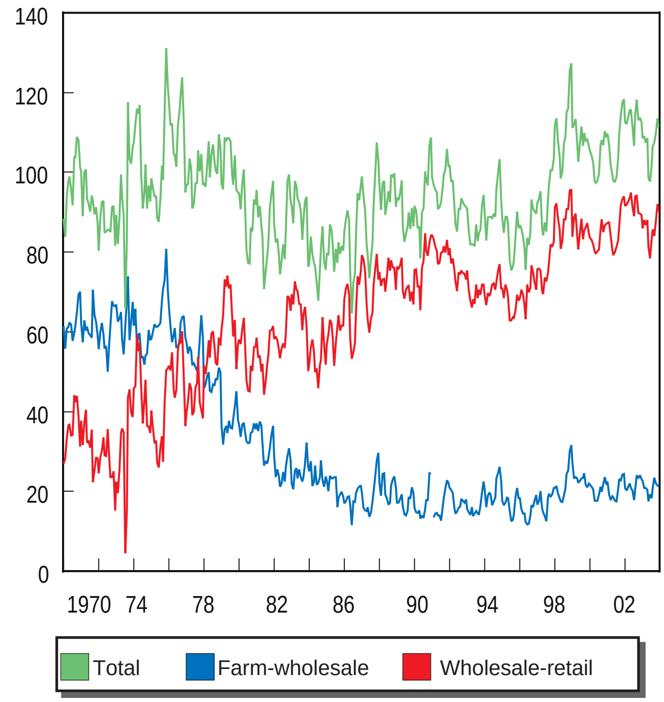
Beef price spreads deflated by the CPI



Source: ERS.

Figure 8

Pork price spreads deflated by the CPI



Source: ERS.

able to supply more animals at lower prices. Economic studies of the meatpacking industry also demonstrate increasing productivity, which is consistent with the longrun decline in farm-to-wholesale spreads. Lower livestock prices and lower packing costs have led to lower wholesale prices. While there are no studies published on meat department productivity, there is evidence of declining productivity in grocery stores' overall operations (*Fortune Magazine*;, Harris et al.; Food Marketing Institute; U.S. Department of Labor, Bureau of Labor Statistics). A decline in productivity would lead to an increase in gross margins. As productivity declines, grocery stores would use more labor and materials to process wholesale beef and pork into retail beef and pork. The increasing costs of processing meat will generally lead to increasing gross margins between the wholesale and retail value of meats.

Some of the measured decline in grocery store productivity is likely a shift in product composition. Grocery store productivity is measured by comparing labor hours and sales. Grocery stores have switched their product mix over time toward more food service. Part of the apparent decline in total store productivity is likely due to the increasing levels of food service. The new product mix requires more labor, which would lead to lower productivity measures for the store as a whole—regardless of the actual productivity of individual departments. Wholesale-retail spreads for beef and pork have increased more rapidly than inflation. This kind of increase is consistent with declining productivity of grocery store meat departments.

Grocery stores seem to be selling more boneless, closely trimmed, and value-added meat cuts and people have often cited this as a cause of increasing wholesale-retail price spreads. However, this explanation is not consistent with BLS procedures and ERS calculations. ERS's retail beef and pork composites have been adjusted to reflect the shift to more closely trimmed and boneless products. Past retail values were adjusted to make them consistent with current cutting practices. The BLS collects consistent products over time. ERS takes the value of these cuts and calculates retail composites. Although value-added cuts may be increasingly important to stores and consumers, ERS composites are based on a fixed mix of (relatively) low-value-added cuts. One goal of the ERS retail price calculation procedure is to give producers an estimate of the end-use value of their livestock that is consistent over time. The estimated wholesale-retail spreads for beef and pork have been increasing over time. If these spreads included the shift to more value-added products, their increase would be even greater.

A large part of the decline in real livestock prices has been driven by increasing efficiency on the supply side. On the derived-demand side, the decline in the real farm-to-wholesale price spread has increased the derived demand for hogs and cattle, resulting in higher livestock prices. The increase in livestock demand caused by more efficient meatpacking has been offset by the increase in the real wholesale-to-retail spread. But again, the retail meat case is only part of the total demand for meat. Total, inflation-corrected price spreads have increased since the 1970s. If grocery stores were the only outlet for meat, then the increases in wholesale-retail spreads would have more than offset the increased efficiency of the packing sector.

Price Spreads and Price Dynamics

Prices and price spreads fluctuate a great deal from month to month. In the derived-demand view of price and price spread interaction, these fluctuations in price spreads might imply wide swings in the cost of meat processing. These frequent, extreme changes in meat processing costs are not plausible. Economists frequently use "dynamic adjustment" to explain price and price spread behavior.

The following results are based on statistical models of dynamic price adjustment. Economists often use supply and demand interactions to analyze how prices and quantities are set. The statistical models used here focus only on price setting behavior in pork and beef markets. The models measure how quantities affect prices in the short run, without measuring how prices affect quantities. Beef and pork prices are analyzed separately. The statistical analysis is based on a "partial-adjustment model." The idea of partial adjustment actually encompasses the range from "no adjustment" to "complete adjustment." In practice, the no-adjustment model assumes that this month's prices (and price spreads) are basically last month's. Under partial adjustment, prices this month are somewhere between the no-adjustment prices and the full-adjustment prices.

Sometimes, partial-adjustment models work out to be "overreacting" models. Rather than ending up somewhere between the no-adjustment and full-adjustment values, prices may overshoot their full-adjustment values. Another way of looking at these types of models is to consider last month's price as where the price "was," and this month's full-adjustment value as where the price "ought to be." Adjustment dynamics look at how prices react to the difference between where they were and where they "ought to be."

The models are similar to those estimated previously by ERS researchers (Hahn, 1989, 1990; Mathews et al, 1999) with some new features. Details on the statistical models are in the Appendix. These models have asymmetric price dynamics built into them. The asymmetric part of the model allows prices to adjust at different rates depending on whether they are increasing or decreasing. (A price's adjustment rate can also depend on the directions of the other prices.)

The no-adjustment case is defined as this month's prices being last month's prices. We have yet to define the complete- (or full-) adjustment case. One of the reasons that prices fluctuate so much from month to month is that livestock and meat supplies fluctuate month to month. The complete-adjustment case is that set of prices and spreads that fully reflects changes in livestock supplies and other factors. This definition of "complete-adjustment values" is vague. However, when estimating a partial-adjustment model, one has to measure (directly or indirectly) the complete-adjustment values for each period in the data. The complete adjustment values depend on pork and beef production, the month of the year, and trends. As all these variables change from month to month, complete-adjustment values also change. (See the Appendix for technical details.)

It is common for increases in livestock supply to be followed by decreases in supply. With partial adjustment to supply and demand shocks, prices can be more stable than they would be under complete adjustment. If prices at different levels adjust at different rates, partial adjustment can make price spreads more volatile even while making prices less volatile.

ERS calculates gross-farm, byproduct, wholesale, and retail values. From these, ERS calculates another four numbers: the net farm value and three price spreads (farm-wholesale, wholesale-retail, and farm-retail). The asymmetric adjustment models are estimated using the first four sets of variables. We need four sets of complete-adjustment values to complete the model. Algebra enables any four of the eight price spread statistics to determine the rest. The statistical models estimate the complete-adjustment values of the wholesale value, byproduct value, farm-to-wholesale spread, and wholesale-to-retail spread.

