The Effect of California Weather Conditions on Price Premia for Organically Grown Vegetables in the United States

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Organic vegetable producers typically earn a premium over conventional producers to cover the added costs of organic production. The premium can vary greatly, making organic vegetable farming riskier than conventional farming and causing potential financial problems for new organic farming enterprises. Further, organic vegetable production is geographically concentrated in California, and the variation in organic price premia depends upon regional production factors, especially weather conditions. This study examines the relationship between organic vegetable price premia and California weather conditions near organic vegetable farms. Analysis is based on a unique data set of daily prices from the Boston Terminal Wholesale Market and California weather data from the National Climate Data Center.

Prices for organic products are typically higher than for their conventional counterparts by an organic price premium. The premium provides a market incentive for growers to produce organic crops without artificial pesticides, herbicides, and genetic modifications. For example, Greene and Calvin (1997) reported that price premia for organic mesclun (leaf lettuce) averaged 14 percent for the winter season, ranging between eight and 22 percent. Price premia for organic carrots averaged 110 percent and ranged between 52 and 157 percent from January 1996 to March 1997 in the Boston wholesale market.

Organic vegetables have existed for many years as a relatively small but increasing segment of the retail and wholesale food market in the United States. Over time, more consumers have come to place value on the production process and are willing to pay the premium for certified organic food. According to Dunn (1995), organic foods represented $2.5 billion out of $334 billion in retail food sales in 1994. This number climbed from just $78 million in 1980 (CCOF, 2000) and has since reached $6.0 billion in 1999 (USDA, 2000b) and $7.7 billion in 2000 (CCOF, 2000), an increase of nearly one hundred-fold in twenty years.

The supply of organic vegetables is still much smaller than the supply of conventional vegetables, exacerbating the risks associated with organic production, processing, and distribution. Despite the risks, entrepreneurs continue to expand organic production. The Organic Farming Research Foundation (1998) recently reported that nearly three-quarters of survey respondents planned to increase the volume of organic produce marketed. Sixty-three percent indicated they planned to increase the number of markets and buyers they sell to, and 56 percent planned to increase the number of acres in organic production. The emerging importance of organic food in the new century underlies a great need to begin research on organic food markets.

U.S. organic vegetable production is concentrated in California, which boasts six times more certified organic vegetable acreage than any other state (USDA, 2000a). As with other crops, weather has a major impact on organic crop production, but unlike commodities such as wheat and corn that are produced over wide geographical areas, national organic output is influenced primarily by the weather in a single location. The interaction between weather and prices is therefore a chief concern for organic food growers, distributors, and consumers. While crop prices tend to have a significant seasonal component because of production patterns, this seasonality is frequently interrupted by unexpected weather changes or other shocks to the pricing system. Many researchers have found statistically significant relationships between yields and weather variables. Ash (1988), for example, found a strong correlation between growing season precipitation and temperature.

This study compares prices of certified organic carrots and mesclun (leaf lettuce) with their conventional counterparts. Carrots are a primary source of Vitamin A in the U.S. diet. Mesclun is a new

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commercial crop and was the "1997 vegetable of the year" among other lettuce varieties (Levavi 1999). Carrots and mesclun account for the largest volume of all organic produce in the Boston wholesale market. Production regions for carrots and mesclun are concentrated in California, with sixty-three percent of U.S. carrot acreage and seventy-eight percent of mesclun acreage concentrated in the state (USDA, 1998). The objective of this study is to determine the effect of weather conditions on price premia for organic mesclun and carrots.

Theory of Organic Price Premia

Weather is one of the principal factors affecting organic vegetable production and prices. Weather affects organic food consumption because high price premia for organic products may induce consumers to buy conventional food instead. If organic food demand is more inelastic (less sensitive to price changes) than conventional food demand, good weather leads to low organic price premia and poor weather leads to higher premia.

In Figure 1, (a) is the organic market and (b) is the conventional market. P^o and P^c are organic vegetable price and conventional vegetable price respectively. Q^o and Q^c are the quantity of each product, organic and conventional. D^o represents organic market demand, which is more inelastic (less sensitive to price changes) than conventional market demand D^c. Favorable weather shifts both organic and conventional supply, S_0^o and S_0^c, to S_1^o and S_1^c, respectively. Thus, favorable weather conditions cause reductions in prices of both products. However, organic price P^o drops more than P^c, because organic demand is more inelastic than conventional demand. Therefore the price premium P^o - P^c also falls when the weather is favorable.

