TEMPORAL MARKET PRICE RELATIONSHIPS

In the preceding chapters of Parts II and III, we discussed markets in space and form, observing that prices in these markets would be interconnected through transfer and processing costs. We now consider markets in time and to the parallel concept of market prices interrelated through storage costs.

11.1 THE TIME DIMENSION AND STORAGE COSTS

Just as production and consumption are most commonly carried on at points widely separated in space, so production and consumption are usually separated in time, and perhaps by relatively long periods of time. In some instances, for example, in many personal services, production and consumption are and must be simultaneous. The dentist produces his services and at the same time these services are “consumed”—a good example despite the fact that some teeth need not accompany the owner. Similarly, electrical power is generated and consumed almost simultaneously except in those cases that involve batteries for “storage.” But in most cases there is a time lag between production and consumption, and the creation of time utility in bridging this gap is a productive activity (storage) that can be accomplished only at a cost in terms of resources.
We need not be especially concerned here about the particular nature of storage costs other than to point out that the operation usually involves providing certain physical facilities (warehouses, grain elevators, or storage vats and tanks) and that operating costs will normally be a function of the length of time period. Fixed costs will include the usual types of overhead expenses associated with the physical facilities plus certain handling costs, such as placing and removing the products, that will be necessary without regard to the length of storage period. Variable costs will include continuing items such as protection expenses, handling expenses related to storage time (for example, turning the product), fuel and power expenses in connection with heat or refrigeration, and interest on the inventory. The similarity between transport costs and storage costs should be clear, but it should also be recognized that storage refers to the time dimension and that some costs, normally considered as fixed in the usual production sense, will properly be considered as variable in this time dimension.

In addition to the direct costs of storage, changes in product characteristics during storage must be considered as a cost in terms of depreciated product values. Thus, commodities such as butter and eggs deteriorate in storage even under the best of conditions, and therefore the stored products will have somewhat lower market values than the equivalent fresh products. In addition to quality deterioration, there may be loss of weight or volume through evaporation, loss of weight and quality through insect damage, and so on.

Similar losses through time are the corrosion of metals and the degeneration of rubber and other materials. In some instances, of course, storage may enhance market value—as in aged cheeses and wines—but even here the product will degenerate if kept in storage for too long a period. All of these product changes (deterioration or improvement) can be expressed in terms of changes in market values and counted as part of storage costs. This is suggested in very simple terms by the diagrams in Figure 11.1.

11.2 TWO-PERIOD DEMAND CASE

The back-to-back diagram used to illustrate the two-region spatial equilibrium model in section 5.1 is equally helpful in understanding a two-period storage case. Suppose that a product is produced in period 1, say the harvest period, and may be consumed either in period 1 or in period 2 when no production takes place. We assume in Figure 11.2 that supply is perfectly inelastic, although this is not necessary to our argument. In the absence of storage of this product from the harvest period to period 2, the
FIGURE 11.1 The relation between storage costs and the length of storage period including (a) Product deterioration; (b) Product improvement.

FIGURE 11.2 Two-period equilibrium with zero storage costs.
quantity $a$ is consumed at harvest time at the equilibrium price $P$. We now construct an excess supply curve for period 1 just as was done in chapter 5. This excess supply curve passes through point $P$, is positively sloped, and represents the amount by which supply exceeds (or falls short of) the quantity demanded at every price.

The construction of an excess supply curve for period 2 follows our earlier instructions; namely, this excess supply curve represents the amount by which the available supply, in this case zero, exceeds the quantity demanded at each price. The obvious result of this subtraction is to produce an excess supply curve for period 2, each point on which is the negative of the corresponding point on the demand curve and, therefore, lies to the right of the price axis. (The reader is reminded that the quantity axis for period 1 is measured to the right of the origin and for period 2 to the left of the origin.) In Figure 11.2 the excess supply curve for period 2 is, thus, the negative of the demand curve for period 2; that is, $ES_2$ is the mirror image of $D_2$.

With storage, but in the absence of storage costs, the equilibrium price is found where these two excess supply curves intersect, or price $P_s$ in Figure 11.2. Of the total supply $a$, the amount $d$ will be consumed in period 1 and the amount $b$ will be stored in period 1 for consumption in period 2. The obvious effect of storage has been to raise the price in period 1 and to limit consumption during that period while making possible consumption of the product in period 2.

