Seasonal Price Risk and the Cost of Storage:
Potato Markets in India and the United States

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Abstract

This paper develops and applies a decomposition of seasonal price spreads to potato markets in India and the United States. In India, the average "storage price margin" is three to four times that found in the United States. We use the decomposition to quantify the relative importance of interest rates, wastage, storage costs and risk premium in explaining the difference in seasonal margins. The paper discusses the implications of the findings for marketing institutions and government policy.

JEL classification: Q11, Q13

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1. Introduction

Understanding the determinants of marketing margins is a classic problem in agricultural marketing. Compared to the developed countries, agricultural markets in developing countries are characterized by high marketing margins. The literature suggests that high margins could be due to non-competitive market structures or the result of high transactions and marketing costs (Jones, 1972; Scott, 1981; Hayami and Kawagoe, 1993). Marketing costs may vary systematically between the developed and developing countries because of the lack of market infrastructure such as transportation and communication networks, wholesaling centers, storage facilities, market yards, and market information services. Developing countries also lack sophisticated pricing mechanisms such as forward, futures and options contracts. The lack of market infrastructure and the absence of a full set of contingent markets can matter to marketing costs as well as market structure. Analysis that can identify the causes of high marketing margins points the way to policy recommendations and public investments to improve marketing institutions.

Marketing margins in developing countries are often particularly high for horticultural crops, where seasonal production and rapid quality deterioration following harvest put a premium on well-functioning marketing institutions and infrastructure to regulate supply and facilitate storage. In many developing countries, rising incomes and changing tastes have significantly increased the year-round demand for horticultural crops, even to the extent that in India market stability of these once unimportant commodities has become a political concern.[1] In many developing countries, potatoes were a minor vegetable only 30 years ago but have since become a relatively low-cost vegetable accessible to most urban and rural consumers.

This paper is a comparative study of potato markets in India and the United States. In both countries, potato production is sharply seasonal. Storage needs are, therefore, roughly similar in both countries. Yet, in India, the average "storage price margin" or the difference in the price at harvest and the price when supplies must be met from stores, is three to four times that found in the United States. Our objective is to understand why storage margins in India are high relative to that of the United States. Besides the observable costs of storage (including wastage and interest), we pay attention to the cost of bearing risk. Compared to the U.S, price variability in India is high making potato storage a risky undertaking. On the other hand, the U.S. represents a mature market with well-developed marketing institutions that provide information and other marketing infrastructure to facilitate the allocation of seasonal supplies. By quantifying the components of potato storage costs, including the cost of risk-bearing, and contrasting the marketing institutions in these countries, we hope to identify policies that are likely to enjoy high social returns by improving overall market efficiency and reducing supply and price uncertainty.

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[1] During 1998, for example, onion and potato prices exhibited marked instability which contributed to ruling party losses in some state elections held that year (*The Economist,* "Knowing your Onions in India", 7, November 1998).

2. A Model of Seasonal Potato Storage With Price Risk

Potatoes differ from grains in that they cannot be stored from one year to the next, but also differ from many other horticultural crops in that when stored under climate-controlled conditions they can be kept for up to nine months without losing quality (Rastovski and van Es, 1981). In this section we develop a two period model of crop marketing in which production takes place in period 1, with no carry over stock from the previous year. Consumption in period 2 must be supplied through storage from period 1, and all stocks must be liquidated by the end of period 2.[2] The storage in period 1 could be undertaken by producers, processors or traders. For this reason, we refer to the agents that make the storage decisions as simply market agents.

Consider now a market agent's decision problem. A market agent buys the commodity in period 1, and after storage, sells it in period 2.[3] At the time of storage in period 1, the period 1 or harvest price is known with certainty and is denoted by p_1. But, seen from period 1, the period 2 price is a random variable $\tilde{p}_2$ where $E(\tilde{p}_2) = p_2$. The market agent's problem is to decide on the optimal amount of period 1 storage denoted by q_s. We assume that for every unit of output carried over to period 2, a fraction λ is lost due to transpiration, pests and rotting. Period 2 sales are therefore $(1-\lambda)q_s$. Let the function $c(q_s)$ denote the direct costs of storage due to capital, labor and materials.