The full-adjustment wholesale and byproduct values were made functions of, among other things, pork and beef production. Month-to-month changes in production can make the full-adjustment values volatile. The full-adjustment price spreads were made smooth functions of time. (The month-to-month changes in the full-adjustment price spreads are small.) Dynamic adjustment is partly self-generating. Differential rates of adjustment can mean that this month's price spreads are quite different from their full-adjustment values. The actual price spread can be either above or below its full-adjustment value. This month's actual price spread is next month's no-adjustment price spread. Part of next month's dynamic adjustment will be an attempt to narrow the gap between this month's price spread and next month's full-adjustment value. Narrowing price spreads might require increases in the farm price. A higher-than-full-adjustment price spread this month might be a leading indicator that farm prices could increase next month.

Derived-demand analysis demonstrates that lowering spreads causes some combination of higher farm prices and lower retail prices. In the short run, the opposite can happen: low price spreads can lead to higher retail prices and/or lower farm prices. In this case, the price spread is low relative to its full-adjustment value. "Low" actual price spreads can lead to widening of price spreads in later periods. Making price spreads wider means lowering farm prices, raising retail prices, or some combination of both. The difference between the long- and shortrun results is caused by dynamic price adjustment.

Two sets of analyses were performed, one using the beef data and one using the pork data. In each of these sets of analysis, statistical tests were performed. The first tests attempt to answer the questions: (1) "Do prices exhibit dynamic adjustment?" and (2) "If price adjustment is dynamic, is it asymmetric?" Prices will be dynamic if the model has partial adjustment. Price adjustment is asymmetric if the rates of adjustment depend on the direction in which prices are going. The asymmetric part of adjustment is only possible if there is partial adjustment in the first place. The complete and no-adjustment cases are both defined as symmetric.

Dynamic adjustment was tested by comparing the dynamic, asymmetric estimates to the complete adjustment estimates. The dynamic, asymmetric estimates are statistically different from the complete-adjustment ones. The asymmetry of the estimates is also statistically significant.

Statistical comparisons of partial adjustment and asymmetry depend on two factors. The first is how far the estimates are from showing either complete adjustment or asymmetry and the second is how accurately this difference is measured. This concept is easier explained using an example. Technically speaking, 99.99-percent adjustment is partial adjustment. (Full adjustment is 100-percent adjustment.) The 0.01-percent difference has little practical effect on price adjustment. However, this difference will be statistically significant if it is measured accurately enough. An adjustment rate of 10 percent would make a large, practical difference, but if imprecisely measured, might not be statistically significant.

So dynamics and asymmetry are statistically significant, but do they have large effects on price adjustment? To evaluate the "practical" effects of dynamics and asymmetry, the estimated beef and pork models were simulated under the unrealistic scenario where the complete-adjustment prices and spreads were fixed for a long period. If the full-adjustment values are fixed for a long enough time, the actual prices will become the full adjustment prices. The length of time it takes prices to adjust to their full-adjustment values and the difference between adjustment times for increasing and decreasing prices show the practical effects of the estimated dynamics and asymmetry.

The model was simulated with full-adjustment values fixed for 100 months. All prices converged before the end of the 100 months. None of the prices shows immediate adjustment. However, pork prices adjust considerably faster than beef prices. In all cases for both species, price-increasing adjustment is quicker than price-decreasing adjustment. It takes 2 months for pork's gross farm value to fully adjust when it is increasing and 5 months when it is decreasing. Pork's wholesale value fully adjusts in 6 months when increasing and 10 months when decreasing, while retail adjustment takes 7 months for increases versus 12 months for decreases. Beef price adjustment takes over a year in all cases. Increases in beef's gross farm value take 18 months, while decreases take 29 months. Increases in the wholesale value take 17 months, while decreases take 29 months. Retail price increases take 21 months; decreases, 32 months.

Dynamic adjustment in prices leads to dynamic adjustment in price spreads. Price spreads can be different from their full-adjustment values. If price spreads are below the full-adjustment level (that is, too small), price-spread adjustment may lead to lower farm prices. Widening the farm-wholesale spread requires the farm price to drop or the wholesale price to rise. In the long run, wide price spreads tend to depress livestock prices. In the short run, large price spreads can be a leading indicator that livestock prices are going to rise.

It is, however, possible that livestock prices are not affected by price-spread adjustment. For example, economists commonly use markup models, wherein the farm price changes first. The wholesale price dynamically adjusts to the farm price and the farm-to-wholesale price spread. The retail price dynamically adjusts to the wholesale price and the wholesale-to-retail price spread. In a markup model, the farm price does not react to dynamic-price-spread adjustment. The simulations above show that farm prices adjust more quickly than wholesale and retail prices. This type of adjustment is what you would expect to see in the markup case.

One can also build models where the wholesale or retail prices move first and the others follow. Markup models and those where retail or wholesale prices lead the others can be called "leader-follower" models. Leader-follower models imply that one level of the market is the most important center for price discovery. Leader-follower models are special cases of more general models where each price can have a role in price discovery. Each of the leader-follower models was tested against the most general case. None of the leader-follower models passed the statistical tests. Leader-follower models have a relatively simple explanation for price discovery. The fact that all these relatively simple models failed the statistical tests suggests that price discovery is more complicated. All levels of the marketing chain have a role in the discovery of meat and animal prices.

To evaluate the effects of price spread adjustment on livestock prices, simulations were run to see what effect a difference between full-adjustment and last month's price spreads does to this month's prices. Price changes caused by differences between last month's actual and this month's full-adjustment farm-to-wholesale spreads affect both livestock and wholesale prices. Adjustments that narrow price spreads raise farm prices and lower wholesale prices. Farm-wholesale spread widening adjustments lower farm prices and raise wholesale prices. Because of the asymmetry of price transmission, there are 16 types of adjustment to the farm-wholesale spread. We will discuss averages.

The simulations all used 1-cent differences between the actual and full-adjustment values. A 1-cent change in this case will represent full adjustment. A half-cent change is 50-percent adjustment. A 1.1-cent change represents a 10-percent overadjustment. For example, suppose that the full-adjustment farm-wholesale price spread is 1 cent below last month's price spread. Dynamic adjustment will work to make this month's price spread lower than last month's. Beef prices tend to overadjust in the current month. The farm price will go up by 0.4 cent and the wholesale price will drop by 0.9 cent, for a total drop in the farm-wholesale spread of 1.3 cents. Pork prices show partial adjustment in the current month. If pork's target farm-wholesale price spread is 1 cent below last month's price spread, then farm prices rise by 0.8 cent and wholesale prices drop by 0.1 cent.

Much of the data used by ERS to create its gross-farm, byproduct, and wholesale values is available on a daily basis from USDA's Agricultural Marketing Service. BLS retail price data for a month are published 2-3 weeks after the end of the month. Livestock interests supported the development of a retail scanner data set for meat partly because of their concern over the lag in BLS price reporting. It was generally believed that quicker reporting of retail prices might improve information flow in livestock and meat markets. Scanner data are electronic, and it was believed that they would be more quickly available than BLS data. Because of various data-delivery and processing problems, it turns out that scanner data take longer to deliver than the BLS data. However, the model estimates show that current changes in retail prices affect wholesale and farm values even though retail-price information is not publicly available. Still, it might be the case that more timely reporting of retail prices could change the pattern of price transmission and improve the flow of information through the system.

The lags and asymmetry in price transmission might be considered evidence of problems in information flow through the markets. Would improving information flow help livestock producers? A partial answer to this question might be found by seeing how speeding up price transmission affects livestock prices and producer revenues. As an extreme case, one might compare prices and revenues with actual prices to those with full adjustment.

Because prices adjust more quickly upward than downward, actual prices tend to be somewhat higher than their full-adjustment values. The farm price for cattle averages about 4 percent higher under asymmetric adjustment than it would be with complete adjustment. Hog prices average around 1 percent higher.

