Evaluation of Selected Fresh Vegetable Terminal Markets: A Stochastic Dominance Approach

Roger Hinson, Mooyul Huh, and John G. Lee

Abstract

Vegetable production can offer a high-valued cash crop alternative. While returns may be high, vegetables are perceived to have more risk than conventional row crops. This study used stochastic dominance analysis to evaluate terminal market price risk for four vegetable crops across five market locations. Results from the analysis identify differences in efficient market selection depending on the form which price risk follows. While vegetables as a whole are considered risky, substantial differences in the type of terminal market price variability existed between the commodities.

Key Words: market windows, vegetable price risk, stochastic dominance.

Given recent low commodity prices, crop failures due to drought, and farm financial stress, agricultural producers and researchers are examining alternative crops. Vegetable production is one such alternative. These high-valued crops are particularly suitable to the long growing season of the Southern United States. A reflection of this increased interest is the 253 percent increase in southern state funding for vegetable research since 1985 (USDA-CSRS).

While vegetables may be considered a high-valued alternative crop, production and marketing risk is perceived to be much greater than it is in conventional row crops. Production risks not only entail yield variability due to weather, but also quality differences in the product which can ultimately affect its marketability. Marketing risk is inherently greater for vegetables compared to cash grain crops because the crop is perishable. Conventional risk-reducing strategies are limited. Cold storage, for most crops, is available only to extend shelf life, and is expensive; there is no opportunity to hedge; and the limited capacity of smaller regional markets portends quick saturation and low prices.

Because of heightened interest in vegetable production as an alternative in traditional row crop farming areas, one focus of vegetable marketing research has been the identification of potential markets where price exceeds estimated cost of production. Under the generic term "marketing window analysis," vegetable prices have been analyzed in terms of relevant properties (seasonality, magnitude and variability) of the series. It is an advantage to the seller of vegetable crops (perhaps the grower acting on his own behalf, an employee of a vegetable packing shed, or a broker contracted to handle sales) to know where prices are greatest for his product and to try to gain access to that market.

Historical relationships between terminal vegetable market prices are important to produce sellers. One study (Riechers and Hinson) used one- and two-way Granger causality (Granger and Newbold) to focus on leads and lags between markets rather than on price levels. In general, the market closest to the origin of a majority of any particular vegetable crop appeared to lead other markets. Although leads and lags unrelated to origin/destination were evident, they were thought to be partly attributable to exchange of information among market participants.

A vegetable seller would probably view terminal market cities as alternative and independent marketing strategies for two reasons. First, there are already alternative suppliers for vegetable products. From an economic perspective, a wholesale business would require an incentive to receive product from a new supplier at the expense of established suppliers. The incentive provided by a new entrant to the wholesaler would be a discounted price, providing the wholesaler a larger margin (defined as the difference between cost of goods to the wholesaler and revenue from goods sold). Second, and perhaps more important, is trust based on a history of performance in delivering on verbal contracts which characterize the industry. Sellers from a non-traditional

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production area usually find it difficult to penetrate existing seller/buyer relationships. The problem would be more difficult if a strategy involved more than one market. Hence the assumption that markets are independent seems plausible.

The purpose of this study was to evaluate the tradeoff between expected price level and variability for alternative marketing strategies. Historic terminal market price data was used to compare weekly prices in an effort to identify strategies (the marketing week and location) that should be targeted by the seller. Identification of a preferred market would depend on analysis of both price variability and average price levels. Stochastic dominance with respect to a function was used to identify these risk-efficient strategies.

PREVIOUS RESEARCH

Marketing Windows

Several approaches to identification of best markets have been used. Feasibility studies have been a source of information, incorporating costs and revenues from both production and packing activities to assist with decision-making. A short version of the feasibility study, the "market window analysis," has been used as a first approximation to reduce the number of alternatives subjected to more detailed study. The market window concept has been used to compare the potential for alternative vegetable crops on small farms in Florida (Collette and Wall); and on vegetable farms in Georgia, Alabama, Louisiana, and South Carolina (Mizelle; Zwingli, *et al*; Hinson and Lanclos; and Venturella, *et al*). In some studies, volume at the market of interest was considered, while in others it was not. With minor variations, these studies followed steps described by O'Rourke:

> The strategy...has been to consider historical price data at a particular time in the marketing season paying particular attention to magnitude and variability...The prices are then compared to some measure of production cost to assess profitability. The price variability analysis introduces some limited consideration of risk.