Empirical Approach

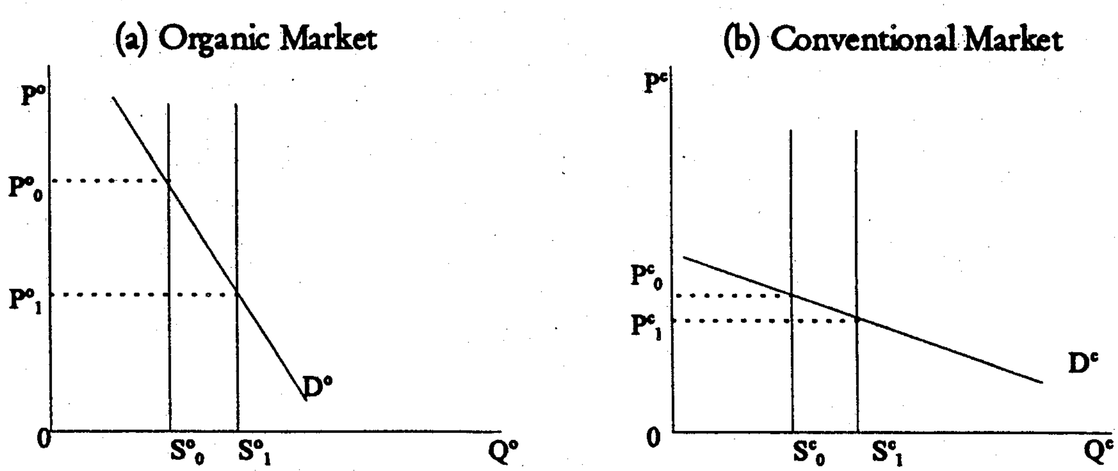
The goal of this study is to establish and quantify the link between weather in organic growing regions and price premia for organic carrots and lettuce. Without previous work to build upon directly, the initial attempt to describe such a link is necessarily limited. Nevertheless, the importance of organic food and the lack of research in this area makes a simple approach all the more useful as a guide to future analyses.

A series of empirical tests was carried out relating weather movement to organic price premia. Because this study attempts to show only the direction and average magnitude of the relationship between weather variables and organic premia, a simple regression model was employed. The price premium and weather variables are assumed to have the relationship

(1) $$R = W\beta + e$$

where R is the difference between organic and conventional price and W is a matrix of weather information such as actual maximum or minimum temperature, precipitation, and the heat index. β is a column vector of coefficients that measure the effect of weather on premia and e is the unexplained portion, which is uncorrelated with variables in W.

Figure 1. Effect of Weather on Organic Price Premia.



This simple specification captures only the average affect over the samples, and the estimates of b must be interpreted carefully. Important explanatory variables linked to organic price premia may still be undiscovered. However, reduced form (1) is useful as an empirical approximation relating weather conditions to price premia.

Data

Boston Terminal Market Wholesale Prices

Fruits and Vegetables, published by USDA's Agricultural Marketing Service, collects information on the current supply, consumption, and prices of nearly 400 domestic and 70 international fruits, vegetables, nuts, ornamental, and specialty crops. These data are collected through face-to-face interviews and telephone conversations with salespersons, brokers, and buyers. Terminal markets are assembly and distribution centers located in large metropolitan areas. Producers must transport and deliver organic products to the market in relatively large quantities. Consistent high quality and reliable large-volume deliveries make the terminal markets attractive to wholesale buyers. Market buyers typically include large wholesalers and sometimes local chain stores. Terminal Market Reports are issued from 16 wholesale terminal markets throughout the United States. These reports include price data on commodities traded at the local market; data on arrivals by airline, rail, and truck; and in port cities, arrivals by boat.