We now modify Figure 11.2 to facilitate the introduction of storage costs. In Figure 11.3, we reproduce the earlier demand curves and the

![FIGURE 11.3 Two-period equilibrium with storage costs introduced.](image)
supply curve and add a new curve representing the difference between the two excess supply curves labeled \( ES_2 - ES_1 \). As in our earlier spatial analysis, each point on this curve represents the vertical difference between the two excess supply curves. Now suppose that the storage cost per unit is represented by the amount \( s \). We measure horizontally from point \( s \) on the price axis to our excess supply difference curve and find that this intersection occurs at quantity \( c \). Reading vertically, we find that this quantity intersects \( ES_1 \) at price \( P_1 \) and \( ES_2 \) at price \( P_2 \) for period 1 and period 2, respectively. Again, reading horizontally from these prices, we find that the total supply is allocated between the two time periods in such a way that quantity \( od'' \) is consumed in the first period and \( od' \), which is equal to \( oe' \) by construction, is consumed in the second period. Equilibrium prices in the two periods are thus separated by the cost of storage, a result that is exactly comparable to our earlier analyses in which we found that the prices in two regions that engage in trade will differ exactly by transfer cost and that the prices of two forms of a given raw product will differ exactly by differences in the cost of processing.

It is also possible to analyze the temporal dimension of market price by using a slight modification of the transportation model. In Table 11.1, we show a six-region, space-time model in which the three exporting regions, Minnesota, Wisconsin, and New York, sell a given product (milk?) in three importing regions, New England, South Atlantic, and California, in each of the two periods. In this formulation the transfer cost from a given exporting region to a given importing region differs from period 1 to period 2 by the cost of storage. Any special costs required to prepare the product for storage would also be included. Here we have a perfectly inelastic demand curve in each region in each time period and a given quantity of output in each exporting region which is to be allocated among regions and between the two time periods.

The transportation-model solution provides information comparable to that described earlier. Section 1b summarizes the equilibrium cost matrix. The row identified as \( v_j \) represents intermarket price differences with the additional information concerning intertemporal price differences. For example, in New England, the equilibrium price, relative to the base region, in period 1 is $1.85 and in period 2 is $1.95, or a 10-cent differential between the two time periods. As in the earlier example, the \(-u_i\) column represents export region price differences before the sign has been changed. Finally, Section 1c illustrates the cost of using nonoptimum routes, some of which here represent nonoptimum periods for storage. By summing the quantities in each period-two column in a given row, it is possible to determine the amount of storage needed in an exporting region. This example is vastly oversimplified, but it can be extended to larger.
### TABLE 11.1 Hypothetical Six-Region, Two-Dimension Model (Space-Time)

<table>
<thead>
<tr>
<th>Exporting Region</th>
<th>New England</th>
<th>South Atlantic</th>
<th>California</th>
<th>Surplus $(S_i)$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Period 1</td>
<td>Period 2</td>
<td>Period 1</td>
<td>Period 2</td>
</tr>
<tr>
<td>Minnesota</td>
<td>2.70</td>
<td>2.80</td>
<td>3.20</td>
<td>3.25</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>2.25</td>
<td>2.30</td>
<td>2.70</td>
<td>2.80</td>
</tr>
<tr>
<td>New York</td>
<td>0.55</td>
<td>0.65</td>
<td>2.60</td>
<td>2.65</td>
</tr>
</tbody>
</table>

**Physical Units**

#### 1a. Cost-Flow Matrix

<table>
<thead>
<tr>
<th>Exporting Region</th>
<th>Minnesota</th>
<th>Wisconsin</th>
<th>New York</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.70</td>
<td>2.25</td>
<td>0.55</td>
</tr>
<tr>
<td></td>
<td>3.20</td>
<td>2.70</td>
<td>2.60</td>
</tr>
<tr>
<td></td>
<td>3.25</td>
<td>2.80</td>
<td>2.65</td>
</tr>
</tbody>
</table>

