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## **THE STORAGE OF POTATOES AND THE MAINE POTATOES FUTURES MARKET**

Benjamin Sexauer

**Department of Agricultural and Applied  
Economics**

University of Minnesota  
Institute of Agriculture, Forestry, and Home Economics  
St. Paul, MN 55108

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## THE STORAGE OF POTATOES AND THE MAINE POTATOES FUTURES MARKET<sup>3</sup>

The relationship between the storage of potatoes and the carrying charges reflected on the futures market for Maine potatoes gives rise to a situation in which the observed facts do not seem to agree with the accepted theory. The theory regarding intertemporal price relationships based on the work of Brennan, Telser, and Working establishes that the difference between the current price and the expected price of a storable commodity must be equal to the marginal cost of storage minus the convenience yield. The relationship between the amount of a commodity held in storage and the equality of the marginal cost of storage with the temporal price spread gives rise to a supply of storage curve. As estimated by Brennan, Telser and Working, this supply of storage curve slopes upward to the right. More storage will be supplied at a high return per unit and less storage at a low return per unit stored.

The carrying charges reflected on the Maine Potatoes Futures Market seemingly contradict the theory of the price of storage in two respects. First, the spreads between futures, which establish a return to storage, sometimes appear to greatly exceed any typically plausible cost of storage. On March 1, 1976, the March future for Maine potatoes sold for \$8.35 per hundredweight, whereas the May future was selling for \$12.63 per cwt. The return to storing potatoes for two months was \$4.28 per cwt. Second, the relationship between the level of potato stocks and the carrying charge appears to be the opposite of that previously estimated for commodities with continuous inventories. For potatoes, the seasonal pattern associates large stocks with a narrow carrying charge and small

stocks with a wide carrying charge. The level of potato inventories and the spread on the futures market produce a relationship that slopes downward to the right.

### POTATO STORAGE

The fall potato crop accounts for over 75% of annual U.S. production and in recent years has been about 84% of the total. Fall crop potatoes are stored for consumption over a seven or eight month period. However, potatoes cannot be effectively stored for a whole year, since they are semi-perishable. Potatoes, therefore, give rise to a discontinuous inventory situation. The task of intertemporal allocation is more difficult for a discontinuous inventory commodity. Potato prices must be established during the storage season with the objective of exhausting the supply of potatoes in storage coincidentally with the availability of spring and early summer potatoes (Gray). Potato storage is conducted not by merchandising or storage specialists, but primarily by growers. The primary requirements of a potato storage facility are adequate insulation, ventilation, and heating and the means to enter and remove the tubers efficiently.

### THE SUPPLY OF STORAGE RELATIONSHIP

The basic supply of storage relationship is:  $(P_t^{t+1} - P_t) = f(S_t)$  where  $P_t$  = price in period t,  $P_t^{t+1}$  = in period t, the price expected to exist in period t+1, and  $S_t$  = the inventory of the commodity. The important characteristics of the conventional supply of storage curve are the wide, basically horizontal segment in the middle, the steep upward slope when storage capacity is reached, and the negative price of storage section, which can exist because of a convenience yield derived from inventory

holding (Working, p. 1259).

In a rigorous development of this theory, Brennan conceived of a demand for storage and a supply of storage curve, which achieve equilibrium when the net marginal cost of storage equals the expected change in price. With a futures market, the expected price change is the relevant spread. The supply of storage curve is identified in a statistical sense, because it remains basically stable; while the demand for storage curve shifts between seasons and within a season (Brennan, p. 57). The supply curves, which have been estimated for a number of commodities, closely approximate the shape of the idealized supply of storage function. However, these supply of storage functions were estimated for highly storable, continuous inventory commodities such as the major grains. Brennan did examine the storage relationship for cheese, butter, and shell eggs, but these products, although perishable, are continually, not seasonally produced.