Price adjustment asymmetry can have different effects on revenues than it does on prices. Three producer revenue indices were created for both hogs and cattle by multiplying monthly production and three sets of farm values. The first set of farm values is the actual farm values. The other two sets are two different measures of the full-adjustment price. The full-adjustment farm price is an estimated function of observed variables such as beef and pork production. The estimated functional relationship determines one estimate of the full-adjustment value.

One feature of statistical models is that their equations are usually only approximations. Statistical equations are about what you would expect to see on average. Consequently, there will be some difference between what the statistical model predicts and what actually happens. The difference is usually called the "error." One possible source of error is that the estimated full-adjustment function might only approximate the true full-adjustment values. The first set of full-adjustment estimates takes the functions as accurate. The second set assigns all the errors in the equations to the full-adjustment estimates. The first set of full-adjustment estimates is much more stable than the second set. The first set of full-adjustment estimates is more stable than the actual prices, while the second set is less stable than the actual prices.

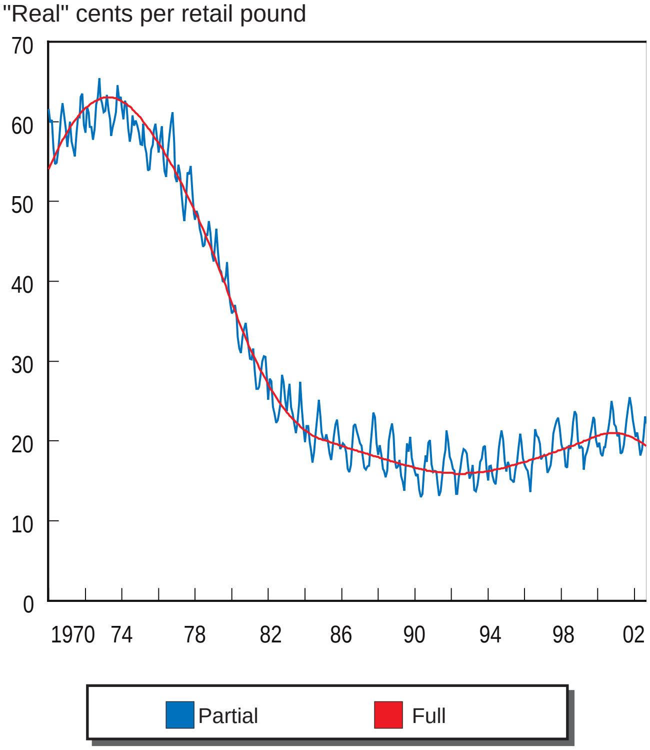
Sometimes the actual revenue index is higher than a full-adjustment index. Sometimes it is lower. The lags and asymmetry of price transmission do appear to help cattle producers' revenues. The cattle revenue index using actual prices averages 2 percent higher than the first full-adjustment index and 7 percent higher than the second index. Lags and asymmetry have little effect on hog producers' revenue. Over time, the differences between the actual and first full-adjustment index cancel out. Hog producers' actual revenue index averages 1 percent higher than the second full-adjustment index.

For both sets of producers, actual revenues vary less from month to month than the second full-adjustment index. Beef revenues are higher and more stable under partial adjustment, while pork revenues are more stable, but not higher. Livestock producers benefit from more stable revenues. There is little difference between the variances of the actual livestock index and the index using the first full-adjustment price, even though this estimated price is more stable than the actual price.

Figure 9

Simulated full and partial adjustment farm-wholesale price spreads for pork

"Real" cents per retail pound

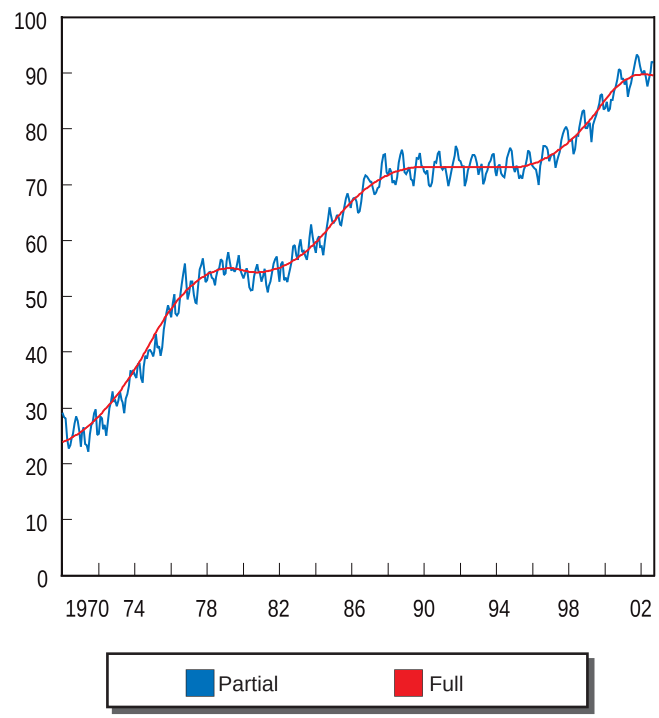


Source: ERS.

Figure 10

Simulated full and partial adjustment wholesale-retail price spreads for pork

"Real" cents per retail pound

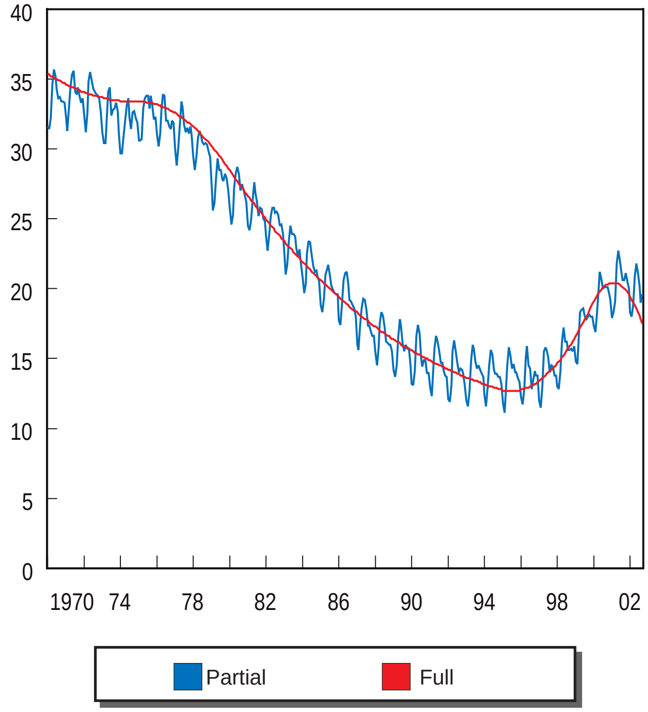


Source: ERS.

Figure 11

Simulated full and partial adjustment farm-wholesale price spreads for beef

"Real" cents per retail pound

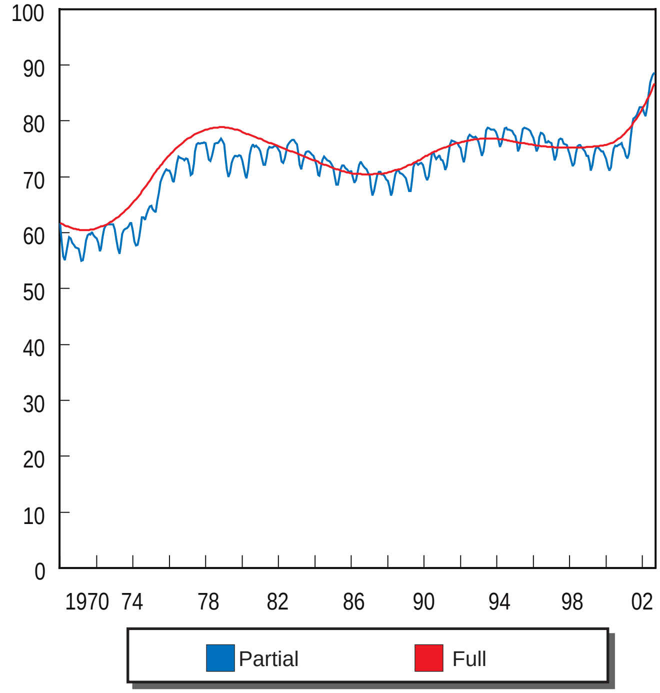


Source: ERS.