#### Deficit $D_i$ (physical units)

|                | 2.5  | 2.5  | 4.0  | 4.0  | 7.5  | 7.5  | 28.0  |

#### 1b. Equilibrium Cost Matrix

<table>
<thead>
<tr>
<th>Exporting Region</th>
<th>Minnesota</th>
<th>Wisconsin</th>
<th>New York</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.85</td>
<td>2.20</td>
<td>0.55c</td>
</tr>
<tr>
<td></td>
<td>1.95</td>
<td>2.30c</td>
<td>0.65c</td>
</tr>
<tr>
<td></td>
<td>2.35</td>
<td>2.70c</td>
<td>1.05</td>
</tr>
<tr>
<td></td>
<td>2.45</td>
<td>2.80c</td>
<td>1.15</td>
</tr>
<tr>
<td></td>
<td>4.00c</td>
<td>4.35</td>
<td>2.70</td>
</tr>
<tr>
<td></td>
<td>4.20c</td>
<td>4.55c</td>
<td>2.90</td>
</tr>
<tr>
<td></td>
<td>0.00</td>
<td>0.35</td>
<td>-1.30</td>
</tr>
</tbody>
</table>

#### 1c. Cost of Using Nonoptimum Routes

<table>
<thead>
<tr>
<th>Exporting Region</th>
<th>Minnesota</th>
<th>Wisconsin</th>
<th>New York</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.85</td>
<td>0.05</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>0.85</td>
<td>0.00</td>
<td>1.55</td>
</tr>
<tr>
<td></td>
<td>0.80</td>
<td>0.00</td>
<td>1.50</td>
</tr>
<tr>
<td></td>
<td>0.00</td>
<td>0.15</td>
<td>5.30</td>
</tr>
<tr>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>5.40</td>
</tr>
</tbody>
</table>


*Numbers in parentheses are optimum allocations of supplies in physical units.

*Producer price differentials before sign change.

*Transfer cost for active route used in developing equilibrium cost matrix.

*Consumer price differentials relative to Minnesota base.
more interesting problems including simultaneous treatment of form, time, and space.

11.3 MULTI-PERIOD DEMAND CASE

*Arbitrage* is the name given to the activities of individuals who buy in one market in the expectation of selling in another market at a profit, and we have illustrated how this is the effective mechanism that brings consistency to market prices through space. *Speculation* is the term used to describe arbitrage between markets in time. Thus, through the speculative actions of individuals, prices through time are interrelated by storage costs.

If we assume perfect knowledge as to the future (an admittedly unrealistic assumption to be discussed later), then traders will be informed about present and future supply and demand conditions. If the outlook is for significantly higher prices, products will be put into storage. This will reduce supplies currently on the market and, thus, force present prices up; it also increases potential supplies in the future and so will force future prices down. Speculation and storage operations will continue as long as the difference between future and present prices exceeds storage costs, since this excess will represent potential profits.

In equilibrium, then, future and present prices will differ by exactly the costs of storage, including normal profits. But notice that this is a one-way process always moving from the present to the future. If future prospects are for higher prices, storage operations can bring future and present prices into alignment. But if for any reason the prospect is for lower future prices, the discrepancies must remain because of the impossibility of inverse storage. The only moderation of the differential between present and future prices, then, would come from shifts in consumer demands through decisions to defer consumption until the later lower-priced period.

The relation between storage costs and prices is perhaps most apparent in connection with the seasonal production of nonperishable products. Most agricultural products are harvested during a relatively short period during the summer or fall months while consumption tends to be spread throughout the year. After the harvest there is no opportunity to change the available supply, but there are alternatives in terms of the distribution of the given supply through storage and sales operations. Consider the case with a given crop harvested in September with no carry-over from year to year, and with identical demand curves month-by-month through the year. Assume that storage costs involve a fixed
"warehouse" charge plus a variable cost per month. For ease in presentation, we make the not unrealistic assumption that variable cost per month is constant. Under these conditions and with perfect knowledge, what patterns of storage movements, prices, and consumption will result?

The essentials of this problem are indicated in Figure 11.4 where $DD'$ represents the demand curve for the product in any month. Month-by-month prices are represented by $P_1, P_2, \ldots, P_{12}$. Here $P_1$ represents the price in the market in month 1 (the harvest month, September) on the assumption that the product goes into consumption without storage. The price $P_2$ represents month 2, and is higher than $P_1$ by an amount equaling the fixed warehouse charge plus variable storage costs for one month. Prices $P_3, P_4, \ldots, P_{12}$ increase each month by the variable storage costs per month. Each of these monthly prices interact with the demand to determine the quantity to be sold $Q_1, Q_2, \ldots Q_{12}$ within the stated restraint that the total of the monthly sales must exactly equal the fixed quantity available from the harvest.

Consideration of this problem will indicate that the opening price $P_1$ is, not given, as suggested in this diagram, but instead that this price—and, hence, the whole seasonal price structure—is determined by the available harvest, by the demands, and by the requirement that the amount available, and exactly this amount, will be distributed and sold throughout the season. This can be made clear by reexpressing our storage problem in equation form.¹

We have given the following.