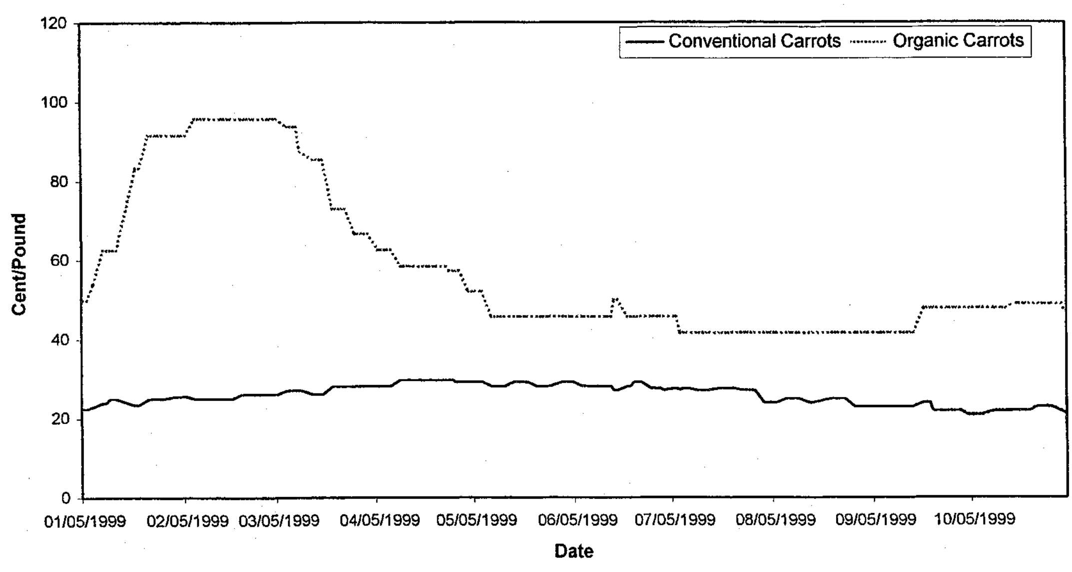
The New York Terminal Market reported prices only for organically grown potatoes and only for a very short period (two weeks of October 1999). Fourteen other terminal markets did not report any organic prices in 1999. Only the Boston Terminal Market reported both organic and conventional vegetable wholesale prices consistently.

Boston Terminal Market wholesale price data for 5 January to 2 November 1999 were collected on a daily basis. The data consist of a high and a low price because of quality variation among lots sold. Organic prices were available for broccoli (June to September 1999), carrots, mushrooms (occasionally throughout 1999), mesclun, and sweet potatoes (October 1999). Only carrot and mesclun prices were reported consistently in the Boston Market throughout the sample period. Sales and trades were reported daily with the exception of holidays and weekends. This study focuses its analysis on the daily wholesale price reported for three-pound cartons of leaf lettuce and 48-pound cartons of medium to large carrots.

Carrots

California produces about eighty-five percent of all carrots grown in the United States. Approximately ten percent of the volume of carrots was classified as organic in the Boston wholesale market. Most carrots are traded in 48-pound film bags or 50-pound sacks. Carrots are classified medium, medium-large, large, and jumbo. Conventional car-

Figure 2. Organic and Conventional Carrot Prices (January to November 1999).



rots come from seven states (Arizona, California, Colorado, Florida, Georgia, Michigan, and Texas) and two foreign countries (Canada and Mexico). Only California carrots were reported on the Boston market as both conventional and organic.

Price premia for organic carrots have fluctuated from less than $12 to more than $36 per 48-pound carton (see Figure 2). Between 9 February and 5 March 1999 the price of organic carrots peaked at $48 while the price of conventional carrots ranged $12 to $12.50. The average organic premium for this period was 284 percent, with an average premium of 121 percent.

Organic and conventional peeled baby carrots from California are traded in 24-pound cartons of film bags. Between 16 February and 5 March 1999 peeled organic baby carrots reached a price of $42 while prices for conventional carrots ranged from $13.75 to $14.25, resulting in a premium of 200 percent. The average premium was 112 percent.

Mesclun (Leaf Lettuce)

California produces mesclun year-round. Supplies peak in May and June and are lowest in December, January, and February. Lower volume during the winter corresponds to increased supply from western Arizona, so the overall national supply is nearly static. Most of California's mesclun is shipped by refrigerated truck to markets throughout the United States.