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2 We ignore production decisions and take the harvested quantity as given in order to focus on the marketing problem. See Fuglie (1995) for an analysis of the joint potato production and storage problem.

3 It might be objected that such an arbitrage transaction does not describe the activities of either the producer or the processor. However, as will be shown later, a producer's act of storage is equivalent to the outcome of two actions: sell all output at harvest price plus the arbitrage transaction. Similarly, a

We assume $c'(q_s) > 0$ and $c''(q_s) \geq 0$. If r denotes the interest rate, the market agent's gain from storage is $(1+r)^{-1}(1-\lambda)\tilde{p}_2 q_s - p_1 q_s - c(q_s)$.

The market agent is risk-averse and maximizes an increasing and strictly concave utility function U. If Y_0 denotes the agent's income from activities other than storage, the market agent's problem is to choose q_s to maximize $EU(Y)$ where Y is

$$(1) \qquad Y = (1+r)^{-1}(1-\lambda)\tilde{p}_2 q_s - p_1 q_s - c(q_s) + Y_0$$

The incomes included in Y_0 will vary according to whether the market agent is a producer, processor or specialist trader. For instance, consider a producer of potatoes alone. This agent's problem is to allocate the harvest quantity q between period 1 sales q_1 and period 1 storage q_s. The producer's income is therefore

$$Y = p_1 q_1 + (1+r)^{-1}(1-\lambda)\tilde{p}_2 q_s - c(q_s)$$

But since $q = q_1 + q_2$, the above can be written as

$$(2) \qquad Y = (1+r)^{-1}(1-\lambda)\tilde{p}_2 q_s - p_1 q_s - c(q_s) + p_1 q$$

which is equivalent to (1) when we let $Y_0 = p_1 q$. Similarly, (1) also describes a potato processor's operation that needs potatoes for its processing operation in period 2. To see this, suppose the processor requires to process q units of potatoes. Let $F(q)$ be the value of the resulting output. The processor's problem is to decide how much of the raw material is to be sourced from the two periods. If the processor buys q_s units in the first

processor's action is equivalent to the arbitrage transaction plus the purchase of required quantity at period 2 spot price.

period then period 2 purchases are $(q - (1\text{-}\lambda)q_s)$. Hence the processor's profits are

$Y = (1+r)^{-1}F(q) - p_1 q_s - (1+r)^{-1}\tilde{p}_2(q-(1-\lambda)q_s) - c(q_s)$ which can be rewritten as

$$(3) \qquad Y = (1+r)^{-1}(1-\lambda)\tilde{p}_2\, q_s - p_1 q_s - c(q_s) + (1+r)^{-1}(F(Q) - \tilde{p}_2\, q)$$

which is equivalent to (1) if we let $Y_0 = (1+r)^{-1}(F(Q) - \tilde{p}_2\, q)$.

Thus, we see that (1) is general enough to cover the activities of producers, processors and of course, specialist traders. Notice that the generality of (1) extends beyond the examples described above. In particular, (1) also describes the storage problem of market agents who deal in potatoes as well as other commodities. The gains from transacting in other commodities (whether by storage, production or processing) can be merged into Y_0.

For a market agent, optimal storage satisfies the following condition[4]:

$$(4) \qquad E\left[U'(Y)(\delta\,\tilde{p}_2 - p_1 - c'(q_s))\right] = 0$$

where δ denotes $(1+r)^{-1}(1-\lambda)$. From (4) we obtain

$$(5) \qquad \delta p_2 - p_1 = c'(q_s) - Cov(U'(Y), \delta\tilde{p}_2)/EU'(Y)$$

where *Cov* is the covariance operator. If (5) holds, then the market agent is indifferent between selling all, some, or none of his stock in either period. The left hand side of (5) is the expected gain from arbitrage after accounting for wastage and discounting. The right hand side is the cost of storing a unit of output. The first term is the direct marginal

[4] As period 2 supplies are entirely from storage, the optimal storage will necessarily be positive.

cost while the second term is the cost of risk bearing and can be called the marginal risk premium (*mrp*).