Selection of an appropriate price series is crucial to the success of market window analysis. Price series at shipping points and at terminal markets are reported by U.S. Department of Agriculture / Agricultural Marketing Service (USDA-AMS). Prices f.o.b. at the packing shed are a better representation of price received by the packer. On the other hand, terminal market prices more accurately reflect nuances of consumer demand in individual markets. The typical approach has utilized weekly terminal market prices (Zwingli; O'Rourke; Hinson), although monthly f.o.b. shipping point prices have been used as an alternative (Venturella).

Also typical has been the comparison of prices based on E-V analysis, assuming that averages and standard deviations accurately describe the relevant price distributions. To facilitate the direct comparison between crops, coefficients of variations were used to compare price series (Zwingli; Venturella) and net income per acre (Zwingli). It should be noted that consideration has not been given to factors such as quantity-induced market risk, additional moments of the price and/or yield distributions, or the downward price influence associated with the proposed increase in production. A previous study by Colette and Wall tested homogeneity of price variance and found differences between crops. While vegetable production appeared to offer income enhancement, it must be weighed against the price risk at regional markets. The attitude toward risk of a vegetable seller assessing potential fresh vegetable markets has not been directly incorporated into previous market window studies. Differences in degree of risk aversion could result in very different interpretations of market characteristics and parameters that constitute acceptable performance.

Stochastic Dominance

Stochastic dominance is capable of determining whether any strategy dominates another completely or in part with respect to expected utility from uncertain outcomes. Stochastic dominance techniques have been applied to a number of agricultural settings to rank alternative depreciation methods (Richardson and Nixon), agricultural policy decisions (Kramer and Pope), sorghum storage decisions (Rister, *et al.*), value of weather forecasts (Mjelde and Cochran), and farm level marketing strategies (Bailey and Richardson). Anderson, Dillion, and Hardaker provide a review of stochastic dominance criteria and the use of stochastic dominance to evaluate plant breeding, fertilizer rates, and risk-efficient farm plans.

Unlike first, second, and third degree stochastic dominance criteria used to order uncertain prospects, stochastic dominance with respect to a function does not impose global restrictions on a decision maker's preferences (King and Robison). Meyer (1974, 1977) indicates that stochastic dominance with respect to a function can be more efficient in ranking alternative strategies than first-, second-, and third-degree stochastic dominance when the appropriate risk aversion intervals can be specified.

Stochastic dominance with respect to a function establishes both necessary and sufficient conditions for the price cumulative density function (CDF) of F(y) to be preferred to the CDF of G(y) by all individuals whose absolute risk aversion coefficients are between specified lower and upper bounds. Application of stochastic dominance with respect to a function requires that a utility function U(y) be identified and used to minimize the following:

$$\int [F(y) - G(y)]\, U'(y)\, dy \quad \text{for} -\infty < y < \infty$$

subject to: $r_l(y) < -U''(y) / U'(y) < r_u(y)$, where $r_l(y)$ is a lower bound and $r_u(y)$ is an upper bound on the absolute risk aversion coefficient.

For the purpose of this analysis, stochastic dominance with respect to a function was used to rank alternative CDFs of weekly vegetable prices at different terminal markets.

DATA AND PROCEDURES

Five terminal market cities—Atlanta, Chicago, Dallas, New Orleans, and St. Louis—were chosen for this analysis because they are currently important markets for southern vegetable crops. Also, these markets are where southern vegetable production areas should have a transportation cost advantage compared to California, Texas, and Arizona vegetable producers.

Available price series (USDA-AMS) permit a choice between daily or weekly average prices for either the shipping point or terminal market prices. Daily reports represent the maximum available information, while the weekly price report assumes that price on a selected day may be used to represent the price for the week. Because vegetable markets can change quickly, a short reporting period would be preferred. However, none of the market window studies used daily prices, choosing instead to lose some of the information contained in daily reports and focus on weekly comparisons. This approach seems reasonable given the variation in time between planting and harvest and that the objective is the identification of a target marketing week.

Weekly prices for the period 1980-1987, as reported in annual summaries from each of the five markets (Atlanta, Chicago, Dallas, New Orleans, and St. Louis) comprised the data set. Four crops were selected for analysis: broccoli, bell peppers, cabbage, and cucumbers. Terminal market prices were collected from the first handler and contained charges that must be deducted to estimate f.o.b. packing shed price. Specific charges were: markup by the first handler, transportation charge to the destination market, and a brokerage fee.[1] The adjustments to terminal market price are necessary to evaluate efficient marketing strategies across crops and geographic locations. It is realized that supply and demand conditions at terminal markets vary, and margins may fluctuate, being higher when supplies are tight and lower when supplies are plentiful. Differences may also exist because wholesalers may have more information about demand at the market than do sellers at distant shipping points.