In Figure 1, the level of Maine potato stocks has been plotted with the relevant monthly carrying charge or return to storage reflected on the Maine Potato Futures Market.<sup>1/</sup> The monthly spread is between the near future and the next future contract divided by the number of intervening months. In Figure 1, the March 1 stock figures are aligned with the March to April spread on the last trading day in February for crop years 1954 to 1974 (21 observations), and the November stock levels with the November to March spread on the last trading day in October for 1952 to 1974 (23 observations).<sup>2/</sup>

High stock levels in Figure 1 are associated with a low carrying charge and low stocks with a high carrying charge, the reverse of the nor-

mal price of storage relationship. Also, there is no inverse; the carrying charge is always positive, with one exception. The strong seasonal pattern is explained in the next section. Regression analysis of the data presented in Figure 1 using ordinary least-squares and an inverse functional form yields the following results.<sup>3/</sup>

$$(1) \quad (P_t^{t+1} - P_t)/h = -41.76 + 15458 (1/S_t) \quad R^2 = .36$$

$$(3.04) \quad (4.81)$$

Where  $(P_t^{t+1} - P_t)/h$  = the monthly carrying charge, the spread divided by the number of months ( $h$ ) until the delivery month, and  $S_t$  = stocks of Maine fall crop potatoes. When equation (1) is plotted on Figure 1, the problem is clearly revealed. The slope of equation (1) is negative, the opposite of the normal upward sloping supply of storage curve. In addition, the relationship between the monthly carrying charge and stocks is not a strong one. However, stocks is an important variable as reflected by the  $t$  statistic.

#### THE COSTS OF POTATO STORAGE

The explanation for this pattern can be found in the influence that the potato's biological characteristics and its storage situation have on the costs of storage. The price of storage for potatoes is not primarily a function of the level of stocks as Working's price of storage theory postulates. Potato storage is significantly more complex than storing grains. Potatoes are a tuber, a rather delicate living organism, which respire, loses weight, sprouts, and is subject to diseases and rotting. Because of the potato's perishability, the costs of storage are influenced by the length of the storage period, the price level, and the storage characteristics of the tubers.

Figure 2 quantifies as accurately as possible the costs of storing potatoes over the course of the storage season. The horizontal axis represents a temporal not a quantity measure. Figure 2 is based partially on cost estimates derived by Sparks. Although his studies apply to Russet Burbank potatoes in Idaho, the orders of magnitude, if not the exact values, should still be fairly applicable to the storage situation in Maine. The average fixed cost curve covers the investment costs of the storage facility including interest, taxes, insurance, and depreciation (Sparks, pp. 90-91).

The average basic costs curve includes the fixed costs, the costs of operation and maintenance, handling, and anti-sprout material, plus the costs associated with weight loss. Based on Sparks' figures and those from other studies, during a storage of six months, a weight loss of some 5.61 to 6.65% can be expected (Smith, p. 351 and Sparks and Summers, p. 14). In addition, the monthly rate of weight loss is highest at the beginning and toward the end of the storage season. The cost is obtained by multiplying the percentage losses by the value of the potatoes. A price of \$3.00 per cwt. was assumed for Figure 2. Even counting the cost of weight loss, average basic costs are a decreasing function of the length of the storage.

However, the tabulation of costs summarized in the average basic costs curve is incomplete. Potatoes undergo quality deterioration other than simple weight loss. The cost due to grade defects and quality change are also dependent on the price level and the length of storage. The average total cost curve adds the costs associated with quality change at a \$3.00 per cwt. price level to the average basic costs. This curve is drawn as a dashed line to indicate its hypothetical nature. Its measurement, though, is based on a careful appraisal of potato storage. This distinction



was made between a basic costs curve and a total costs curve due to the accuracy of the underlying cost estimates of the former and the less reliable inferences about some of the deterioration cost components of the latter.

The average total cost curve lies only slightly above the basic costs curve during the first part of the storage season, when losses to quality change are low. However, deterioration losses are not a simple linear function of the length of the storage. Toward the end of the storage season, quality change losses begin to increase sharply as the tubers break dormancy and the outside temperature begins to rise and fluctuate. The percentage of monthly shipments of Maine tablestock potatoes with no sprouting has averaged over 99 percent through January for crop years 1966-1973. The figure becomes 95 percent for February, 92 percent for March, 85 percent for April, 81 percent for May, and only 62 percent for June (Johnston and Pelsue, p.27). Because of the potato tuber's ultimate perishability, storage losses would reach 100 percent at some point in the summer. The average total cost curve in Figure 2 assumes that quality change losses would reach 100 percent sometime in July.