Figure 12

Simulated full and partial adjustment wholesale-retail price spreads for beef

"Real" cents per retail pound

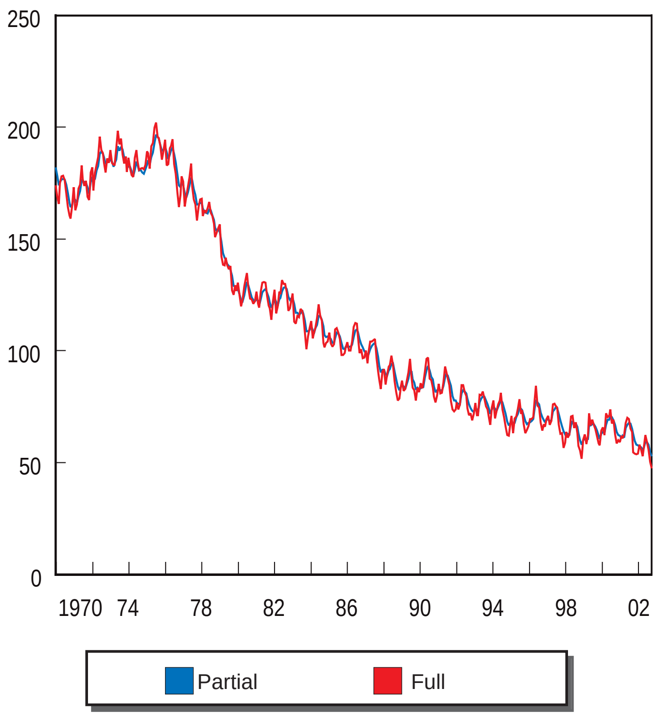


Source: ERS.

Figure 13

Simulated full and partial adjustment wholesale values for pork

"Real" cents per retail pound

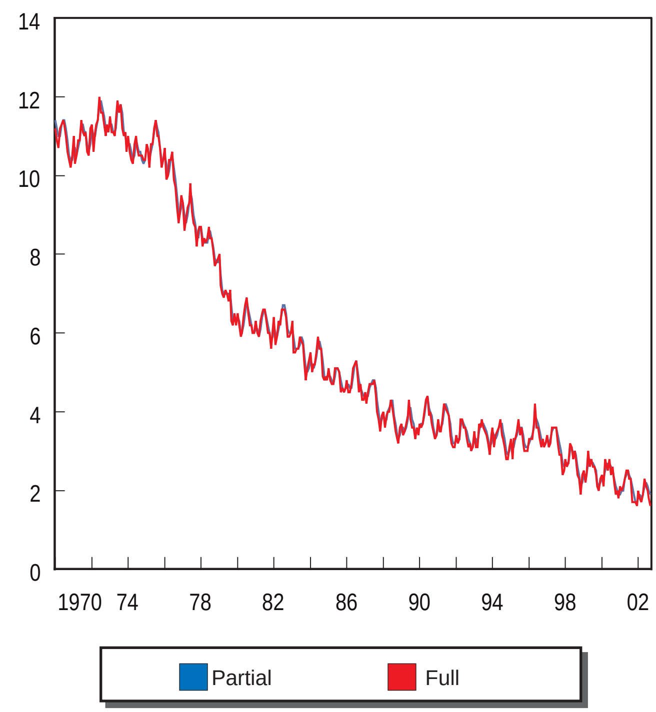


Source: ERS.

Figure 14

Simulated full and partial adjustment byproduct values for pork

"Real" cents per retail pound

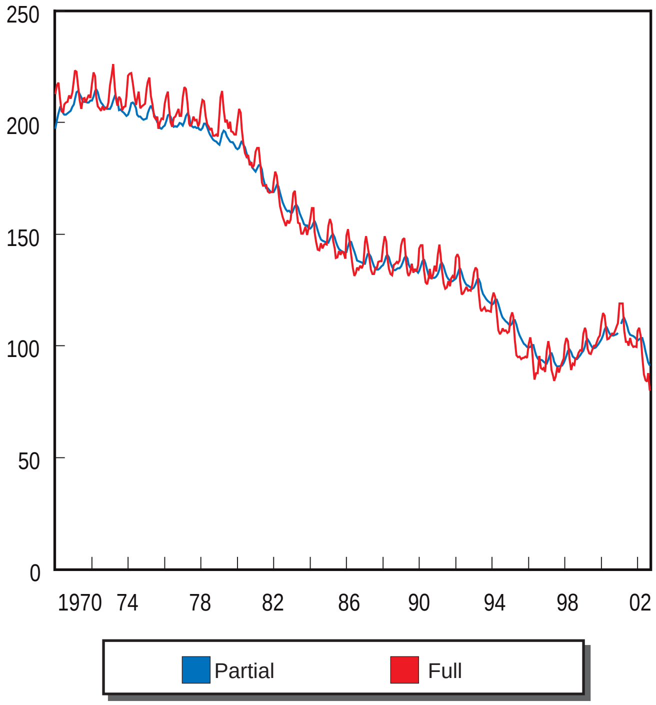


Source: ERS.

Figure 15

Simulated full and partial adjustment wholesale values for beef

"Real" cents per retail pound

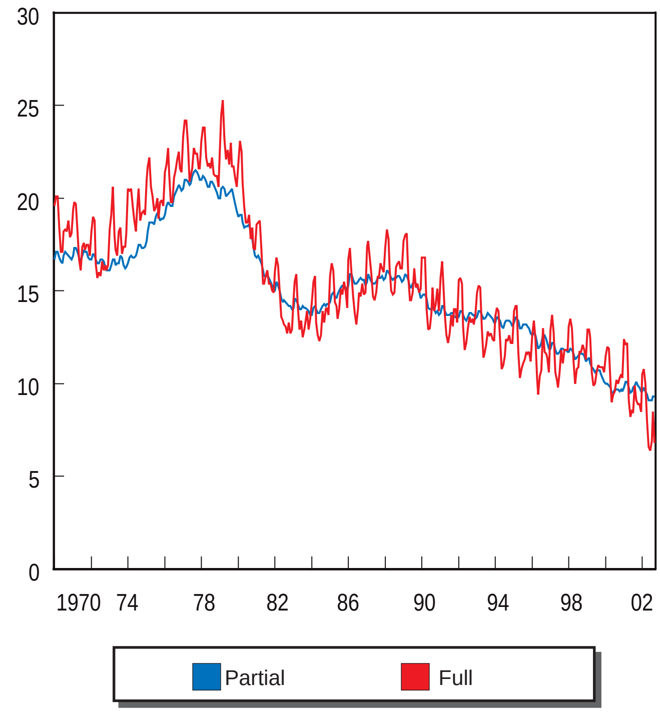


Source: ERS.

Figure 16

Simulated full and partial adjustment byproduct values for beef

"Real" cents per retail pound



Source: ERS.

Faster price transmission is unlikely to help livestock producers much—and may even hurt them. This is not to say that improved market information would be bad for producers. There is no guarantee that improved information would change price transmission, but it could provide other benefits to livestock producers. For example, ERS price spreads are based on a specific type of animal, which may or may not match the type of animal a specific producer raises. One advantage of the scanner data is that they provide information on more retail cuts than the BLS data.