The search for best marketing strategies was pursued on two fronts. Because E-V analysis is the standard of comparison, means, standard deviations and coefficients of variation for crops by market were calculated and compared. Likewise, stochastic dominance with respect to a function was used to evaluate marketing strategies over the appropriately defined risk-aversion space. A CDF was developed for each crop/market/week combination. This procedure resulted in over 150 possible market/week combinations depending on the crop. Stochastic dominance with respect to a function was used to rank the various marketing strategies. Distributions by crop were compared to each other with the objective of identifying preferred market/week combinations that might be targeted by a produce seller.

After an efficient set of market weeks is identified as the target, the planning process can work backward to identify planting dates expected to produce a harvest of commercial size in the target week. Harvest, however, depends on a set of stochastic factors associated with production which may set in motion a process that makes commercially viable quantities unavailable for sale in the target week. Favorable conditions could produce an earlier harvest, while unfavorable weather could completely destroy the crop or delay its arrival at commercial harvest status.

Because these stochastic forces in production and harvest imply some probability that marketing will not always occur in the target week, additional CDFs based on moving averages were incorporated into the analysis. First was the assumption that harvest might begin in week(s) preceding the target week,

[1] A 15 percent markup by the first handler was reported by handlers and has been used in other studies (Zwingli *et al*; Mook). Transportation cost per unit was determined by multiplying the mileage from Alexandria, LA to each market by $1.20/mile and then dividing by the number of units in a standard 40 foot container. Brokers indicated that 25 cents was a representative fee.

in the target week itself, or in succeeding week(s). Two moving-average terminal market price sets were developed to test the sensitivity of the single-week market specification to a multi-week price formulation. The first moving-average set was developed as a simple equal weighted moving average (MA). A second moving average was based on probabilities of harvest elicited from Extension Horticultural Specialists (EW). It was assumed that elicited harvest probabilities incorporate prior research findings and experience to assign probabilities of harvest in a target week given planting date information. For the EW set, that harvest could occur over a three-week period for broccoli and cucumbers, while a four-week period was appropriate for bell peppers and cabbage. Both sets of harvest probabilities were applied to terminal-market price data to generate price series by week, location, and crop. For consistency of comparison between the multi-week price sets, the same time periods were used in the formation of the MA series.

The adjusted weekly terminal market price distributions and the alternative moving average distributions provided additional input in the stochastic dominance analysis to evaluate the risk-efficient set of marketing weeks. Pratt defines the absolute risk-aversion coefficient $r(y) = \frac{-U''(y)}{U'(y)}$ as a measure of local risk aversion. A scaling procedure following the discussion by Raskin and Cochran was used to define the relevant risk-aversion interval for each crop. For this study, a certainty-equivalent formula ($CE = mu - \frac{1}{2} s^2 r(y)$, where mu is the mean and s^2 is the variance of the different price distributions) was set to zero and solved for a maximal risk aversion coefficient, $r^*(y)$. This coefficient provided an initial upper bound for the stochastic dominance program developed by Cochran and Raskin. If more than one marketing week entered the efficient set for this range, a systematic reduction in the upper and lower risk-aversion bounds was adopted to further reduce the efficient set. This bounding procedure allows one to identify a narrow range in which dominant strategies may change.

RESULTS

Mean weekly prices are reported in Table 1 and are illustrated in Figures 1, 2, 3, and 4. Prices for the New Orleans market consistently exceed those for the other four markets, though the margin varies. This difference exceeds $1 per unit for broccoli and cabbage, a level more than 20 percent higher than for the alternative markets. Bell pepper and cucumber mean prices were similar among markets. The procedure of accounting for transportation cost (between $0.30 and $1.05) from a point relatively close to New Orleans contributes to higher mean prices in that market, but weekly prices still appear to be higher. In addition to the higher mean price, the New Orleans market's standard deviation was lowest except for broccoli. The coefficient of variation (CV), which can be interpreted as a measure of the relative risk associated with a dollar of expected price (Penson and Lins), also was lowest for the New Orleans market.