In addition, since potato storage is primarily by the grower, joint production considerations tend to increase the upward slope of the average total cost curve in the late spring. The potato producer-storer is engaged in two businesses, production and storage. Planting usually begins in Maine from May 10 to May 15. The bulk of the Maine potato production is by small growers who simply do not have the capacity to be planting and moving potatoes out of storage at the same time. Planting must be given priority. Those growers that do store into May will probably be the larger outfits. They will require two crews, one for planting and one for potato handling. Therefore, the costs may be higher.

If all the relevant factors are taken into account, monthly potato storage costs have a u-shaped pattern over the storage season as reflected in the average total cost curve in Figure 2. The average total storage cost curve would shift upward for high priced potatoes and downward for low priced potatoes. The curve would also be affected by the storability of the crop. Although there is no simple physical measurement of this factor, tubers at harvest do vary from year to year in how well they will store. Weather conditions in the fall such as excessive cold or moisture and certain diseases produce tubers which have poor storage properties. For example, a frost in 1975 and heavy rains in 1972 prior to harvest gave rise to unusually severe storage problems.

Finally, the returns to storage curve in Figure 2 describes the normal pattern of the carrying charge reflected on the futures market over the storage season. The return to storage has averaged 10.67 cents/month for the November-March period, 9.42 cents/month for January-March, and 32.81 cents/month for March-April for the years covered by this study. The carrying charge is normally somewhat lower on December 31 than on October 31 and rises sharply by February 28. The return to storage curve would, in fact, approximately coincide with the temporal marginal cost curve if it were drawn in Figure 2. As a general pattern, the carrying charges reflected on the futures market are equal to the cost of holding a unit of potatoes one more unit of time. However, the cost of storage and hence the return to storage are a function of the period in the storage season, the price level, and the storability of the crop which shift the cost curves. The spread observed on March 1, 1976 could, therefore, accurately reflect the marginal cost of storing potatoes, because of the very high price of \$8.35 per cwt.

and the low storability of the 1975 crop due to frost damage.

#### THE CARRYING CHARGE RELATIONSHIP FOR POTATOES

Previous analyses have assumed a stable supply of storage curve which was identified by the shifting demand for storage curve. However, for a seasonally produced, semi-perishable commodity, the supply function is also shifting significantly over time. The storage cost per unit of inventory and hence the supply of storage curve shift as a function of the price level, the length of storage, and the storability of the crop. The supply of storage function for potatoes is not statistically identifiable in the normal single equation approach, which Brennan, Telser and Working utilized. Therefore, the observed negative relationship between the carrying charge and the stock level should not be interpreted as a downward sloping supply of storage curve. A significant identification problem gives rise to the observed downward sloping carrying charge-stocks relationship for potatoes. The situation requires the simultaneous estimation of both the demand and supply schedule.

The demand for storage derives from the demand for consumption of the commodity. The change in price between the next period and the current period ( $P_{t+1} - P_t$ ) is determined by consumption in the two periods. Consumption in a period is equal to the stocks carried into the period plus production minus stocks carried out of the period. In the demand for storage schedule, the price difference ( $P_{t+1} - P_t$ ) was specified by Brennan as a function of current stocks ( $S_t$ ), stocks next period ( $S_{t+1}$ ), and last period ( $S_{t-1}$ ), current production ( $X_t$ ), and production next period ( $X_{t+1}$ ). (Brennan, pp. 51-52 and Telser, pp. 234-235) This

relationship is an ex post one, since  $P_{t+1}$ ,  $S_{t+1}$ , and  $X_{t+1}$  will not be known until next period. However, what is of interest is the perspective on the demand for storage in the current period. Therefore, this function should really be specified as an anticipated demand for storage with the difference between expected price and the current price ( $P_t^{t+1} - P_t$ ) a function of the above factors, except expected stocks ( $S_t^{t+1}$ ) replaces  $S_{t+1}$  and expected production ( $X_t^{t+1}$ ) replaces  $X_{t+1}$ . This demand curve should have a negative slope with respect to  $S_t$ .