Figures 9-16 show the estimated full-adjustment price spreads, wholesale values, and byproduct values for beef and pork. These full-adjustment terms are those estimated by the functional forms and do not include error terms in them. The figures also show the simulated partial adjustment values if there were no error terms in the equations. Figures 9-12 show the price spreads. The full-adjustment price spreads are smooth functions of time, while the partial-adjustment spreads fluctuate around them. This illustrates the basic point that partial adjustment can make price spreads more volatile. The next four figures (13-16) show the wholesale and byproduct values. In these figures, the full-adjustment values fluctuate around the partial adjustment values. Dynamic adjustment makes prices more stable than complete adjustment. The relatively quick adjustment in pork markets makes this phenomenon harder to see. It is more obvious in the slowly adjusting beef markets.

Summary

So, in the beef and pork markets, how much do price spreads matter? Before answering this question, one must determine what price spreads are supposed to measure. Price spreads are based on farm, wholesale, and retail values for beef and pork. These values measure how much an animal's meat is worth at various stages of the farm-to-retail marketing channel. Price spreads provide a rough measure of the economic efficiency of the various segments of the channel. Improved technology that lowers costs can lead to lower price spreads. Improved competition in the market channels can eliminate monopoly or monopsony profits, also improving economic efficiency and lowering price spreads. High price spreads dampen the derived demand for livestock, which will lead to some combination of lower livestock prices and lower livestock production.

How much do price spreads matter? That depends on what time frame one considers. From the long-term perspective, higher price spreads cause lower derived demand for livestock, and possibly lower livestock prices. The farm-to-wholesale price spreads have increased less rapidly than inflation over the past 30 years, while the wholesale-to-retail spread has increased more rapidly than inflation. Total, inflation-adjusted price spreads are slightly higher now than they were 30 years ago.

The declining, inflation-adjusted farm-to-wholesale price spread can be explained by the increased efficiency observed in meatpacking. Grocery stores seem to have experienced a decline in overall productivity, which is consistent with the increasing wholesale-to-retail spreads. Higher retail meat margins will lead to declines in the derived demand for livestock, and may cause lower livestock prices.

The problem with assessing how the change in grocery store productivity has lowered livestock prices is that the grocery store meat case is only one of the outlets for beef and pork. High grocery store costs make other meat outlets more competitive. The effect of grocery store costs on livestock prices depends in part on the share of meat going through the retail meat case. Given the expanding role of export markets, foodservice, and value-added products, changes in grocery store costs probably have less influence on livestock prices now than they did in the past. Increases in the wholesale-retail price spread have decreased the derived demand for livestock. It is hard to say if the declines in the farm-to-wholesale spreads have been enough to offset the higher wholesale-to-retail spreads.

From the short-term perspective, price spreads are volatile, which is consistent with dynamic price adjustment. In other words, it takes some time for all the prices to adjust to changes in conditions. Although adjustment dynamics make price spreads volatile, the extra time it takes prices to adjust to changes makes them more stable than if price adjustment were instantaneous. Price adjustment is also asymmetric, in that all prices adjust more quickly when they are increasing than when they are decreasing. While asymmetry and price adjustment have important effects on month-to-month price changes, it appears that they have little effect on the average levels of livestock prices when calculated over several months. However, dynamic price adjustment makes livestock prices more stable than they would be under complete price adjustment. This increased price stability may benefit livestock producers.

Dynamic adjustment in prices causes dynamic adjustment in price spreads as well. Price spread adjustment has a significant effect on livestock prices. When price spreads are lower than their full-adjustment values, price spread adjustment leads to lower farm prices, and vice versa.

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Appendix

This appendix consists of two parts. The first part examines the theoretical relationship between price spreads or marketing margins and the derived demand for livestock. The second part is an econometric model of shortrun price interactions among the farm, wholesale, retail, and byproduct values for beef and pork.

Price Spreads and Farm Prices

The goal here is to compare how the farm price reacts to margins in any of the product's potential marketing channels. We will leave the definition of marketing channel vague. We will work within a derived demand context, and therefore will treat farm production as exogenous. (We will not worry about supply responses.) We also treat the margins in the marketing channels as fixed/exogenous. The endogenous variables are the farm price, the various retail prices, and the amount of farm product going through the various channels. The following derivations examine the longrun relationship between marketing costs/margins and livestock prices. In the long run, we expect higher marketing costs to produce lower farm prices. Short-term price adjustment can make price spreads higher than their full-adjustment values, which means that relatively high price spreads can be a leading indicator of future increases in livestock prices.

There is one type of farm production, and the level of that production is denoted by "q." This farm production can be used to produce an array of retail goods. This array of retail goods will be denoted by the vector "Y." We are going to assume that the retail prices of the outputs, denoted by the vector "R," can be written as the farm price plus a markup, as in the equation below:

$$R = f*[1] + M \qquad \text{(a1)}$$

In (a1), R is the retail price vector, f is the farm price, [1] is a vector of ones, and M is a marketing margin or price-spread vector. We are measuring retail prices in farm-price-equivalent units. (When calculating beef and pork price spreads, we calculate all the prices in retail-weight equivalent units.) We have assumed away differences in the animals' cuts in specifying (a1). The pricing implied by (a1) is consistent with constant-returns-to-scale transformation of retail products from farm products and competitive markets. One need only aggregate all the marketing inputs used in each sector to a single input for that sector, then scale the R and M appropriately. The derivative of any retail price with respect to the farm price is one (1) and the derivative of the retail price with respect to its input-cost index is also one (1). Equation (a1) is also consistent with a fixed-proportions technology and fixed markups over the farm price.

Because of the way the retail output is scaled, we can relate the total farm input used to the retail output using the following function:

$$q = [1]'Y \qquad \text{(a2)}$$

To complete our system of equations, we are going to assume a set of retail demand functions. The derivatives of this system with respect to price ($\partial Y/\partial R$) are denoted by the matrix "D."

To show the relationship between margins and the farm price, we create the differential system using the demand system, (a2) and (a1):

$$\begin{bmatrix} D & -1 & [0] \\ I & 0 & -[1] \\ [0]' & -[1]' & 0 \end{bmatrix} \begin{bmatrix} \partial R \\ \partial Y \\ \partial f \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ I & 0 \\ [0]' & 1 \end{bmatrix} \begin{bmatrix} \partial M \\ \partial q \end{bmatrix} \qquad \text{(a3)}$$

Solving (a3) for the derivatives of its endogenous variables with respect to its exogenous variables gives:

$$\begin{bmatrix} \partial R \\ \partial Y \\ \partial f \end{bmatrix} = \begin{bmatrix} I - \dfrac{[1]*[1]'D}{[1]'D[1]} & \dfrac{[1]}{[1]'D[1]} \\ D\left(I - \dfrac{[1]*[1]'D}{[1]'D[1]}\right) & \dfrac{D[1]}{[1]'D[1]} \\ \dfrac{-[1]'D}{[1]'D[1]} & \dfrac{1}{[1]'D[1]} \end{bmatrix} \begin{bmatrix} \partial M \\ \partial q \end{bmatrix} \qquad \text{(a4)}$$

The change in the farm price from a change in one of the margins is given by:

$$\frac{\partial f}{\partial M} = \frac{-[1]'D}{[1]'D[1]} \qquad \text{(a5)}$$

Equation (a5) is simply a small part of (a4). We would generally expect that all the terms of (a5) would be negative because increasing margins should not increase the farm price. If there is only one outlet for the farm product, then (a5) implies that increases in the margin causes an equal decrease in the farm price:

$$\frac{\partial f}{\partial M} = \frac{-d}{d} = -1 \qquad \text{(a6)}$$

In (a6) "d" is the demand derivative of the single retail output with respect to its price. It is a single number, not a block of numbers. Likewise the vector [1] collapses to the number 1. In the case with multiple outlets, if all the margins change by one, then (a5) implies that:

$$\partial f = \frac{\partial f}{\partial M} * \partial M = \frac{-[1]'D}{[1]'D[1]} * [1] = \frac{-[1]'D[1]}{[1]'D[1]} = -1 \qquad \text{(a7)}$$

We would expect that having one of the margins change would have a lesser effect on the farm price than having all of the margins change. That is, an increase in one margin is likely to decrease the farm price by less than the change in the margin.