While vegetables as a group might be perceived as carrying more risk compared to conventional row crops, the mean prices and measures of variation indicate a substantial difference in the type of risks potential sellers could face, depending upon the vegetable crop. Broccoli prices had the lowest CVs, while bell peppers and cucumbers possess a distinct seasonal pattern with CVs in the mid-range of the four crops. Cabbage prices were most volatile, as indicated by high CV levels. Figure 4 reinforces this observation, where three particularly noticeable price spikes are embedded in a series of smaller spikes. Moderate variability was noted in January and February. In June, production in Colorado and the Great Lakes states is ending while Texas production is not available in normal cool season quantities until November. Also, Florida cabbage shipments normally resume in November. In January, weather events that affect production could be responsible for the price fluctuations.

Again, the price data displayed in Figures 1 through 4 are average weekly prices, hence they do not illustrate price variability within a particular week. The CVs reported in Table 1 are lower than those reported in the market window studies. For example, results from Zwingli *et al.* and Venturella *et al.* for broccoli at the Atlanta market were .21 and .24, respectively; for cabbage, .45 and .52; for bell peppers, .21 and .49; and for cucumbers, .27 and .40. Differences in CVs probably resulted from varying time horizons and use of different sets of years as the basis for calculations. As a standard of price risk comparison, CVs for soybean average weekly price data during the same 1980-1987 period were calculated. This CV was estimated to be .015, or about five times smaller than the CVs calculated for broccoli.

E-V analysis focused exclusively on properties of the first two moments of the weekly price data. Stochastic dominance with respect to a function was used to rank alternative marketing weeks and locations by crop. Unlike other studies, this type of analysis considered weekly price variability in terminal market selection.

Table 1. Statistical Properties of Average Weekly Vegetable Prices.

	Geographic Location				
Crop/Statistic	Chicago	St. Louis	Dallas	Atlanta	New Orleans
Broccoli ($/22 lb. Carton)					
Mean	7.10	7.24	7.27	7.34	9.17
Std. Dev.	0.69	0.66	0.61	0.65	0.67
Max	8.40	8.60	9.05	9.44	10.54
Min	6.17	6.31	6.39	6.33	8.21
CV	0.09	0.09	0.08	0.09	0.08
Bell Pepper ($/1.11 bu. Carton)					
Mean	9.51	9.44	9.69	8.77	9.93
Std. Dev.	1.85	1.62	1.24	1.41	1.21
Max	12.76	12.82	13.12	12.07	12.72
Min	5.61	6.61	6.67	6.54	8.23
CV	0.19	0.17	0.12	0.16	0.12
Cucumbers ($/1.11 bu Carton)					
Mean	8.36	8.12	8.68	8.01	9.26
Std. Dev.	1.97	1.52	1.30	1.23	1.09
Max	12.76	12.29	12.13	12.81	12.01
Min	4.71	5.84	6.82	6.30	7.62
CV	0.23	0.18	0.15	0.15	0.12
Cabbage ($/50 lb. Sack)					
Mean	4.39	3.74	4.41	4.52	5.47
Std. Dev.	1.02	0.82	0.64	0.79	0.84
Max	6.08	5.71	5.92	6.38	9.80
Min	1.87	1.70	2.41	2.61	3.37
CV	0.28	0.32	0.28	0.27	0.20

The stochastic dominance results of the weekly price set by crop are listed in Table 2. Just as the average weekly price means varied across commodities, the efficient marketing strategy for the alternative crops depends on the degree of risk aversion. In the case of broccoli, three weeks are in the efficient set for the risk aversion bound from 0 to 35.21. Given that risk aversion range, the efficient set is dominated by the New Orleans market rather than by a given week. Similarly, two markets dominated the cabbage market in the risk aversion space bounded by 0 and 6.5. By contrast, the efficient sets for cucumbers and bell peppers tend to be dominated by two specific marketing weeks encompassing three or four markets over the risk aversion bounds reported.

Partitioning of the risk aversion space into smaller intervals can further reduce the efficient set and suggest a change in strategy. A specific preferred market and week can be identified as optimal for the seller who is indifferent to risk and simply prefers more to less. Partitioning of the risk aversion space into arbitrarily chosen intervals indicates that greater levels of risk aversion would cause different distributions of prices to be preferred. This partitioning exercise results in a change in the efficient from 19c to 20e for bell peppers, from 17d to 17e for cucumbers, and from 5e to 22a for cabbage. Two additional partitions are provided to illustrate the sensitivity of the efficient set to different risk aversion levels.