Based on the storage characteristics of potatoes, the supply of storage function should be extended to include the price level, the length of the storage, and the storability of the crop as exogeneous variables. Observations on storability are not available, though. Estimation of the demand and supply schedule yielded the following results:

$$(2) \quad (P_t^{t+1} - P_t)/h = 15.17 - 18.94 S_t + 3.79 S_{t+1} + 15.92 S_{t-1} + 4.06 X_t \\ \quad \quad \quad \quad \quad \quad \quad (.30) \quad (5.56) \quad (5.47) \quad (5.34) \quad (5.57) \\ \quad \quad \quad \quad \quad \quad \quad -3.34 X_{t+1} \quad \quad \quad \quad R^2 = .68 \\ \quad \quad \quad \quad \quad \quad \quad (6.06)$$

$$(3) \quad (P_t^{t+1} - P_t)/h = -23.07 - .0033 S_t + .0168 P_t + 7.56 D_t \quad R^2 = .69 \\ \quad \quad \quad \quad \quad \quad \quad (.48) \quad (.26) \quad (6.79) \quad (.40)$$

The dependent variable and  $S_t$  are specified as in equation (1) and  $D_t$  is a seasonal dummy variable: zero for the November-March period and one for the March-April period;  $P_t$  is the price level of the near future;  $S_{t+1}$  is March 1 stocks for the November-March period and April 1 stocks for the March-April period;  $S_{t-1}$  is Maine fall production for the November-March period and February 1 stocks for the March-April period;  $X_t$  is winter crop production for the November-March period and early spring production for the March-April period, and  $X_{t+1}$  is early spring production for the November-March period and late spring produc-

tion for the March-April period.<sup>4/</sup> Both  $X_t$  and  $X_{t+1}$  apply to United States production. And  $S_{t+1}$  and  $X_{t+1}$  are substituted as proxies for  $S_t^{t+1}$  and  $X_t^{t+1}$ , since these expected levels are not observable.

Equation (2) and (3) were estimated by two-stage least squares to obtain consistent estimates of the coefficients, treating  $S_t$  as an endogenous variable. The functional form is linear. In equation (2), the demand for storage curve, the signs of the coefficients are as predicted by Brennan and 68% of the variation is explained. However, in equation (3), the supply curve, neither the coefficient on stocks or the seasonal dummy variable are statistically significant.

There are two primary explanations for the disappointing estimates of the supply of storage function.<sup>5/</sup> First is the necessary omission of storability as a variable. With storability omitted, the shifts in the supply curve are not accounted for adequately. Second, the supply function may not be statistically identified. Although the demand and supply schedules in their conceptual specification are both identified, the demand equation may not contain an adequate number of sufficiently exogenous variables to allow for the estimation of the supply function. In fact, variables considered exogenous in both equations such as  $S_{t+1}$ ,  $S_{t-1}$ , and  $P_t$  may actually be endogenous to a fuller conceptualization of the system, hence the demand function may also not be truly identified.

## CONCLUSIONS

For the commodities previously studied, the cost of storage was primarily a function of the inventory level and the observed carrying charge-stocks relationship was the supply of storage schedule. The demand function could not be statistically identified under those circum-

stances, though. For a discontinuous inventory, semi-perishable commodity like potatoes, the price level, the length of storage, and the storability of the crop influence the cost of storage. Since both the demand and supply schedule are shifting, the observed downward sloping carrying charge-stocks relationship identifies neither schedule. In this analysis, the demand for storage function for potatoes has been estimated, but the supply schedule could not. For potatoes, the shifts in the supply schedule are substantial enough to trace out the demand schedule. Further work is suggested in estimating more precisely and completely the costs of storage and the supply of storage function as part of a more complete system. In addition, a means of measuring and the collection of data on the storability factor are needed.

## FOOTNOTES

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1/ The stock reports of the USDA are defined as total stocks held by growers, local dealers, and processors and are equal to production minus disappearance. All the data sources are included among the references.

2/ The stock reports for the first of the month are not issued until several days later. By using the spread on the last trading day of the preceding month, the assumption is made that the market accurately predicts the stock report before its issuance. Since a stock report is not issued on November 1, this figure was computed based on the production figure, December 1 stocks, and the relation of total shipments through the end of October and through the end of November.

3/ The t statistics are given in parentheses.