The effect that a margin change has on the farm price depends on all the derivatives of the demand system. Economists seldom work with demand derivatives; they generally work with demand elasticities. The larger the demand elasticity, the larger the demand derivative. For a given elasticity, larger quantities and/or smaller retail prices make the demand derivatives larger. Low margins in a channel mean that its retail prices are low. The more elastic the demand, the lower the margin, and the larger the volume moving through the channel, the larger the effect the channel's margin has on the derived demand for livestock.

We have not defined the term "marketing channel." The generic format that we have used so far is consistent with many definitions. We could treat each possible way that the animal could get from the farm to any consumer as a different channel. For the most part, we are interested in more aggregated definitions of marketing channels. For purposes of discussion, we will consider grocery store markets, the food service group, and the export market. It is safe to combine these channels if the individual firms in each of the three sectors have similar costs. For example, it makes sense to talk about a grocery store sector if grocery stores' meat markups follow one another closely over time.

Note also that we have not separated out the packing sector from the downstream marketing firms. All animals go through the packing sector before their meat enters the other marketing channels. If we treat meatpacking as a single marketing channel and the wholesale meat price as a "retail" price, then (a6) becomes relevant. We expect that a 1-cent increase in the farm-to-wholesale spread would translate into a 1-cent decrease in the farm price.

ERS price spread statistics focus on the farm-to-grocery store part of the marketing system. Equation (a7) implies that a 1-cent increase in the wholesale-retail spread would decrease farm prices by less than 1 cent. The exact effect cannot be estimated with current information. We know that grocery store sales are an important outlet for beef and pork, and grocery store margins are lower than food service margins but probably higher than export margins. We do not know the own- and cross-price elasticities of demand for the various marketing channels' outputs; although we would expect that export demand would be more elastic than the other two channels.

The foodservice and export markets have become increasingly important markets for U.S. meat, which means that the supermarket sector has become less important. This makes the farm-to-retail price spread have less of an influence on the derived demand for livestock.

The derivations above are based on the assumption that the price spreads in the different marketing channels are independent. This is unlikely to be the case, especially if the different marketing channels use some of the same nonmeat inputs. We could make the relationship expressed in (a1) more complex by making the vector of margins, M, a function of input prices. Changes in the costs of common inputs would lead to changes in more than one of the elements of M. Price spread calculations attempt only to measure (at best) total margins, not the contribution of individual inputs to margins.

One special case we could analyze is where the margins in all the markets are proportional to one another. This is the case where if one margin increases by 1 percent, all the others also increase by 1 percent. If this is the case, we can create a common marketing cost index for all the marketing channels. Call it “s.” Each marketing channel's margin would be “s” times some constant. The more marketing inputs used, the higher the constant. We could make “s” equal to the grocery-store margin and the grocery store's constant equal to 1. A 1-cent increase in the farm-to-retail margin implies a k-cent increase in all the other channels' margins. We can express this relationship using the following function:

$$M = Ks \qquad \text{(a8)}$$

“K” in (a8) is a vector of positive constants. Combining (a8) and (a5) gives us:

$$\frac{\partial f}{ds} = \frac{\partial f}{\partial M} * K = \frac{-[1]' DK}{[1]' D[1]} \qquad \text{(a9)}$$

It turns out that equation (a9) is uninformative. A 1-cent change in the farm-to-retail margin can be associated with a decrease in derived demand by more or less than 1 cent. We would expect that the decrease implied by (a9) in the derived demand for livestock is greater than that implied by a change in the farm-to-retail margin alone.

The Dynamic Asymmetric Model

The statistical model used in this analysis is an endogenous switching model. This type of model has been used to model price spread behavior by Hahn (1989, 1990) and in Mathews et al. The previous works were all three-equation systems predicting gross-farm, wholesale, and retail prices, ignoring the byproduct price. This model predicts all four values. The new model also puts fewer restrictions on how prices interact. The new model uses quadratic splines to estimate the full-adjustment price spreads, which is a more flexible approach than was used before.

Standard econometric software does not include routines for the estimation of this type of endogenous switching model. Mathematical programming software was used. The equation structure may appear odd for three reasons. The first is that the equations are designed for the convenience of the software. The second is that no prior markup or markdown structure was imposed on the models. The structure allows the data to “select” the best type of price-transmission relationships. The third reason is that the farm-wholesale and wholesale-retail spread equations are designed to directly calculate the full-adjustment spreads.

The structure of the model makes somewhat more sense if one starts with a general, symmetric, partial-adjustment model, then adds asymmetry to it. A general, symmetric partial adjustment model can be written:

$$dY_t = \Theta(T_t - A_{t-1} + e_t) \qquad \text{(b1)}$$

In (b1), dY_t is a vector of changes in the four values; Θ is a (4 by 4) matrix of adjustment parameters; T_t is a vector of target levels for the meat value, byproduct value, and the two price spreads; A_{t-1} is last month's actual values; while e_t is a vector of four random error terms. The term “target” is generally used in the econometric literature to mean “full-adjustment.” Since this is the technical appendix, we use the more technical language. The target vector is a function of other variables. Its structure will be discussed later. Equation (b1) is a very general, partial adjustment model. It is possible to restrict Θ so that it implies complete adjustment.

Prior expectations on what the bounds of some of the individual elements of Θ should be are shown in table B1. If the elements of the Θ matrix are consistent with these prior expectations, then price adjustment

Appendix table B1—Sign expectations for the Θ matrix[1]

	Price adjustment factor			
Endogenous variable	Meat	Byproduct	Farm-to-wholesale spread	Wholesale-to-retail spread
Gross farm	positive	positive	negative	negative
Byproduct		positive	positive	
Wholesale	positive		positive	negative
Retail	positive		positive	positive

[1]Blank cells have no “sensible” prior values and could be either positive or negative.

will move prices toward their target values rather than away from their target values.

There are four types of target values: meat value, byproduct value, farm-wholesale spread, and wholesale-retail spread. A 1-cent increase in the target meat value will increase the target values for gross-farm value, wholesale value, and retail value by 1 cent. If the target meat value is above the actual meat value, dynamic adjustment ought to raise gross-farm, wholesale, and retail prices. The target meat value is expected to have positive coefficients in the gross-farm, wholesale, and retail parts of the T matrix. We allow the effect of higher target meat values on current byproduct price to be either positive or negative.

The "byproduct" factor in the T matrix is the byproduct value. Live animals have byproducts in them as well as meat. A 1-cent increase in the target byproduct value will also increase the target gross-farm value by one cent. Rising target byproduct values ought to increase current livestock and byproduct values. There are no prior sign constraints on the effect of byproduct-value adjustment on wholesale or retail meat prices.

The other two targets are the farm-wholesale and wholesale-retail price spreads. Suppose the target farm-wholesale price spread is above the actual price spread. The farm-wholesale price spread can increase if farm prices drop, wholesale prices rise, or byproduct prices rise. We also expect that higher wholesale prices caused by widening the farm-wholesale spread will lead to higher retail prices. Making the wholesale-retail spread wider requires lowering the wholesale price and/or raising the retail price. Lowering the wholesale price because of increasing wholesale-retail spreads ought to lower the gross-farm value as well.