Overall, the results indicated that vegetable products should be available for sale in time periods that are marginal for the Gulf states, a reasonable outcome given that prices are higher when supplies are limited or must be transported over considerable distances. Sellers might focus their efforts on selected markets in the cases of broccoli and cabbage, while a specific marketing week might seem more important than location for bell peppers and cucumbers.

Maximal risk-aversion levels are relatively large (from application of the CE formula to per-unit price data with small variances) compared to a 'repre-

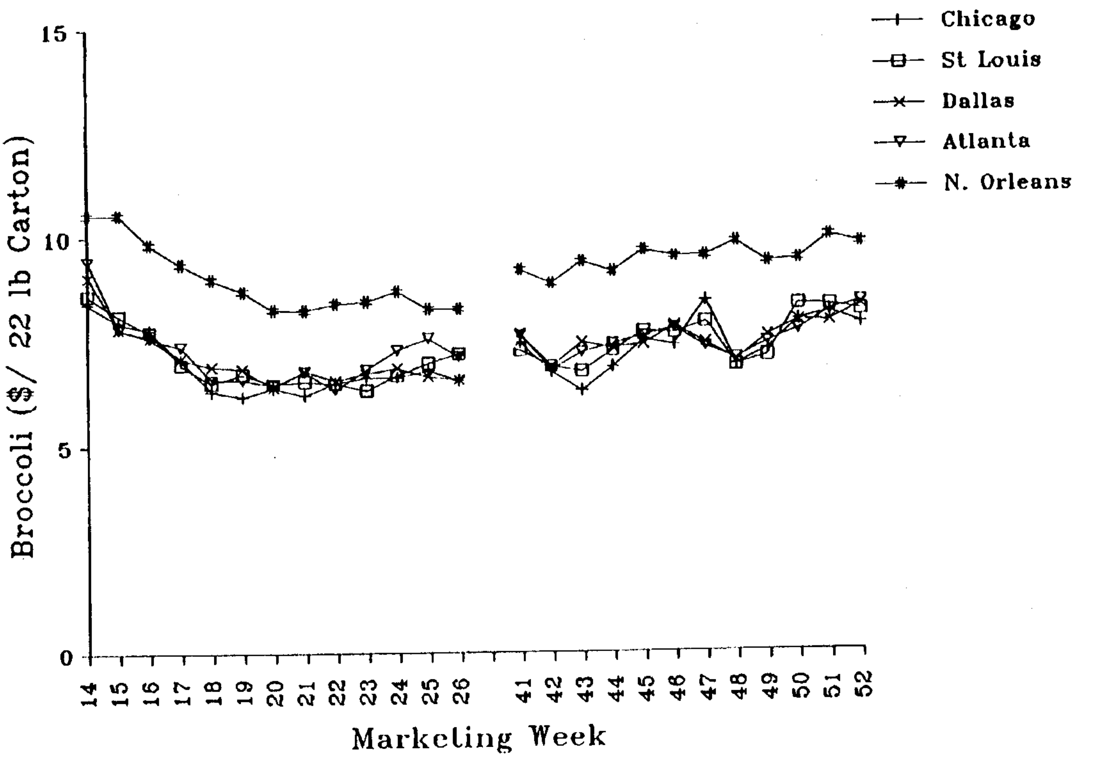

Figure 1. Average Weekly Terminal Market Price for Broccoli.