- Quantity harvested $= Q$
- Monthly demand $= D_t = a - bP_t$
- Storage costs $= C = d + eT$

where $Q =$ constant for the season in question
- $T =$ number of months in storage
- $t =$ the months from month 1 through month 12.

We assume a perfect market, and so we know that the following price relationship must hold true:

$$P_t = P_1 + d + eT.$$ 

In short, the price in any month must be the price at harvest plus storage costs. Finally, we know that the sum of the monthly quantities sold must equal the supply available from the harvest, or

$$Q = D_1 + D_2 + \cdots + D_{12}.$$ 

¹For ease in presentation and comprehension, specific linear equation forms are employed. The analysis is general in nature, however, and not dependent on these particular forms.
FIGURE 11.4 The seasonal prices and quantities sold, illustrating the storage problem with uniform demand across months.

Now, each of the monthly quantities in the last equation can be redefined in terms of the appropriate monthly prices as indicated by the demand equation, and each monthly price can be defined in terms of the opening price $P_1$ and the appropriate storage costs. With these substitutions, we obtain:

$$Q = [a-bP_1] + [a-b(P_1+d+e)] + [a-b(P_1+d+2e)] + \cdots + [a-b(P_1+d+11e)]$$

$$Q = 12a - 12bP_1 - 11bd - 66be.$$  

Notice that in this formulation we have simplified matters by assuming that storage and storage charges would be by one-month periods—in essence, that all quantities taken out of storage would be removed at a single time each month. With this, we have obtained an equation that contains the given total harvest $Q$, the given cost parameters $a$, $b$, $d$, and $e$, and the single unknown price $P_1$. For any assigned values for the constant terms, it would be a simple matter to solve for the opening price $P_1$ and to determine from this the prices and the quantities removed from storage and sold every month.

The general nature of the results of this process can be illustrated readily. The top diagram in Figure 11.5 shows the seasonal price and sales patterns and is drawn with price and quantity scales one-half those in Figure 11.4. Notice that prices increase abruptly between the harvest month and the first month of storage, as a result of the fixed warehouse
FIGURE 11.5 The seasonal changes in prices, sales, and storage stocks. (Source. Derived from Figure 11.4.)

Figure 11.6 shows seasonal price cycles for a number of years on the assumption that all conditions including the quantity harvested remain constant from year to year. It should be understood that these examples have magnified storage costs relative to product price levels to emphasize the price and cost relationships involved. In many real situations, storage
costs would be relatively small and seasonal price patterns correspondingly would be reduced in amplitude.

In some cases, storable products result from a continuous or year-round production pattern, but with seasonal changes in the quantities produced, in demand, or both. A familiar example is found in butter.

**FIGURE 11.6** The seasonal price cycles over a number of years with uniform harvests and constant demand.

**FIGURE 11.7** The price variations for a product having a seasonal pattern of production. (Note. The "no storage" price cycles reflect curvilinear demand functions.) [Source. J. B. Hassler, "Pricing Efficiency in the Manufactured Dairy Products Industry," *Hilgardia*, Vol. 22, No. 8 (August, 1953), Figure 3, p. 250.]
production where the flow of the raw material from dairy farms continues throughout the year but with wide variations between the spring and fall months. Without storage operations, these seasonal production patterns would give rise to substantial price fluctuations. But butter can be and is stored, and into-storage movements from April through July and out-of-storage movements from September through March level out the seasonal price pattern. This is suggested by the diagrams in Figure 11.7. The particular patterns for any commodity, of course, will depend on the production patterns, on the demands, and on storage costs.

11.4 CARRY-OVER BETWEEN PRODUCTION PERIODS

Clearly a carry-over of a commodity from one year to the following year will not occur if production and demand are constant, since identical price patterns year after year will not permit storage at a profit. But, if a large crop is followed by a small crop, the whole seasonal price pattern will be increased in the second year, and this difference in price may be sufficient for profitable storage with a carry-over from the first to the second year.

This situation is similar to trade possibilities between regions; trade depends on differences in prices, and these differences must be great enough to pay for interregional transfer costs. In the case of markets in time, however, "trade" must always go in one direction—from present to future time periods. This means that interyear trade under conditions of perfect knowledge can bring prices into perfect alignment when high-price seasons follow low-price seasons but cannot be effective when low-price seasons follow high-price seasons.