With mathematical programming software one can impose bounds on coefficients, which was done in this case. Imposing these bounds insures that the estimated adjustment directions make sense and it also helps to insure that the endogenous switching model is *coherent*. Gourieroux, Laffont, and Monfort (1980) discuss coherency conditions. A switching equation is coherent if you can solve it. If an equation is not coherent, then it may have more than one solution or none.

Equation (b1) is useful for estimation of symmetric models and static models, but not much help for specifying asymmetric models. The first step in making (b1) asymmetric is to transform it by multiplying both sides by the inverse of Θ, which will be called “B.”

$$B \cdot dY_t = T_t - A_{t-1} + e_t \qquad \text{(b2)}$$

The trick to making (b2) asymmetric is to split the changes in endogenous variables into two parts, the increasing part and the decreasing part. The increasing part will be called $dY_{up,t}$ and the decreasing part $dY_{dn,t}$. Explaining the split is easier with a specific example. Consider the gross farm value. When the gross farm value is increasing, its term in $dY_{up,t}$ is the increase in the gross farm value and its term in $dY_{dn,t}$ is 0. When the gross farm value is decreasing, its term in $dY_{up,t}$ is 0 and its term in $dY_{dn,t}$ is the decrease in the gross farm value. The asymmetric version of (b2) is written as:

$$B_{up} \cdot dY_{up,t} + B_{dn} \cdot dY_{dn,t} = T_t - A_{t-1} + e_t \qquad \text{(b3)}$$

One way of transforming (b3) back to (b2) is to require that B_{up} and B_{dn} be the same. Also, since Θ can be restricted to imply complete adjustment, the “B” matrices, if symmetric, can also be restricted to imply complete adjustment. The structure in (b2) can be tested for complete adjustment and asymmetry.

In an endogenous switching model, the coefficients that multiply the dY terms switch when one of the terms changes sign. We could also write (b3) in the same form as (b2), except that there would be 16 versions of the “B” matrix, and the one selected would depend on which directions the four values were moving. The 16 different B matrices were inverted in the program to insure that all the implied Θ matrices had sensible elements.

One commonly used model of price discovery is the “markup” model. In markup models, the farm price changes first. The wholesale price dynamically adjusts to the farm price and the farm-to-wholesale price spread. The retail price dynamically adjusts to the wholesale price and the wholesale-to-retail price spread. In a markup model, the farm price does not react to price spreads in the short run. One can also build models where the wholesale or retail prices move first and the others follow. The strict leader-follower models imply that one level of the market is the most important center for price discovery. Leader-follower models are special cases of more general models where each price can have a role in price discovery.

The problem with a “pure” leader-follower model when analyzing beef and pork price spreads is that there are actually two kinds of products being valued: the value of meat and the value of byproducts. The gross farm value or animal value has both meat and byproducts in it. The wholesale and retail values are exclusively meat. Obviously, the byproduct value is exclusively byproducts. To make a leader-follower model in this case, one needs to select two leading prices and two following prices. The two leaders determine meat and byproduct values. One of the prices selected as a leader has to have meat in it, and the other has to have byproducts in it. As noted above, there are three variables in the model with meat in them. There are two with byproducts. Picking one of the three variables with meat and one of the two with byproducts, and dropping the livestock-livestock pair gives five models of price leaders/followers.

The asymmetric price leader-follower models were generated by restricting the terms of the two “B” matrices. The leader-follower models have a block-recursive structure. The “meat” and byproduct value equations only have the two leader terms in them. The wholesale-to-retail spread equations are functions of only the retail and wholesale prices, while the farm-to-wholesale equation is a function of the gross farm, byproduct, and wholesale values only. This makes the following prices a markup or markdown from the leading prices.

The target values , T_t, are a function of other variables. The two target spreads are derived from a quadratic spline function. Past models of this type (e.g. Hahn (1989, 1990), Mathews et al.) specified the target spread using a trend over time. Graphing this type of target value over the months gives a straight line over time. The spline approach is more flexible. It has an intercept and a trend, like previous research, and a trend squared term. To add further flexibility, every 5 years, the intercept, trend, and trend-squared terms change. The different spline functions are related: they are required to join at the ends. For example, there is one function that covers 1970-1974 and another that covers 1975-1980. The 1970 and 1975 functions are required to give the same values for December 1974 and January 1975. The two functions can be different in other months. The 1975 and 1980 functions match in December 1979 and January 1980, and so on. Although the specification started with 21 potential spline coefficients, the joint restrictions allow these 21 to be reduced to 9 free terms. Inflation was factored into the model by multiplying the nine free spline terms by the consumer price index, CPI.

The byproduct and meat price equations also have the nine spline terms. In addition, these two equations have seasonality and depend on beef and pork production. Seasonality is measured using four harmonic variables. Beef and pork production get the asymmetric treatment also as they are both split into increases, decreases, and last month's values. The seasonal and quantity terms are also multiplied by the CPI to account for inflation over the sample.

The last part of the general, asymmetric model that needs to be specified is the error term. It is specified using a very general, first-order process:

$$e_t = R \cdot e_{t-1} + u_t \qquad \text{(b4)}$$

In (b4), R is a matrix of general autocorrelation effects and u_t is a normally distributed error term with mean 0 that is identically and independently distributed over time. This very general error structure was selected so that the leader-follower models and the most general model would nest one another.

Estimates and Tests

Table B2 presents the statistical tests for dynamic adjustment and asymmetry. The complete adjustment and symmetric adjustment models are rejected for both beef and pork. Table B3 presents the tests of the asymmetric leader-follower models against the general, asymmetric model. You will note that there are two sets of tests of the leader-follower models in table B3. One set imposes the block-recursive structure only on the “B” matrices. The other assumed that the error structure, including the autocorrelation, was also block recursive. One of the indirect implications one might draw from the results of table B3 is that allowing very general autocorrelation greatly improves model performance. Some models not reported here were run with more structured autoregressive relationships; freeing up the autoregression greatly improves model performance.

Tables B4 and B5 show the “B” matrix estimates and the quantity and seasonality estimates for the most general beef and pork models. Rather than report the spline-coefficient estimates, the splines' effects on the byproduct and wholesale values for beef and pork are graphed in figures B1 and B2. The spline effects on

Appendix table B2—Testing hypotheses: dynamics and asymmetry

Species	Hypothesis	Degrees of freedom	Likelihood ratio test	Significance level	5% critical value
Beef	Adding dynamics to static model	16	226.20	0.00%	26.30
Beef	Adding asymmetry to dynamic model	16	37.06	0.21%	26.30
Beef	Adding dynamics and asymmetry to static model	32	263.26	0.00%	46.19
Pork	Adding dynamics to static model	16	207.05	0.00%	26.30
Pork	Adding asymmetry to dynamic model	16	43.34	0.02%	26.30
Pork	Adding dynamics and asymmetry to static model	32	250.40	0.00%	46.19

the price spreads are graphed in the main part of the document.

One of the sets of simulations measured the ability of the system to explain changes in the prices. Predictions of changes in the gross-farm, byproduct, wholesale, and retail values can be used to make predictions of the net-farm value and spreads. The symmetric versions of the model are linear, which means that the current error terms' mean effect on the values is zero. Switching and asymmetry make the model nonlinear, and the average effects of this month's error terms are not zero. Getting the average error term effect is a complicated problem involving multinomial probit analysis, so the simulations estimated median (error terms are 0) predictions. Table B6 shows the fit between actual and median values and price spreads using r-square as a measure of fit. The r-squares are quite good, given that first-differences in the data are being analyzed.