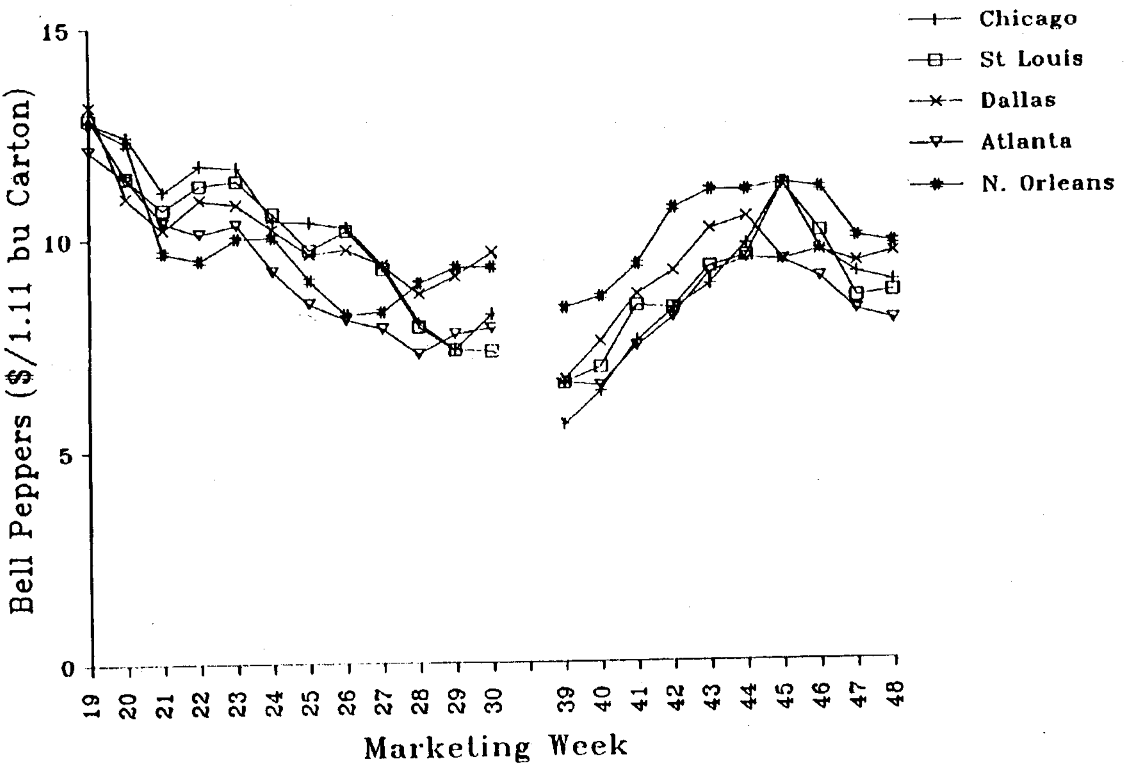

Figure 2. Average Terminal Market Price for Bell Peppers.

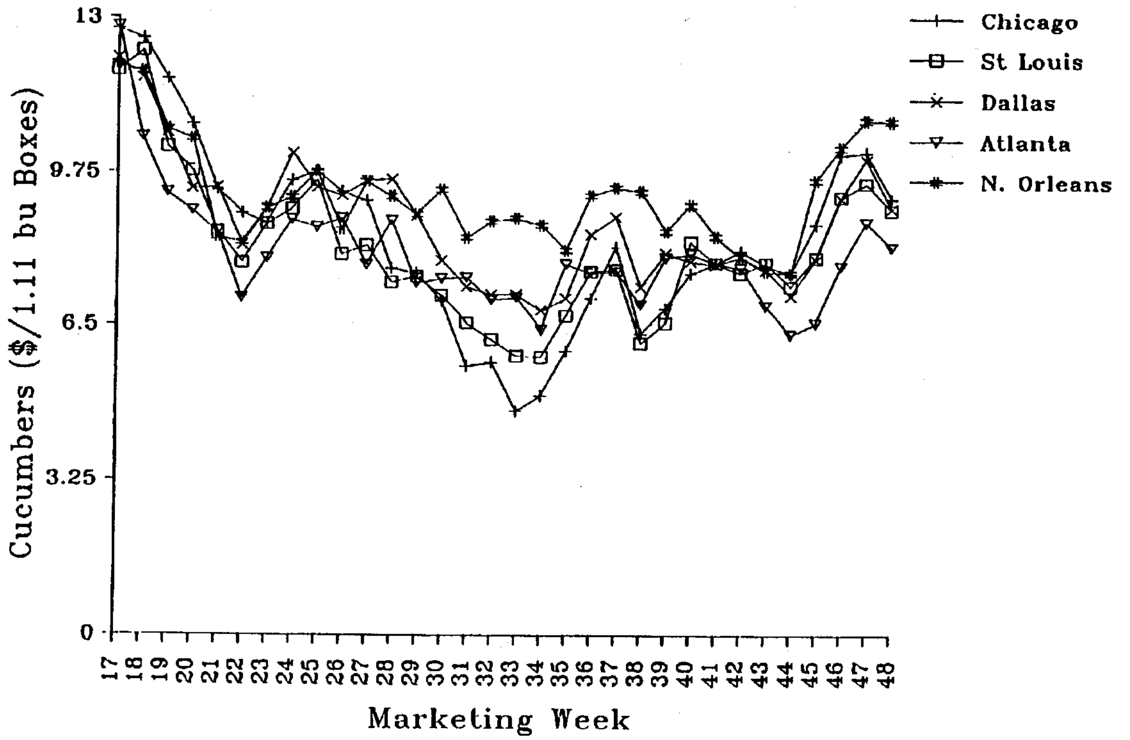

Figure 3. Average Weekly Terminal Market Price for Cucumbers.