We have already explored the case of interseason storage; only minor modifications are required to cover the between-year situation. The basic idea is suggested by the construction in Figure 11.8. We assume two successive years and start by considering the case in which these years are isolated—in which no trade or storage occurs between the two. Suppose that the first production period has been characterized by abundant yields for the crop in question and that the second has been less favorable. The seasonal price pattern for the first year is indicated by the solid line to the left in the diagram. This has been developed as explained in the previous section; the shape or slope of this line is entirely dependent on the nature of storage costs, and its level reflects the total quantity available and the demand conditions. Seasonal price patterns for the second year are also depicted by solid lines in this diagram: Case A represents a situation in which yields are only moderately lower than in the first year.
and prices only moderately higher, and Case B represents a situation in which the available supply is substantially reduced with prices thus substantially higher.

When we remember that the slope of these seasonal price lines represents storage costs, it is easy to understand that interperiod trade will not be economical in Case A but that it will be in Case B. Prices are higher in Case A than in the preceding year, but the difference is not as large as storage costs. In Case B, however, the increase in price is greater than the costs of storage and, hence, trade between the two periods (that is to say, storage with a carry-over from the first to the second period) will be profitable. When trade is established between these two markets in time, the aggregate supplies available are brought to bear on the aggregate demands with price results as indicated by the broken line.

It may be revealing to trace out the general interactions by an extension of the equations used in the previous section. With the particular demand and storage cost functions specified earlier, the condition that the aggregate quantities consumed during a single year must equal the size of the crop available resulted in the following equation:

\[ Q = 12a - 12bP_1 - 11bd - 66be. \]

All quantities in this equation except the opening price \( P_1 \) are given, so it is relatively easy to solve for \( P_1 \) and from this determine the entire seasonal price pattern and, hence, the seasonal storage and consumption patterns.

When two years are joined through storage into a single market in time, the appropriate equation becomes

\[ Q + Q' = 2(12a - 12bP_1 - 11bd - 66be) - 12(12be). \]
The last term in this equation simply modifies (or displaces) the prices during the second season by the appropriate storage costs. With this expression, it is again a straightforward matter to solve for the opening price $P_1$, and from this generate the entire price structure over the two seasons. In turn, these prices will interact with the demand functions to determine month-by-month consumption, and they can be accumulated to show the patterns of stocks in storage and the carry-over between seasons.

The interperiod trade patterns are suggested in Figure 11.9 for a hypothetical case involving eight successive years. Crop yields in years 1, 4, and 8 are at "normal" levels. Years 2 and 5 have high production and, if trade between seasons were not possible, this would mean low prices in year 2 and especially low prices in year 5. Year 6 has production slightly lower and prices slightly higher than normal. Years 3 and 7 represent years of low production and relatively high prices. Let us trace out the changing situation through this span of years.

Prices drop between year 1 and year 2 and storage operations cannot influence this drop because of the impossibility of storing from a present to a past period. Prices rise between year 2 and year 3, however, and this

![Figure 11.9](image-url)

**Figure 11.9** Year-to-year price changes and the effects of interperiod trade on prices and storage stocks. *(Note. Solid lines show years in "isolation," broken lines interyear trade.)*
rise is more than enough to cover interseasonal storage costs. The broken line spanning the two years represents the prices that will hold with storage and carry-over—this is the case illustrated in the previous Figure 11.8. The decline in prices from year 3 to year 5 again prohibits profitable storage operations, but prices move upward during years 5, 6, and 7. These three years provide an interesting example: prices in year 6 are well above those in year 5 and, hence, encourage storage operations. Prices in year 7, however, are little higher than in year 6, and this would seem to preclude any carry-over of stocks between these two years. Notice that prices in year 7 are high enough relative to year 5 to justify storage over the three-year period. More to the point, prices in year 7 exceed the price levels for years 5 and 6 combined by more than the added storage costs. Consequently, these three seasons will be united through storage into a single market in time, with prices throughout the period as shown by the broken line. Finally, production and prices return to normal levels in year 8.

The lower part of Figure 11.9 summarizes changes in storage stocks for these eight years. As in the upper diagram, solid lines represent the storage patterns for each year in isolation. The broken lines show the modifications that would result from interperiod trade in the cases where this would be economical. Notice that these with-trade patterns show stocks building up to higher levels than in the isolated cases. When interperiod trade is established, part of the supplies available in the low-price season (or seasons) is transferred and used to satisfy demands in the high-price years.