If ρ is the risk premium that a market agent is willing to pay to avoid all risk, then the marginal risk premium is the increment in risk premium due to a marginal unit of storage. To see this, note that ρ satisfies $EU(Y) = U(E(Y) - \rho)$. Maximizing expected utility is equivalent to maximizing the certainty equivalent. The first order condition to the latter problem is

$$\partial E(Y) / \partial q_s - \partial \rho / \partial q_s = 0 .$$

Upon substitution into (1), this becomes $\delta p_2 - p_1 - c'(q_s) - \partial \rho / \partial q_s = 0$. Comparing this with (5), it is clear that $-Cov(U'(Y), \delta \tilde{p}_2) / EU'(Y)) = \partial \rho / \partial q_s$. If a market agent is risk neutral, marginal utility does not vary with income and the marginal risk premium is zero. However, for a risk-averse market agent, marginal utility is decreasing in $\tilde{p}_2$ and therefore the marginal risk premium is positive.

Using (5), the expected price margin between the two periods can be written as

$$p_2 - p_1 = p_2(1 - \delta) + c'(q_s) + mrp$$

where $mrp = -Cov(U'(Y), \delta \tilde{p}_2) / EU'(Y))$. Substituting for δ and dividing by second period price, we obtain a decomposition of the storage price margin (in percentage terms) into the various cost components.

(6) $$\frac{(p_2 - p_1)}{p_2} = (r/(1+r)) + (\lambda/(1+r)) + (c'(q_s)/p_2) + (mrp/p_2)$$

The right-hand side of (6) is the sum of the four components of cost due to the storage of a marginal unit. The first term is due to interest income foregone by delaying sales till the second period. The second term is due to storage losses. The third term is the direct marginal costs and the fourth term is the compensation for undertaking the risky enterprise of storing an additional unit.

It is useful to write (6) in terms of a seasonal price index. Define the seasonal price index p as the ratio (p_1/p_2). Then (6) can be written as

$$(7) \qquad 1 - p = (r/(1+r)) + (\lambda/(1+r)) + \omega + \tau$$

where ω is the proportion of period 2 expected price that is accounted by (marginal) storage costs $(c'(q_s)/p_2)$ and τ is the proportion of period 2 expected price accounted by the marginal risk premium (mrp/p_2). (7) is interpreted as follows. Imagine that in each year, the price in period 2 is normalized to unity. Then the left-hand side of (7) is the price margin between the two periods as a fraction of period 2 price. In equilibrium, this is equal to the costs of carrying stocks, the components of which are displayed by the right-hand side of (7). Equation (7), therefore provides a decomposition of seasonal price spreads for an individual market agent. However, individual market agents might differ with respect to storage technologies and risk aversion. Averaging across all variables over the population of market agents, we obtain a decomposition valid for average estimates of storage costs and risk aversion. This is given by

$$(8) \qquad 1 - p = (r/(1+r)) + (\overline{\lambda}/(1+r)) + \overline{\omega} + \overline{\tau}$$

where $\bar{\lambda}$ is the average loss in storage, $\bar{\omega}$ is the average of storage marginal costs (as a proportion of period 2 price), and $\bar{\tau}$ is the market average of individual marginal risk premiums (as a proportion of period 2 price) and can therefore be called the market risk premium.[5] (8) can be used to provide an empirical decomposition of the storage margin into its respective components. By providing estimates of the relative contribution of the different cost elements, such a decomposition can provide insights into the prospects and potential of investments in improved marketing institutions by the public and private sectors. Below we apply this decomposition to seasonal price trends in potato markets in India and the U.S. But first we provide more detail on marketing and price behavior in the two potato markets.

3. Potato Markets in India and the U.S.

Potato markets in both India and the U.S. are characterized by sharply seasonal production and year-round demand. In the U.S., about 90 percent of potatoes are harvested during the fall season between September and November. In India, about 85 percent of production occurs during the *Rabi* (winter) season which is harvested during January-March. International trade in potatoes is limited due to its bulkiness and perishability.[6] In both countries, cold storage is the principal means of keeping potatoes for year-round supply.