4/ An April 1 stock figure is only available since 1972. April stocks were estimated by subtracting March shipments from the March 1 stocks minus a 10% correction factor. The 10% correction factor was determined on the basis of the three years for which April stock data are available.

5/ In addition, a multicollinearity problem exists in equation (3), since the correlation between  $S_t$  and  $D_t$ , the seasonal dummy, is  $-.93$ . The November-March and March-April period were, therefore, analyzed separately. However, this approach did not improve the estimates.

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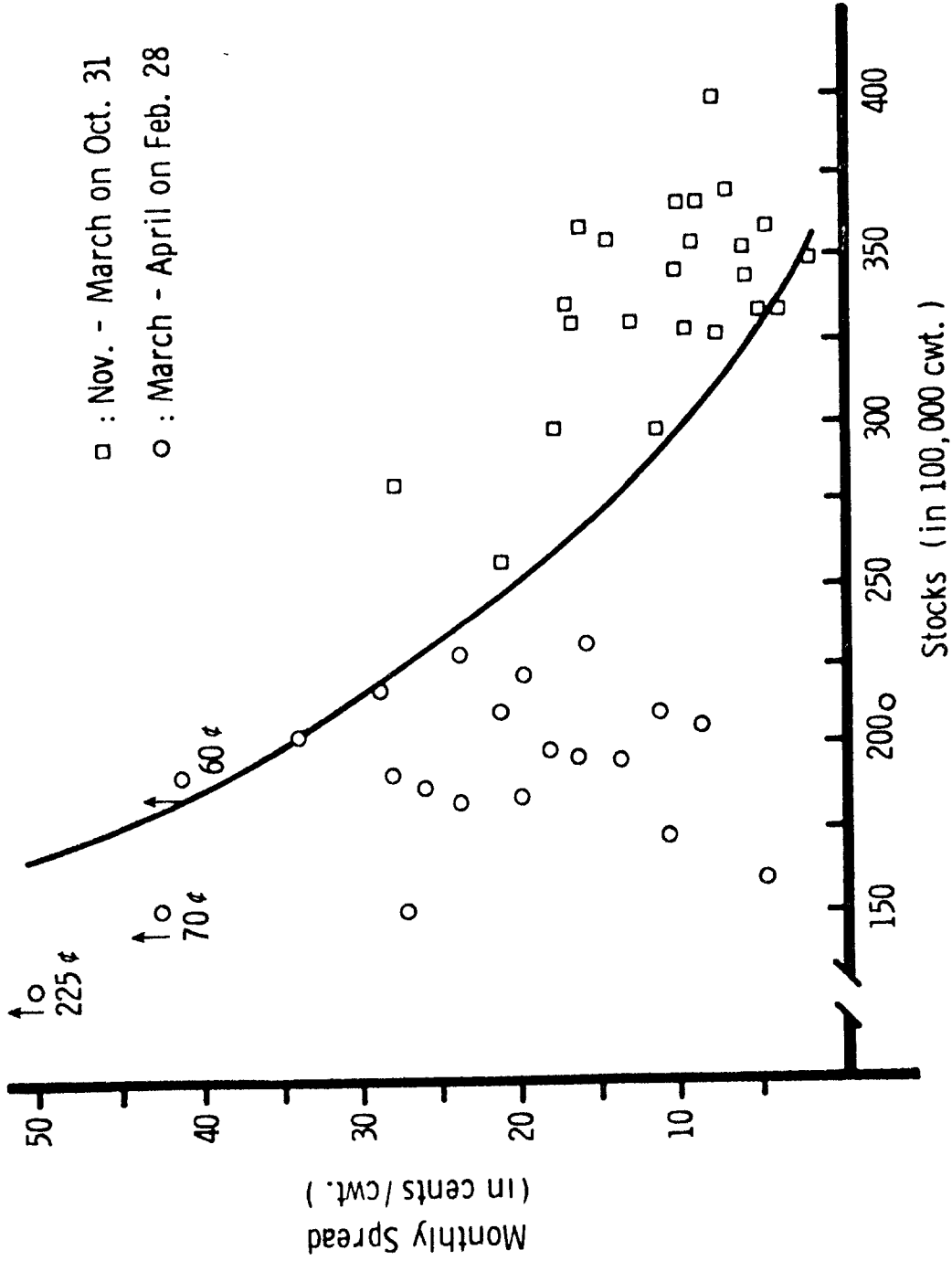


Figure 1. The Relationship Between the Spread on the Futures Market and the Level of Potato Stocks.