Figure B1

Byproduct spline effects

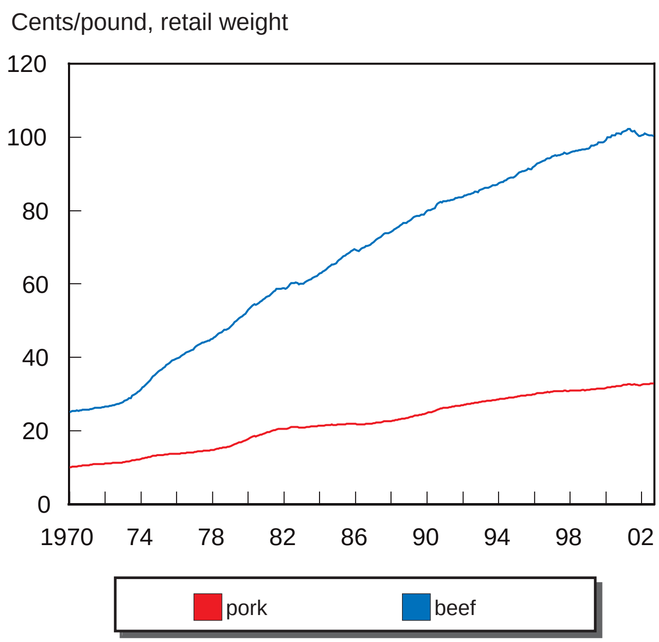
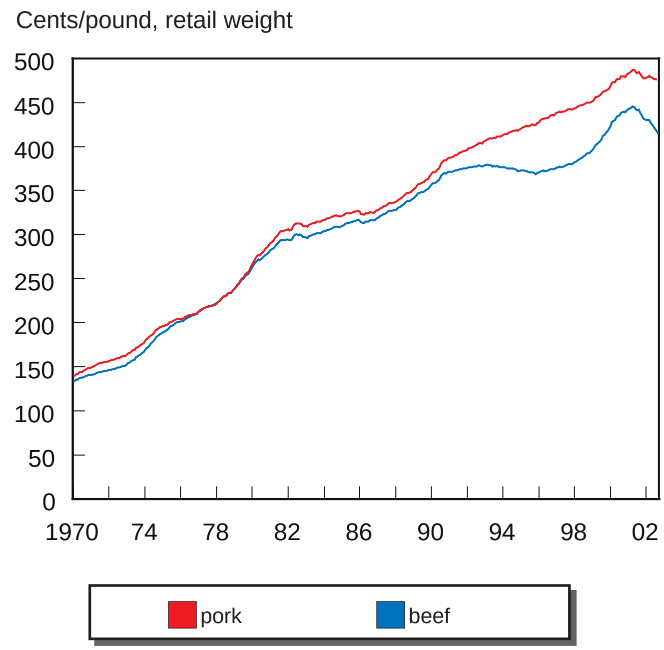


Figure B2

Meat-price spline effects



Appendix table B3—Making the models block recursive: testing uni-directional price transmission

Species	Market determining the values of: Meat	Market determining the values of: Byproducts	Degrees of freedom	Likelihood ratio test	Significance level
		Testing block recursive model against most general, asymmetric model			
Beef	farm	byproduct	26	312.05	0.00%
Beef	wholesale	farm	26	341.02	0.00%
Beef	wholesale	byproduct	26	315.34	0.00%
Beef	retail	farm	26	833.32	0.00%
Beef	retail	byproduct	26	426.36	0.00%
Pork	farm	byproduct	26	243.39	0.00%
Pork	wholesale	farm	26	500.45	0.00%
Pork	wholesale	byproduct	26	386.51	0.00%
Pork	retail	farm	26	994.58	0.00%
Pork	retail	byproduct	26	592.58	0.00%
		Testing block recursive structure with general covariance and autocorrelation			
Beef	farm	byproduct	14	169.32	0.00%
Beef	wholesale	farm	14	76.77	0.00%
Beef	wholesale	byproduct	14	83.05	0.00%
Beef	retail	farm	14	69.87	0.00%
Beef	retail	byproduct	14	57.34	0.00%
Pork	farm	byproduct	14	141.58	0.00%
Pork	wholesale	farm	14	76.13	0.00%
Pork	wholesale	byproduct	14	26.78	2.06%
Pork	retail	farm	14	53.03	0.00%
Pork	retail	byproduct	14	167.81	0.00%

Appendix table B4—Asymmetry coefficient (B-matrix) estimates[1]

Item	Level	Byproduct	Farm-to-wholesale	Wholesale-to-retail
Beef results:				
Increase in byproduct value	1.3903	1.9346	0.7420	1.2175
Decrease in byproduct value	1.7137	2.2751	0.9868	1.3288
Lagged byproduct value	0	1	1	0
Increase in gross farm value	2.8873	0.3413	-0.2001	-0.4571
Decrease in gross farm value	4.1001	0.7554	-0.0083	0.7442
Lagged gross farm value	0	0	-1	0
Increase in wholesale value	0.5926	-0.0424	0.8866	-0.8409
Decrease in wholesale value	0.0000	-0.2928	0.8155	-1.9445
Lagged wholesale value	1	0	1	-1
Increase in retail value	1.8114	0.7318	0.1975	3.4206
Decrease in retail value	4.4807	1.2191	0.7248	3.8695
Lagged retail value	0	0	0	1
Pork results:				
Increase in byproduct value	-1.0615	0.8309	0.9102	0.2371
Decrease in byproduct value	-1.2554	0.8309	0.0000	0.2804
Lagged byproduct value	0	1	1	0
Increase in gross farm value	-0.0618	0.0484	-1.2072	0.0138
Decrease in gross farm value	0.3085	0.0350	-0.9619	-0.0689
Lagged gross farm value	0	0	-1	0
Increase in wholesale value	1.6143	-0.0315	1.6812	-0.4881
Decrease in wholesale value	1.6649	-0.0055	1.8432	-0.3719
Lagged wholesale value	1	0	1	-1
Increase in retail value	0.6595	0.0057	0.5436	1.3994
Decrease in retail value	1.4028	0.0504	0.9187	1.7762
Lagged retail value	0	0	0	1

[1] Lagged-price coefficients are fixed, not estimated.

Appendix table B5—Quantity and seasonal parameter estimates

	Beef estimates		Pork estimates	
	Level	Byproduct	Level	Byproduct
Seasonal factor 1, cosine 1 turn per year	0.3052	0.0199	-0.5606	-0.0345
Seasonal factor 2, cosine 2 turns per year	-1.1511	-0.3424	-0.7406	-0.0817
Seasonal factor 3, sine 1 turn per year	4.7461	0.5406	0.1980	-0.0501
Seasonal factor 4, sine 2 turns per year	2.8960	0.6929	-0.0871	0.0071
Increase in beef production (in logarithms)	-37.1980	-8.3374	44.1702	2.7463
Decrease in beef production (in logarithms)	-41.1724	-9.7517	45.6015	2.5708
Last month's beef production (in logarithms)	-49.8862	-13.0418	40.1690	2.0163
Increase in pork production (in logarithms)	35.2243	7.5408	-55.1258	-3.6281
Decrease in pork production (in logarithms)	24.9107	5.4591	-62.1463	-3.8888
Last month's pork production (in logarithms)	32.7133	7.1576	-70.5305	-4.3162

Appendix table B6—Measuring the most general models' median forecast fit using R-squares

Item	Beef	Pork
	Percent	
Gross farm value	36.61	46.64
Byproduct value	25.13	36.64
Net farm value	35.89	46.64
Wholesale value	35.78	34.26
Retail value	57.89	51.53
Farm-to-wholesale price spread	37.80	43.37
Wholesale-to retail price spread	28.63	29.30
Total price spread	32.25	44.48