Marketing institutions to regulate seasonal supplies are much more advanced in the U.S. compared with India. A futures market introduced for Maine table potatoes

[5] We assume all agents face the same prices and interest rates.

during the 1950s-1970s was instrumental in reducing seasonal price risk but was only partially effective at eliminating cob-web type annual cycles (Gray, 1983). In recent decades, the growth of forward contracting between U.S. producers and processors has served to reduce price risk, and a potato futures market was reintroduced in 1997 after several years' absence. In addition, the USDA publishes monthly reports on acreage planted, production, and remaining stocks during the growing, harvest, and storage seasons, respectively, and weekly reports on shipments and arrivals in major markets (Lucier et al., 1991).

In India, the principal potato marketing institutions are wholesale markets in major urban areas where traders meet to establish spot prices. While wholesale spot price information in the various markets is widely available, there is little or no means of coordinating market expectations of future seasonal price movements. Estimates of aggregate production or remaining supply in storage, which would help marketing agents establish their own expectations, are not available in a timely fashion. As a result, expectations and hence seasonal price may fluctuate greatly.[7]

To encourage potato storage, the principal policy instruments in India have been to provide loans to expand cold storage facilities and regulate the rates and practices of cold storage operators (Fuglie et al., 2000). However, Indian trading firms in general face significant difficulties in managing marketing and storage risk. Such firms are usually family partnerships that rely almost entirely on internal funds. Access to bank finance is limited and the terms of such credit are regulated by the central bank (Reserve Bank of

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[6] International trade in potatoes is mostly in the form of certified seed or to potato processed products.

India) to influence the cost of stockholding. Fear of inflation often leads the central bank to raise the interest rates on credit against stocks. Further, some policies provide a disincentive to sustained involvement of agents in commodity storage and trade. The most important of these is the Essential Commodities Act, which empowers State governments to impose stock limits on traders. Local governments anxious to keep down prices in their areas sometimes hinder internal movement of commodities. External trade is regulated by the Central government and depending on the concerns of authorities, trade is either strictly controlled or freely allowed.[8] For all of these reasons, commodity trade in India has not been attractive to corporate firms that have access to capital markets and that are equipped with modern risk management techniques.

Comparing these market environments, we may expect price instability to be relatively large in India and therefore market risk a more significant component of marketing and storage costs. Under competitive market conditions, we would expect that annual supply shocks would affect prices at harvest while seasonal price trends would reflect the costs of storage. As Working (1949), and later Gray (1983), showed, in a well-informed competitive market the seasonal price pattern between harvests reflects the carrying cost of stocks. Annual supply shocks should affect current and near-future prices about equally.   Thus, seasonal price trends should be largely independent of annual price shocks except to the extent that prices at harvest affect the opportunity cost

[7] See Ramaswami (2000) for such evidence about the wheat market in India
[8] Kotwal and Ramaswami (1998) review the impact of regulations on domestic and external trade in agricultural commodities.

of storage. Variation around the seasonal trend would be due mainly to unexpected changes in the distribution of production during the year or seasonal demand shocks.

To assess potato marketing risk, we begin by analyzing the variance of potato prices using urban price series from each country. For the U.S., we use monthly wholesale price data from Chicago and New York for the period 1974-1992. For India, we use monthly price data from the wholesale markets of New Delhi and Calcutta during 1974-1992. These markets are relatively close to the consumer end of the marketing chain and most transactions take place between traders, wholesalers and retailers.

Consider a model where the price is linearly related to annual and seasonal shocks. Let

$$y_{it} = \mu + a_i + b_t + \varepsilon_{it} \quad (9)$$

where y_{it} is the price of potatoes in month i of year t, a_i is a seasonal factor, and b_t is an annual factor. By analysis of variance, we can compute the increment to the explained sum of squares due to seasonal factors and that due to annual shocks. If, as might be expected, the seasonal factors and annual shocks are independent and have negligible correlations in the sample, then the sum of the explained sum of squares due to seasonal shocks alone and that due to annual shocks alone would be approximately equal to the explained sum of squares of the model in (9). If so, we could interpret the ratio of the explained sum of squares (due to a particular shock) to the total sum of squares as the contribution of that shock to total variation.