USDA (1999) observed that about 30 percent of the mesclun traded in the Boston wholesale market is organically grown. Table 1 shows that organic mesclun prices are only slightly higher than prices of conventional mesclun. In 1999 conventional mesclun from Arizona averaged $6.75 per three-pound carton and ranged from $6 to $8.75 while the price of mesclun from California averaged $6.84 per carton and ranged from $5.50 to $9.75.

Certified Organic Farm Locations

California Certified Organic Farmers (CCOF) is the one of largest private certifying organizations in the United States. CCOF certifies organic acreage, handling and processing. According to CCOF there are approximately 600 certified organic farms in California and about 70,000 acres are certified by CCOF (1999). The distribution of these certified organic areas are 75% percent to wholesale markets and 40 percent to direct retail markets.

CCOF provided the addresses and phone numbers of all certified growers but they could not identify growers by commodity, so a telephone survey of growers was undertaken to identify which farms produced carrots and mesclun. The results indicated that 69 certified organic farms in California produce mesclun and carrots, out of approximately 600 total farms. Twenty-eight certified organic farms produce carrots and 47 certified organic farms produce mesclun. These farms were concentrated in coastal and central California, as shown in Figure 3. Total certified acres for these vegetables approached 10,000.

Table 1. Descriptive Statistics of Daily Price and Premia for Organic and Conventional Carrots, Peeled Baby Carrots, and Mesclun, cents per pound (5 January to 2 November 1999).

	Organic Regular Carrots	Conventional Regular Carrots	Organic Baby Carrots	Conventional Baby Carrots	Organic Mesclun	Conventional Mesclun	Premium For Regular Carrots	Premium For Baby Carrots	Premium For Mesclun
Mean	57.32	25.98	124.21	70.49	249.9	226.4	31.34	53.73	23.5
Mode	47.92	26.04	116.67	70.63	249.6	216.7	25.00	45.42	25.0
Std. Dev.	18.80	2.43	19.96	1.13	21.2	15.5	18.81	20.29	16.1
Maximum	95.83	29.69	175.00	72.50	333.3	300.0	70.83	106.25	100.0
Minimum	40.63	21.53	100.00	67.50	208.3	191.7	13.54	27.50	-16.7
Skewness	1.125	-0.231	1.415	-0.429	1.601	1.838	1.156	1.398	0.901
Obs.	201	201	201	201	201	201	201	201	201

California Weather Data

California weather data were obtained from the National Climate Data Center (NCDC) at the National Oceanic and Atmospheric Administration (NOAA). The NCDC computer tapes contain data from all official weather collection sites in California. Organic producers' farms were matched to weather stations by their zip codes. Weather stations were found within 0 to 80 km of each farm. The data include daily minimum and maximum temperatures, precipitation, sunshine ratio, soil temperature, and other weather statistics.

Because ground level temperatures during the growing period were of primary concern in this study, daily minimum and maximum temperature were collected from November 1998 to August 1999, exactly two months before the product was delivered to the Boston terminal market. Data were obtained from the weather stations corresponding to the locations of the 69 organic farms producing carrots and mesclun. The names of the weather stations with latitude, longitude, and elevation are available from the authors.