Prices are increased in the early years, consumption curtailed, and stocks correspondingly increased. The stocks remaining at the end of the first year are carried over to become part of the supply available during the following year. Observe the carry-overs at the end of years 2, 5, and 6.

11.5 FAT YEARS AND LEAN

A somewhat different type of interperiod storage is represented by the Biblical story of the seven lean years. It will be remembered that Pharaoh dreamed that seven well-favored and fat-fleshed kine came up out of the river and that they were followed and devoured by seven ill-favored and lean-fleshed kine. Joseph correctly interpreted this dream as foretelling seven years of plenty to be followed by seven years of famine. Pharaoh thereupon set Joseph over all the land of Egypt and Joseph took up and stored a fifth part of all the grain produced during the seven fat years and in all the land of Egypt there was bread during the seven lean years.
In terms of our analysis of the perfect market in time, this story represents a period of high production and low prices followed by a period of low production and high prices. With perfect knowledge of future production, and with a given storage cost relationship, these fat and lean years could be interrelated as indicated in Figure 11.10. Figure 11.11
TEMPORAL MARKET PRICE RELATIONSHIPS

shows the corresponding patterns of production, of storage operations, and of consumption. In this diagram the shaded area to the left represents the economical movement into storage during the fat years, and the equivalent area to the right represents the withdrawal from storage during the lean years. Consumption declines steadily throughout the period, even though the effects of the famine years are greatly moderated by the storage program. The pattern of consumption throughout the period would be more uniform, of course, if storage costs were lower or demands were more inelastic.

11.6 A SPATIAL AND SEASONAL ILLUSTRATION

This example is drawn from a study of temporal and spatial corn prices in three North Carolina market areas—the northeastern Coastal Plain, the central Coastal Plain, and the Piedmont. The perfect market concept was used as a bench mark for developing hypotheses that describe the expected behavior of prices in the selected North Carolina markets. Theoretical price limits were developed for each pricing point by adding transfer costs to prices in markets from which purchases were made and by subtracting transfer costs from prices in markets to which corn was shipped. Out-of-state shipping destinations selected for surplus Coastal Plain corn were Norfolk, Baltimore, and Harrisonburg. Cincinnati was used as a pricing point to represent corn coming into the state from the Midwest.

Theoretical price models were developed for each of the three areas selected for study. To compare reported corn prices with expected prices based on these models, it was necessary to develop a framework for looking at several markets simultaneously in different seasons of the crop year.

At a specified time, prices in two markets trading with each other may be expected to be equal except for transfer costs between the markets. Harvest period prices in a particular market will be equal to postharvest prices except for the addition of storage costs. Differences in form or grade are reflected in premiums and discounts from a standard grade. Thus, by using storage costs and transfer costs between a local market and a central market, price limits for the local market can be obtained for a specific grade of corn.

Although prices in a local area may be correlated with the ones in

This section draws on a study by Travis D. Phillips and Richard A. King, "A Spatial and Seasonal Analysis of Corn Prices in North Carolina," North Carolina State College, Agricultural Economics Information Series No. 95 (Raleigh, 1962).
central markets, the equilibrium price in a local market depends on the local supply and demand and the costs of bringing corn in or shipping it out. The procedure for deriving theoretical price limits over a season for a simplified two-market situation is illustrated in Figure 11.12. Price in a deficit area $aa'$ will approach the major supplying area's price plus transfer costs. The price paid for corn from a smaller nearby surplus area may be less than the delivered price from the major surplus producing area but not more because purchasers can obtain all their needs from the major supplying area at the going price represented by points on $aa'$.

Prices in a surplus area may go as low as the receiving area's price minus transfer costs $cc'$. Shippers in surplus areas, such as eastern North Carolina, may be able to obtain a higher price than this lower limit by shipping to a nearby deficit area. However, theoretical prices in the surplus area will not fall below this floor because all that is shipped could be sold at the going price represented by points on $cc'$.

The above model is highly oversimplified because an area may well be buying from or selling to several markets at a time. The slopes of $aa'$ and $cc'$ which represent storage charges should contain, in general, some curvature because of the high initial handling charges and possible economies from longer periods of storage. Also, although there has been little research that compares costs in different parts of the country, storage
costs in buying and selling markets may not be the same. Therefore, the two lines would not be parallel. Adjustment for spatial differences allows a direct comparison of the observed prices with the appropriate theoretical selling or buying limit.