Table 1 displays the results of the exercise. The analysis of price variance reveals sharp differences in the nature of price risk for table potatoes for fresh use between the two countries. Potato prices exhibit greater overall variability in India compared with the United States, with the coefficient of variation equal to 42 percent for the Calcutta market, 52 percent for Delhi, compared with 34 percent for Chicago and New York. In each country, annual shocks represent the major source of price variation. But seasonal price variation is higher in India compared with the U.S. In India, the average seasonal price trend accounted from 18 to 25 percent of price variation, compared with 6-7 percent in the U.S. While annual supply shocks remain an important source of price variability in each country, U.S. potato marketing institutions appear to have achieved significantly lower seasonal price variability. For deflated potato prices, Table 2 reports a decomposition of price variability.   As one might expect, the importance of annual shocks diminishes considerably and the relative importance of seasonal shocks rises. However, it still remains that seasonal shocks contribute more to price variability in India than in the U.S.

4. Estimates of Producer Price Spreads and Storage Costs

We now use the theoretical model derived above to estimate the contribution of marketing risk and other factors to the cost of carrying potato stocks. To obtain these estimates, we focus on potato storage in Meerut District, Uttar Pradesh, in the Ganges River Valley of northern India, and the Red River Valley along the Minnesota-North Dakota border in the U.S. Each area represents an important potato-growing region in their country. Meerut is a major supplier of table potatoes to towns and cities in northern

India, including Delhi. The Red River Valley supplies potatoes for table use and the chipping industry throughout the Mid West.

Table 3 shows the average seasonal price trend and variation around trend for these two regions using monthly producer prices from 1981-90. To derive the average trend in seasonal prices, we first normalize monthly prices each year by the price at harvest for that year. This removes the impact of annual shocks from the monthly price series so that the resulting index only shows the relative change in prices over a storage season. The mean seasonal price trend over the 10-year period is an indication of the expected compensation for incurring storage costs. On average, prices during the storage season rose by 42% above harvest prices in the United States. In India, the average seasonal price increase was much large, 113% higher than harvest prices. The coefficient of variation (σ_p) provides a measure of the price risk faced by a market agent who is considering storing potatoes versus selling at a known price at harvest. In both regions, price variation around the seasonal trend rose steadily during the storage season. During the final month of the storage period σ_p was 37 percent in Meerut and 18 percent in Minnesota. Uncertainty in seasonal prices was nearly twice as high in India compared with the U.S.

We now examine producer storage costs in each region. Corresponding to the theoretical model, we divide the potato season into two periods: period 1 is defined as the main harvesting month and period 2 is the final month of the storage season.

The components of storage costs other than the risk premium in Meerut are from a 1990 farm survey by Dahiya et al. (1994). At that time, cold storage rental rates were subject to government controls, although actual charges paid by farmers were sometimes higher. Cold storage rates in neighboring states which were not subject to price controls were about 25 percent higher which probably more accurately reflected the opportunity cost of cold storage.[9] At the government-mandated rate, the marginal costs of cold storage in Meerut were estimated to be 301 Rupees per metric ton (Rs/MT) during 1989-91. Assuming the market opportunity cost of cold storage space was 25 percent higher than the fixed rate, the marginal direct costs of cold storage are estimated to be 376 Rs/MT. The actual average cold storage cost faced by farmers in Meerut District during this period probably lies somewhere in between these two estimates. Dahiya et al. reported quantity losses of 4.5 percent on average after 7 months of storage. While interest rates may vary widely in India due to capital market segmentation, informal credit markets typically charge around 2 percent per month for short-term loans (Fuglie et al., 2000), which we assume reflects the opportunity cost of capital in stores for a representative market agent.

Storage costs for the Red River Valley are based on a survey of on-farm storage in 1985 by Benson and Preston (1986). Variable costs of labor, materials, handling, insurance, and other charges were estimated to be $12.32/MT for up to 7 months of storage, and fixed costs at $13.64/MT per year, for a total direct cost of storage of $25.96/MT. Storage losses are reported to average 2.8 percent after 7 months of storage

[9] In fact, at the government controlled rental rate for cold storage, cold storage was barely profitable for cold storage owners even if used at full capacity (Dahiya et al., 1994). By 1997, more than 200 of 918 cold stores in Uttar Pradesh were inoperative due to lack of maintenance or financial insolvency (A. P. Bhatnagar, personal communication, 1997), a situation that contributed to the lifting of price controls the following year. When price controls were finally lifted in 1998, cold storage rates subsequently rose by about 25%, to levels similar to neighboring states (V.S. Khatana, personal communication, 1999).