Minimum and Maximum Temperature

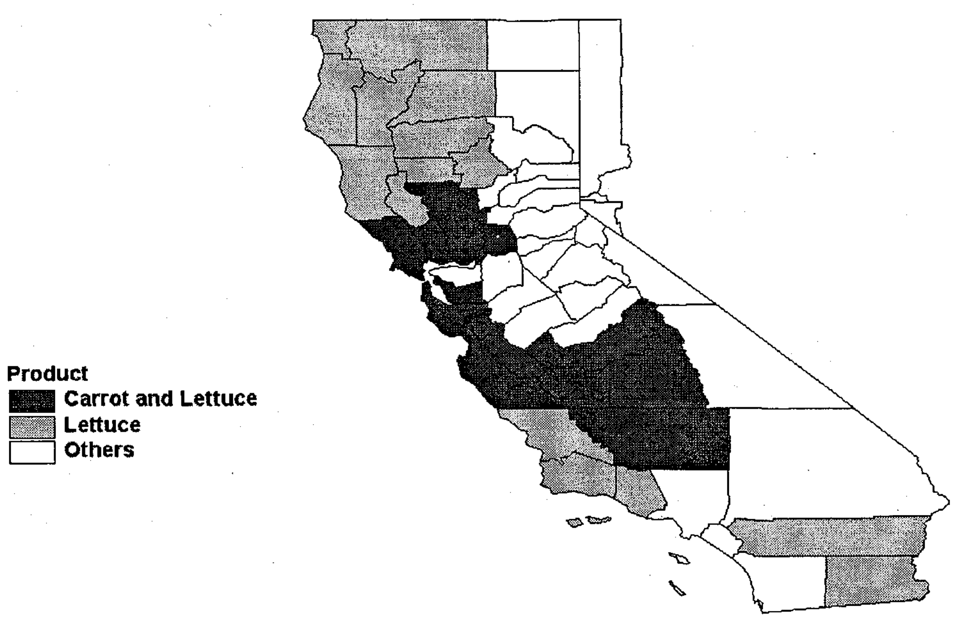
Each 24-hour interval is divided into 12-hour daytime and evening periods. The daytime period begins at 7:00 AM and ends at 7:00 PM on the same day. The evening period begins at 7:00 PM and ends at 7:00 AM the following day. The weather service reports actual rainfall and maximum temperature for the daytime period and rainfall and minimum temperature for the evening period. Crop damage may occur if the temperature drops below 7 °C. Thus the minimum temperature is an important factor in organic carrot and mesclun production.

Temperatures in production areas were averaged using linear weights. The minimum and maximum temperatures for different regions on the same day were averaged across production regions to arrive at mean minimum and maximum temperatures on a particular day. Minimum and maximum temperature were computed separately for carrot production regions and lettuce production regions.

Heat Index

The temperature in most of California ranges from 5 °C to 27 °C in the organic crop production

Figure 3. Certified Organic Carrot and Lettuce Production Regions in California. [a]



[a] Data based on certified organic lettuce and carrot farm addresses from CCOF. Map created using ArcView® GIS Version 3.1. Production areas created using Neuron Data's Open Interface Software Program.

areas. Bleasdale (1982) and others suggest using cumulative heat units, represented by

$$(2) \qquad H_d = \sum_{d=s}^{h} (AT_d - BT)$$

where H_d is heat units, AT is the average temperature, BT is the threshold temperature, d is the date, s is the planting date, and h is the harvest date. Lorenz and Maynard (1980) present threshold temperatures for selected vegetables. The threshold temperature for carrots and mesclun is 7 °C at ground level. The difference between average and threshold temperature is multiplied by 24 hours daily. Carrot and mesclun production require approximately two months for planting, maturation, and harvest, so heat units are based on 60 days.

Figure 4 shows the heat index for carrots and leaf lettuce over time. For mesclun, the harvest period depends upon maturity of the leaf. A two-month harvest period after seeding is used for heat index calculation. A higher heat index usually results in higher productivity for vegetable production.

Precipitation

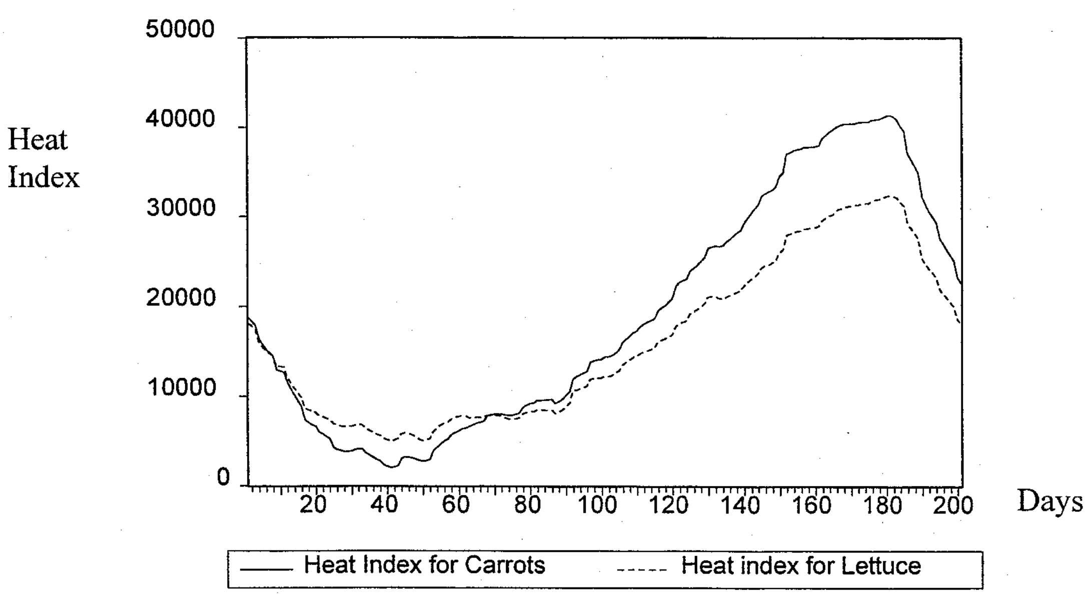
Precipitation is measured hourly each day, but cumulative weekly precipitation was used in this analysis. California has considerable precipitation in the winter season and less in the spring and summer. The lettuce production area reported more precipitation than the carrot production area during the study period. Crop production generally declined due to extremely heavy rainfall caused by El Niño. Much rainfall falls when the temperature is below 10 °C, which is a desirable condition for lettuce production.