The perfect-market idea of a uniform price after adjustments have been made for form, time, and space offers a convenient framework for the development of theoretical price limits to be used as bench marks for understanding observed price relationships. This does not imply that the existing marketing structure operates as a perfect market, or that it should so operate. To be consistent with the perfect market, observed prices may vary by amounts less than the extremes set by the theoretical price limits; price fluctuations that exceed the limits reflect changes in expectations or imply imperfection in the marketing system.

By integrating the theory of the behavior of prices in a single market with our knowledge of corn movements and marketing practices in North Carolina, we developed the hypothetical price relationships among markets. The relationships are shown graphically in Figure 11.13. The arrows indicate the major flows in each of two seasons. Market A represents a Coastal Plain market shipping to the Piedmont (market E) and to Virginia and the Baltimore areas (markets B and C). Market D represents the Cincinnati area, which supplies the deficit requirements.
during the postharvest period. Transfer costs $T_u$ represent the adjustment factors required to make prices among markets comparable.

The Coastal Plain furnishes roughly three-fourths of western North Carolina supplies during the harvest period and also ships large quantities to neighboring deficit areas to the north. In recent years, these shipments have gone to Norfolk and Harrisonburg in Virginia and to Baltimore and its vicinity. The remaining requirements for the Piedmont are met by imports from the Ohio-Indiana area. Although the quantity received during the harvest period is small, shipments from Cincinnati establish the upper limit to prices offered in the Piedmont for corn from the Coastal Plain. When large quantities of Coastal Plain corn are available, harvest-period prices in the Piedmont for corn from the Coastal Plain may be several cents per bushel lower than that from Cincinnati. During the postharvest period more than one-half of the corn fed in the Piedmont comes from the Midwest; therefore, prices in the Piedmont would theoretically be expected to follow closely the price of corn delivered from Cincinnati.

Much of the early corn produced in the northeastern Coastal Plain area is shipped out during the harvest period, so that later in the season small quantities are required from the Midwest. Under these conditions, postharvest prices in this part of the Coastal Plain should approach the ones for corn delivered from Cincinnati. The central Coastal Plain continues shipping small quantities of corn to the Piedmont throughout the year. These shipments to the Piedmont are too small to influence prices there; consequently, corn delivered from the Coastal Plain sells for roughly the same price as that delivered from Cincinnati. As surplus corn in the central area disappears, even though no in-shipments from Cincinnati occur, prices in the area approach the price of corn delivered from Cincinnati.

Although the perfect-market model implies a specific price at a particular time for a given market, a "price region" was used, indicated by the shaded areas of the models shown. Since prices in a market area would not be expected to change abruptly from the lower selling limit to the upper buying limit, the shaded area allows for gradual price adjustment as the type of marketing transaction changes.

**Northeastern Coastal Plain.** The northeastern Coastal Plain area is a surplus-producing, deficit-storage area with some corn brought back into the area during the postharvest period. The model for the northeastern area, shown in Figure 11.14a reflects the practice of pushing up the harvest date to take advantage of high prices still being paid in the Delmarva area for old-crop corn. The vertical distance $a_g$ reflects storage charges for corn produced the previous year and the prices paid in the
Delmarva area. The distance $ag$ represents the gains from early harvest. Of course, prices received for corn in the Delmarva area would not be expected to change abruptly from $fg$ to $ab$ but would follow a relatively smooth path. The horizontal distance between the line $ag$ and the price axis represents the length of time by which harvest in the northeastern area precedes harvest in major surplus areas that supply the Delmarva area.

The area $abcfg$ represents the possible price range during the harvest period when corn is being shipped from the area. The transitional period between harvest and the period when corn becomes deficit and the importing activities increase is illustrated by the triangular area $bcd$. Toward the end of the crop year when some corn is shipped in, price is represented by the line $de$. These limits differ for each production, utilization, and storage situation and also depend on factors such as the disappearance rates and the mobility of corn stored within the area. The possible range for point $d$ might be anywhere from point $c$ to point $e$.

**Central Coastal Plain.** Storage relations for the Central Coastal Plain area were difficult to quantify. Since no corn was found coming back into the area during the postharvest period, it was concluded that sufficient
farm and commercial storage capacity exists to satisfy local requirements. The fact that some corn continues to move out of the area in the post-harvest period indicates that storage capacity is, in fact, somewhat above this minimum level.