(Sparks and Summers, 1974) and we assume a 9 percent annual nominal interest rate for the opportunity cost of holding potato stocks.

5. Explaining Marketing Margins

Table 4 displays the storage price margin and storage costs for the two producing regions. The period-2 prices are roughly similar in dollar terms ($126/MT in the U.S. and $118/MT in India using an average exchange rate for the 10-year period). In India, period 1 price is on average 53% lower than period 2 price. In the U.S., the difference is of the order of 29%. Given the estimates of average price spreads, storage costs, wastage and interest rates, the market risk premium is estimated from (8). In India, the market risk premium constitutes 17 percent of the end-of-storage price (p_2) of potatoes and around 30 percent of total storage costs, using the government controlled rental rates that prevailed at the time. In the U.S., the market risk premium is negligible and the storage costs are fully accounted by direct costs, interest and wastage.

The largest component of storage cost in India and the U.S. are the marginal cost of space, labor, and materials. Despite much lower labor costs, marginal direct costs for cold storage in India are similar to those in the U.S. Cold storage rental charges account for 20-26 percent of the final price of potatoes in India and 21 percent in the U.S. One reason may be higher energy costs in India, where ambient temperatures are higher during much of the storage period. Another reason may be storage management. Many cold stores in India, for example, store potatoes for table consumption at the same temperature as seed potatoes, even though ware potatoes can be stored at higher temperatures without losing quality (Fuglie et al., 2000).

To account for the relative importance of the directly observed costs and the market risk premium in explaining seasonal price movements, let the variables relating to India be superscripted by I and the variables relating to the U.S., be superscripted by A. Then, using (8), the differences in the cost structure of storage between the two countries can be written as

$$
\begin{aligned}
(1 - p^I) - (1 - p^A) = {} & [(r^I/(1+r^I)) - (r^A/(1+r^A))] \\
& + [(\bar{\lambda}^I/(1+r^I)) - (\bar{\lambda}^A/(1+r^A))] \\
& + (\bar{\omega}^I - \bar{\omega}^A) + (\bar{\tau}^I - \bar{\tau}^A)
\end{aligned} \tag{10}
$$

The left hand side of (10) simplifies to $(p^A - p^I)$. Since the seasonal price index is the ratio of period 1 price to period 2 price, (10) is equivalent to

$$
\begin{aligned}
\left(\frac{p_1}{p_2}\right)^A - \left(\frac{p_1}{p_2}\right)^I = {} & [(r^I/(1+r^I)) - (r^A/(1+r^A))] \\
& + [(\bar{\lambda}^I/(1+r^I)) - (\bar{\lambda}^A/(1+r^A))] \\
& + (\bar{\omega}^I - \bar{\omega}^A) + (\bar{\tau}^I - \bar{\tau}^A)
\end{aligned} \tag{11}
$$

Note that the ratio (p_1/p_2) is bounded by 1. Higher is this ratio, lower is the seasonal price margin. Table 5 uses (11) and the data in Table 4 to decompose the differences in the seasonal price structure between the two countries into differences in the constituent elements. The first two columns consider the case where the storage rental rates in India are subject to government controls. The next two columns consider the case where the storage rental rates in India are according to the market rates.

Seasonal margins in the U.S. are much lower than in India. As a result, relative to period 2 price, the period 1 price is higher in the U.S. Difference in the cost of risk bearing is the major reason for the difference in seasonal price ratios, accounting for 46% to 71% depending on whether rental charges in India are according to market or government regulations. Difference in interest costs is the second most important factor accounting for 29% of the difference in seasonal price ratio. Difference in storage losses is unimportant. Difference in direct costs is either unimportant (-4%) or account for 21% of the difference in seasonal price ratios depending on whether storage rates are government controlled or not. Even though direct costs are the largest component of price margins in either country, they are not the most important factor for explaining the difference in seasonal margins.