Empirical Results

Roll (1984) used minimum and maximum temperatures to analyze the volatility of orange juice futures price returns. The results showed a significant relationship between the minimum temperature and futures returns for orange juice. Lave (1963) employed a heat index for grapes to analyze the raisin industry. He found a statistically significant effect of the cumulative heat index on the quantity of raisins.

The exogenous variables used in this study include minimum and maximum temperature, heat index, and precipitation. The precipitation variable was calculated as the sum of seven days' precipitation. Precipitation was found to have little explanatory power by itself because too little and too much precipitation are both bad for crops. Precipitation did have an interaction effect, however, because ideal rainfall depends on temperature. Therefore precipitation was omitted from the regressions ex-

Figure 4. 60-Day Heat Index for Carrots and Lettuce Production, calculated using equation (2). Units are degree-hours.



cept as an interaction term.

Linear regressors were unable to capture the nonlinear effects of persistent hot temperatures that may cause drought or harm crops. A quadratic transformation of the temperature variable was better able to explain the relationship. By performing omitted variable tests, a quadratic functional form was found to be the most suitable. The regression equation is

$$(3)\ R_t = \alpha_1 + \beta_1 T_t + \beta_2 T_t^2 + \beta_3 T_t PN_t + \varepsilon_t$$

where R_t is daily organic price premium for each product (regular carrots, peeled baby carrots, and mesclun); α_1 is a constant; β_1 is a linear effect of temperature on price premium; β_2 is a quadratic effect of temperature on price premium; β_3 is the effect of the interaction term on price premium; $T_t PN_t$ is an interaction term for precipitation and temperature used to explain the endogenous variable, organic price premium; and ε_t is random prediction error. Equation (3) was estimated using a two-month lag because both organic and conventional vegetables require two months to grow, as described above. Experimentation with a three-month lag resulted in different parameter estimates but a much lower R^2, indicating poor fit.

Results are displayed in Table 2. Minimum and maximum temperature results show that the linear coefficients for organic and conventional carrots are negative and statistically significant. The quadratic coefficients are positive and statistically significant. This implies that high temperatures in California organic growing regions decrease the price premia for organic carrots and baby carrots until excessively high temperatures begin to increase the premium again. The effect is about 1.8 cents per degree, depending on T_t and PN_t. Suitable weather conditions result in a large harvest so that the prices and organic price premia decrease. Conversely, poor weather causes an increase in prices and premia.

The effects differ for maximum and minimum temperatures. Maximum temperature has a greater effect on the price premium than minimum temperature. This result differs from the study by Roll (1984) which found minimum temperature had the greater effect on orange juice prices. This suggests that the effects differ depending on the crop in question.

All estimated effects of temperature on organic mesclun price premia were small and statistically insignificant, which suggests further analysis based on the heat index. The regression equation is

$$(4)\ R_t = \alpha_1 + \beta_1 H_t + \beta_2 H_t^2 + \beta_3 H_t PN_t + \varepsilon_t$$

where H_t is the heat index. Equation (4) was estimated for each crop the same way as was equation (3).