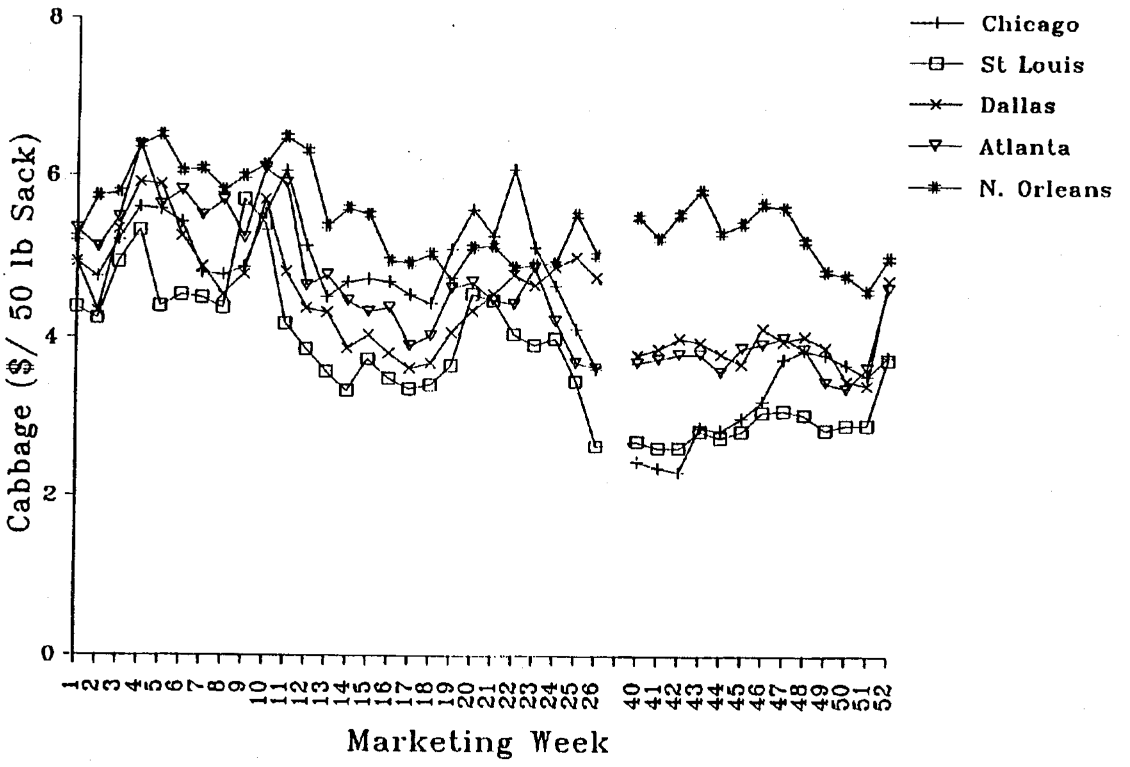

Figure 4. Average Weekly Terminal Market Price for Cabbage.

Table 2. Risk Efficient Marketing Week(s) by Crop.

Price Series	CROP Risk Aversion Levels [$r_1(y)$ to $r_u(y)$]			
	BROCCOLI			
	-0.001 to 0.001	0.00 to 1.00	1.00 to 5.10	5.10 to 35.21[a]
Weekly	14e[b]	14e,15e	14e,51e	14e
Three Week (MA)	15e	15e	15e, 51e	51e
Expert Weighted (EW)	15e	15e,51e	51e	51e
	BELL PEPPERS			
	-0.001 to 0.001	0.00 to 0.50	0.50 to 2.00	2.00 to 7.32[a]
Weekly	19c	19c, 20e,	20e, 19a	20e
Four Week (MA)	20a	20a, 20c, 44e	25a, 43e, 44a, 45a	25a, 44b
Expert Weighted (EW)	20a	20a, 44e	24a, 43a, 43e, 44a, 44e	43b
	CUCUMBERS			
	-0.001 to 0.001	0.00 to 0.50	0.50 to 2.00	2.00 to 9.49[a]
Weekly	17d	17a, 17c, 17d, 18a, 18b, 18e	17e,18e	17e
Three Week (MA)	18a	18a, 18e, 19a	18e	18e
Expert Weighted (EW)	18a	18a, 19a	19a	19a
	CABBAGE			
	-0.001 to 0.001	0.00 to 0.10	0.10 to 2.50	2.50 to 6.5[a]
Weekly	5e	5e, 12e	4e, 12e,22a	22a
Four Week (MA)	11e	11e	11e, 13e, 14e, 42e, 45e	43e
Expert Weighted (EW)	11e	11e	11e, 13e, 14e, 42e, 45e,	42e

[a] Refers to the maximal r(y).