6. Conclusions

This paper compared the seasonal allocation of potatoes between India and the United States. We observe significant differences in the institutions and performance in the two potato marketing and storage systems. Average marketing margins and price volatility around seasonal trend are much higher in India than in the U.S. Our decomposition analysis showed that higher marketing margins in India cannot be adequately explained by the observed components of storage cost such as interest on stocks, compensation for losses, and costs for labor and materials. Rather, a higher market risk premium to compensate for price volatility appears to be the main factor driving higher potato marketing margins in India. On average, the premium for bearing price risk in the Indian potato market accounted for about 30 percent of the total storage costs while it was negligible in the U.S. market. Why is this so? One reason is that price variability around seasonal trend in India is about twice as high as that in United States. It is also likely that a representative market agent in India, with relatively low income, may be more averse to risk. As a result, the difference in the market risk premium was the single most important factor for explaining the differences in seasonal spreads between the two countries.

In this paper, market risk premiums were estimated as a residual from the application of (8) to data on seasonal price spreads, interest rates, wastage factors and storage costs. The application of the competitive model could be criticised because monopoly distortions might be a reason for the higher seasonal spreads. However, while monopoly power explains high seasonal margins, it does not account for high volatility. Indeed, monopolistic markets should be associated with lower volatility because they avoid the fluctuations due to forecasting errors stemming from coordination failures among of millions of atomistic agents. High volatility need not be due to forecasting errors alone. Miranda and Glauber (1993) have shown that potato demand tends to become more inelastic towards the end of marketing season because of dwindling stocks. As a result, the impact of demand shocks is magnified in price variability. It is not clear, however, why demand shocks should be more important in India rather than in the U.S. But if it is so, that is another reason why carrying stocks is risky.

The importance of risk costs in the Indian case is reflective of the limited ability of Indian trading firms to bear market risks. Trading firms are generally family partnerships relying almost entirely on internal funds as access to bank finance is tightly regulated. Further, the policy environment does not encourage sustained involvement of agents in storage since State governments may impose stock limits on traders and place restrictions on internal and external trade.

The Indian potato market also lacks effective market mechanisms to guide the allocation of supplies throughout the year, such as timely production estimates, stock reports, and price discovery mechanisms. In the U.S., on the other hand, marketing institutions have resulted in relatively low seasonal price variability. As discussed earlier, such institutions include forward contracting, futures trading and dissemination of market information by government agencies.

These results point to areas where public and private efforts to improve market performance may be most fruitful. In situations where marketing and pricing institutions are weak and price risk is high, public investment in market information services and other marketing infrastructure could significantly improve allocative efficiency and price stability. Such investments could therefore enjoy high social returns. A centralized collection and provision of such marketing services exploits the public-good nature of information. This approach has considerable advantages over more direct interventions in supply and price management, such as buffer stock schemes. Direct interventions are particularly difficult for semi-perishable commodities such as potatoes, which cannot be stored between years. In addition, such schemes often suffer from trying to meet both price stability and income support objectives, and economic distortions can build up over time (Newbery and Stiglitz, 1981). Public policy in India also needs to review the extensive controls on storage and trading activity. These have severely constrained the capacity of firms to manage and diversify risks in commodity markets.

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Table 1. Analysis of variance of monthly potato prices in urban markets

	Calcutta	Delhi	New York	Chicago
Number of observations	225	212	211	207
Average price	1,401	1,201	505	450
Standard deviation of price	589	621	171	154
Coefficient of variation of price	42%	52%	34%	34%
Sources of price variation				
Seasonal	25%	18%	6%	7%
Annual	60%	71%	59%	70%
Seasonal + Annual	84%	85%	71%	81%
Unexplained	16%	15%	29%	19%

Indian and U.S. price series are from January 1974 through December 1992. Some markets have fewer observations due to missing observations. Indian prices in Rupees/MT. U.S. prices in $/MT. Indian price data are from the National Horticultural Board and U.S. price data are from the Economic Research Service.