Results are displayed in Table 3. The mesclun estimates are statistically significant when using the

Table 2: Effect of Temperature and Precipitation on Price Premium for Carrots and Lettuce. [a]

	Carrots		Baby Carrots		Mesclun	
	Max.	Min.	Max.	Min.	Max.	Min.
T	-10.85	-10.03	-16.22	-4.52	-1.30	-2.70
	(-5.51)	(-5.49)	(-7.34)	(-7.13)	(-0.41)	(-0.89)
T^2	0.114	0.153	0.177	0.234	0.0181	0.0635
	(4.65)	(4.43)	(6.44)	(6.02)	(0.46)	(1.07)
T*PN	-0.000202	-0.0000512	-0.000299	-0.000115	-0.000590	-0.0000421
	(-3.49)	(-0.63)	(-4.61)	(-1.25)	(-1.65)	(-0.89)
R-squared	0.385	0.366	0.428	0.407	0.027	0.044

[a] T is temperature in °C, PN is precipitation in mm per week. Price premia are in cents per pound. T-statistics are in parentheses.

Table 3. Effects of Calculated Heat Index on Price Premium for Carrots and Lettuce. [a]

	Carrots	Baby Carrots	Mesclun
H	-0.00601	-0.00734	-0.00212
	(-12.65)	(-13.32)	(-1.80)
H^2	1.85E-07	2.30E-07	1.50E-07
	(9.29)	(10.04)	(2.57)
H*PN	-1.16E-06	-1.72E-06	1.61E-07
	(-3.97)	(-5.13)	(0.71)
R-squared	0.617 0.626	0.091	

[a] H is a 60-day heat index in degree-hours, calculated using equation (2). PN is precipitation in mm per week. T-statistics are in parentheses

heat index, whereas they were insignificant when using temperatures. Mesclun prefers cool, wet weather and the estimated increase in premium is about 0.0013 cents per degree-hour per two-month period, which corresponds to about 1.8 cents per degree-day per day. Lower levels of H_t decrease the premium; higher levels increase it. Precipitation had a statistically insignificant effect and very small positive effect, possibly because of irrigation. Carrot results remain statistically significant with a reduction of about 0.00046 cents per degree-hour per two months, which corresponds to 1.4 cents per degree-day per day, depending on H_t and PN_t. This result compares to 1.8 cents per degree using the temperature model. Results with the heat index uniformly indicate that favorable weather conditions reduce the organic price premia for carrots and mesclun.

The implication of these results is that organic prices are highly variable and sensitive to weather conditions in a geographically concentrated area. The financial risks associated with organic vegetable farming, processing, and distribution are therefore much higher than the financial risks associated with conventional vegetable farming. Risk is considered a disincentive for new business enterprises and may be an impediment to future development of the organic food production and distribution system. If public risk-management subsidies and private insurers were to target the organic food sector and eliminate the risk dichotomy between organic and conventional food, market incentives might stimulate organic production to continue increasing in the twenty-first century.

Conclusions

This study investigates how weather affects organic price premia for carrots and mesclun (leaf lettuce) in the United States based on 1999 Boston wholesale market prices. Organic and conventional prices include regular carrots, peeled baby carrots, and mesclun. Weather conditions include minimum and maximum temperature, precipitation, and cumulative heat indices from California organic production regions. The effects of weather conditions on organic price premia are statistically significant. Favorable weather conditions correspond to low organic price premia.

A statistical relationship exists between carrot price premia and temperatures in California organic growing regions. Premia are more affected by a change in maximum temperature than by minimum temperature. No statistically significant result was found for the effect of temperature on the mesclun price premium, but the heat index exhibits a statistically significant effect on both carrots and mesclun premia. A large amount of price movement over time remains unexplained.

Two important conclusions can be drawn from this study. First, good weather conditions in California's organic growing regions were associated with a substantial reduction in organic price premia for carrots and mesclun. This indicates that the geographic concentration of production is of critical importance for understanding organic vegetable markets. Second, indirect inference indicates that price elasticities of organic and conventional vegetable demand are different and drive changes in organic price premia. Further research is required to quantify the relationship between the two demand curves.

This is the first study to examine organic price premia using regional weather data. Future research should emphasize the geographic concentration of organic production and attempt to characterize its effects on markets. The findings of these studies would be useful to organic food producers, retailers, and wholesale buyers grappling with an emerging organic food market.

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