[b] The number refers to the marketing week while the letter refers to the market location: a= Chicago b= St. Louis c= Dallas d= Atlanta and e= New Orleans.

sentative' distribution of means and variances of net income per acre for specific crops or whole farm returns. In some distributions of the price data, the standard deviation was less than one, resulting in a magnification of the maximal $r^*(y)$. The implication is that an extremely risk-averse individual would make a large expected-price tradeoff for a slight reduction in price variance. While some such individual may exist, presumably most are not close to these maximal values and are willing to accept some risk in return for the opportunity to increase price received.

The MA and EW measures of weighted moving-average prices were included to demonstrate sensitivity of the results to events that might result in commercial harvest in weeks other than the targeted week. These procedures resulted in pushing production away from the marginal production periods. The risk-neutral seller of broccoli using either of the moving-average methods would target one week later for all the crops, a logical outcome because prices are moving down as production becomes seasonally available in many areas of the country. The cabbage weighted-price results are similar to the broccoli results, in that as the risk-aversion parameter is increased, the efficient marketing strategy shifts from a spring to a fall crop.

For broccoli and cucumbers, the number of week-market distributions that would be chosen by the risk averse seller is reduced. For bell peppers and cabbage that number increases, particularly in the third interval. By definition, there are several distributions where the tradeoffs between expected price and variance are not distinguishable.

While some seasons are preferable in terms of marketing considerations for these crops, the results suggest a diversified marketing strategy. Broccoli and cabbage may be produced as fall through spring crops, though not in midsummer. Bell peppers and cucumbers are available as spring and fall crops, though not as winter and early spring crops. Therefore, both spring and fall sales appear to be a viable market alternative for bell peppers when MA and EW specifications are used.

Just as the historic weekly price data illustrates different patterns of market risk across the various vegetable crops, the stochastic dominance analysis provides insight into risk–efficient marketing strategies. In the case of broccoli and cabbage, the seller's advantage is in gaining access to the New Orleans market. For bell peppers and cucumbers, the timing of market entrance appears to be more important than location. For those very risk–averse individuals, the efficient set usually was reduced to a single market and week.

It should be noted that the research results concentrate primarily on terminal-market price risk. Differences in transportation cost or brokerage fees would change the ranking of efficient marketing strategies and thereby limit the specific results of this particular study. Likewise, it was assumed that potential sellers had no barriers to access to the different regional markets. While this study concentrates almost exclusively on price risk, the area of production / harvesting risk of vegetables merits additional research.

CONCLUSIONS

Vegetable production represents a potential high-valued cash crop alternative. While returns may be high, vegetables are perceived to have more risk than conventional row crops. This risk includes both production and price variability. This study examined only the terminal market price risk for four selected vegetables.

The results for broccoli and cabbage are useful for a new, relatively small grower/packer or production area, given the assumption of independent markets, for they suggest accessing a specific market. The seller would be interested in additional market research to support this choice of market. For example, analysis of arrival patterns and quantities at New Orleans would be a reasonable step given the appearance of that market in so many efficient sets. On the other hand, the diversification of markets implied by the efficient sets for bell peppers and cucumbers does not present a similar solution to the problem. Development of the broker/buyer relationship in several markets may be formidable because of the need to become known as a reputable and dependable supplier. For these two crops, all markets except St. Louis are represented in the efficient set for the overall risk-aversion range. For the MA and EW specifications, this problem is reduced or eliminated for cucumbers, but the bell pepper results still contain four locations in the efficient set. The decision to choose one market over others may be determined by the identification of a broker who is willing to work with new suppliers.

The results from this analysis indicate a substantial difference in the type of price risk associated with each crop. Broccoli exhibits a fairly stable average weekly price throughout the year. By contrast, bell peppers and cabbage exhibit substantial seasonality and variability. The stochastic dominance analysis provides additional insight for identifying risk-efficient marketing strategies. These strategies (timing and/or location) depend on the form that commodity prices follow. This information can be extremely important for individuals placed in the position of making a vegetable marketing decision or recommendation.

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