Theoretical limits for this area are presented in Figure 11.14b. Prices would be expected to lie along the lower limit $ab$ for much of the crop year. However, as shipments to the Piedmont decline, prices in the area would be expected to rise toward the ones that would prevail if corn were brought in from the Midwest. These prices are represented by $cd$. To the extent that this rise is anticipated, a gradual price increase represented by line $ac$ may be evident.

**Piedmont.** There appeared to be no need to investigate the case of deficit storage for local production in the Piedmont because practically all of the corn produced in the area is currently farm-stored and fed. Only about 1 percent of this corn, according to the survey, finds its way into marketing channels. The Piedmont is an area possessing more than adequate storage capacity for local production, but having far less production than that needed to meet feeding requirements.

As long as storage capacity does not exceed requirements, expected prices will lie along the upper price limit, since the only transactions with other areas will be purchases. Corn in the form of manufactured feed is shipped out of the area. However, the lower or selling limit has little meaning in this case, since corn alone is not shipped.

The price of corn in the Piedmont area theoretically would be expected to follow rather closely the upper import price line of Figure 11.14c. The price for corn shipped from the central Coastal Plain area to the Piedmont has an upper limit established by the midwestern shipped-in price. However, if the price for corn from the surplus Coastal Plain area is depressed during the harvest period because of a shortage of storage capacity, Piedmont paying price might drop to a somewhat lower level indicated by line $ab$. After this harvest glut, during which time surplus Coastal Plain corn is moved into storage or northward to export buyers or to broiler production areas, prices readjust to the upper limit along line $bc$.

These hypotheses of how market price relationships are expected to behave provide a basis for evaluating observed price relationships. Although reported prices generally conformed to the theoretical price limits, weekly prices often fluctuated widely. Movement of large quantities of corn from the Coastal Plain to the Piedmont during a relatively short period of time during harvest depressed Piedmont prices as compared to delivered prices from Cincinnati. The downward pressure on prices was positively correlated with the size of the Coastal Plain crop.
Several problems confronting individuals engaged in corn production and trade come to light as a result of these price analyses. First, wide weekly price fluctuations between prices paid producers and prices received by dealers arise during harvest in the Coastal Plain, apparently because dealers are buying on the basis of central market prices in areas to which they ship are influenced by local conditions. Changes over the harvest period in returns to dealers also may be associated with a shortage of drying facilities to condition high-moisture corn.

Second, although no data are available to determine the adequacy of present storage facilities, storage from harvest until the following summer in the Coastal Plain would have paid quite well in three of the five years studied. The price analyses indicate that forces outside the area cause seasonal prices to be quite unpredictable. Farmers and dealers may prefer a low harvest price to taking the risk of an unfavorable seasonal price pattern. The strong influence of central market prices in determining North Carolina seasonal price patterns independent of local conditions points up the need for a seasonal price predictor at the central market level.

Third, the question arises as to why Coastal Plain dealers and farmers do not spread their shipments to deficit markets over a few more weeks in order to prevent depressing harvest prices so far below the ones for corn from the Midwest. The analyses indicate that unless there is a shortage of storage facilities, this action would be worth several cents per bushel in years of large crops. However, Coastal Plain "losses" may be offset by Piedmont "gains" in terms of cheaper feed.

11.7 CONCLUDING OBSERVATIONS

Let us summarize in terms of several generalizations about markets in time. We have pointed out that the increase in prices through time will reflect the costs of storage, although the level of prices results from the interaction of available supplies with the aggregated demand functions. From this we can conclude that perfect markets will be interrelated through relatively short time periods if storage costs are relatively high, but through relatively long time periods if storage costs are low. In the limit, as storage costs approach zero, prices approach a single constant level, and the time span covered by a single market approaches infinity. This is equivalent, in markets in space, to the conclusion that product prices completely equalize and all regions become part of a single market if transport costs are zero. Second, the time span of markets will depend on the elasticity of demand—the time span increasing as demands
become more inelastic. This merely means that decreases in available supplies will generate relatively large increases in prices and, hence, will cover storage costs for longer time periods. In the limit, with elasticity approaching zero, consumption will approach a completely uniform pattern through time even though prices vary in accordance with storage costs. Finally, trade between time periods may result either from changes in available production or shifts in demand, since either will give rise to price differences and, thus, will provide the economic incentive for storage operations. The parallels with interregional trade should be clear.

SELECTED READINGS

Temporal Market Price Relationships
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