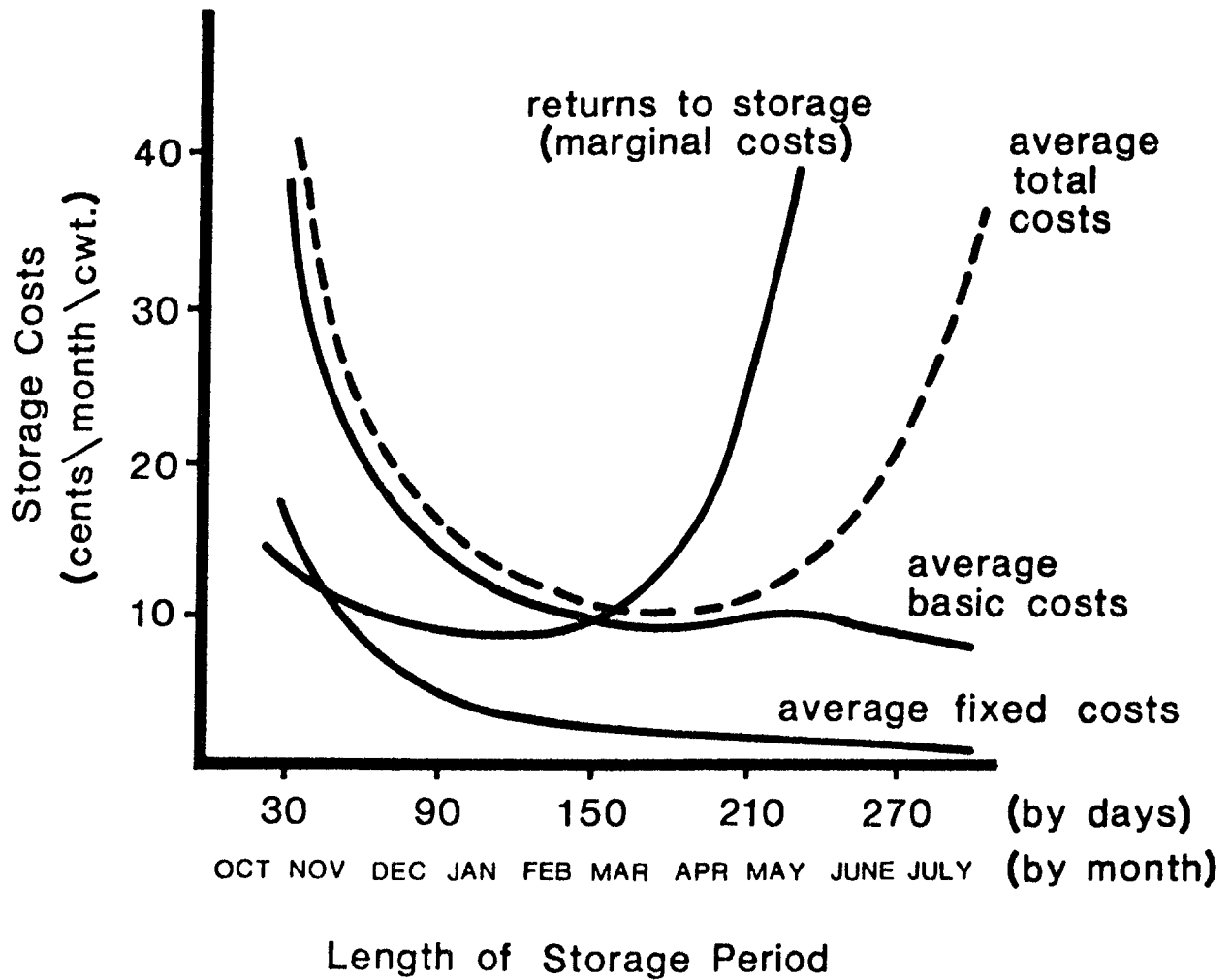


Figure 2. The Pattern of Storage Costs Over the Storage Season.