Table 2. Analysis of variance of deflated monthly potato prices in urban markets

	Calcutta	Delhi	New York	Chicago
Number of observations	225	212	211	207
Average price	1,268	1,089	529	472
Standard deviation of price	407	377	128	115
Coefficient of variation of price	32%	35%	24%	24%
Sources of price variation				
Seasonal	34%	32%	13%	12%
Annual	42%	47%	36%	53%
Seasonal + Annual	76%	81%	49%	65%
Unexplained	24%	19%	51%	35%

Indian and U.S. price series are from January 1974 through December 1992. Some markets have fewer observations due to missing observations. For the Indian data, the deflator is the monthly index of all commodity prices (wholesale). For U.S. data, the deflator is a monthly producer price index. Indian prices in Rupees/MT. U.S. prices in $/MT. Indian price data are from the National Horticultural Board and U.S. price data are from the Economic Research Service. U.S. producer price index is from the Bureau of Labor Statistics.

Table 3. Trend and variation of producer prices during potato storage season

Location		Harvest	Month following harvest of the potato crop 1	2	3	4	5	6
Meerut	Seasonal price trend (mean of P_t/P_h)	1.00	1.33	1.71	2.01	2.21	2.14	2.13
	Coefficient of variation (σ_p)	--	9%	17%	32%	26%	33%	37%
Minnesota	Seasonal price trend (mean of P_t/P_h)	1.00	1.20	1.17	1.21	1.32	1.40	1.42
	Coefficient of variation (σ_p)	--	7%	7%	13%	12%	17%	18%

The seasonal price trend for month t is the mean of P_t/P_h where P_h is the price at harvest and P_t is the price in subsequent months when supplies are drawn from storage. σ_p gives the coefficient of variation of the price trend around its mean.

Data are monthly farm-level prices from January, 1981 to December, 1990 for each market. Indian prices are from the National Horticultural Board and U.S. prices are from the National Agricultural Statistical Service.

Table 4. Potato storage price margins and storage costs in India and the U.S.

	India		USA
	Meerut, Uttar Pradesh		Red River Valley, Minnesota
Prices and margins[a]	Uttar Pradesh		Minnesota
Average price at harvest (P_1)	688 Rs/MT		89 $/MT
Average price at end of storage (P_2)	1,472 Rs/MT		126 $/MT
Storage price margin (1 – P) ($P = P_1 / P_2$)	0.53		0.29
Storage cost components	Controlled rental rate	Market rental rate	
Interest on stock [$r / (1+r)$]	0.12	0.12	0.05
Average storage losses [$\bar{\lambda} / (1+r)$]	0.04	0.04	0.03
(Average) marginal direct costs ($\bar{\omega}$)	0.20	0.26	0.21
Market risk premium ($\bar{\tau}$)	0.17	0.11	0.00
Total costs	0.53	0.53	0.29
Storage cost assumptions	Controlled rental rate	Market rental rate	
Storage period (months)	7	7	7
Annual interest rate	24.0%	24.0%	9.0%
Interest rate for storage period [r]	14.0%	14.0%	5.3%
Storage losses over storage period [λ]	4.5%	4.5%	2.8%
Marginal direct storage costs [$c'(q_s)$]	301 Rs/MT	376 Rs/MT	26 $/MT

[a] The harvest price is the average price received by growers during the two main harvesting months in 1981-1990. The storage price reflects the average markup from the harvest price during the final two months of the 7-month storage period, based on the 10-year average of a seasonal price index normalized on the harvest price for each year.

Table 5: Decomposition of season price structure in India and the U.S.

	Case I: Controlled Rental Rate	As proportion of the difference in seasonal price index	Case II: Market Rental Rate	As proportion of the difference in seasonal price index
Difference in seasonal price index $\left(\frac{p_1}{p_2}\right)^A - \left(\frac{p_1}{p_2}\right)^B$	.24	100%	.24	100%
Difference in interest costs $[(r^I/(1+r^I)) - (r^A/(1+r^A))]$	.07	29%	.07	29%
Difference in storage losses $(\overline{\lambda}^I/(1+r^I)) - (\overline{\lambda}^A/(1+r^A))$	.01	4%	.01	4%
Difference in direct costs $(\overline{\omega}^I - \underline{\omega}^A)$	-.01	-4%	.05	21%
Difference in cost of risk-bearing $(\overline{\tau}^I - \overline{\tau}^A)$	.17	71%	.11	46%