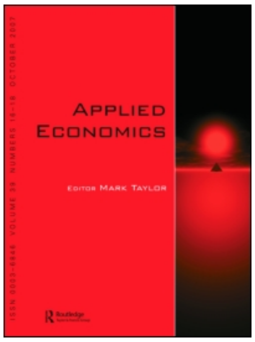

Applied Economics

ISSN: 0003-6846 (Print) 1466-4283 (Online) Journal homepage: https://www.tandfonline.com/loi/raec20

The examination of pecan price differences using spatial correlation estimation

Wojciech J. Florkowski & Camilo Sarmiento

Applied Economics, 2005, **37**, 271–278

The examination of pecan price differences using spatial correlation estimation

Wojciech J. Florkowski*[,a] and Camilo Sarmiento[b]

[a]*Agricultural & Applied Economics, University of Georgia, Griffin Campus, 1109 Experiment Street, Griffin, GA 30223-1797, USA;*
[b]*The Pacific Institute for Research, and Evaluation, Calverton, MD, USA*

A spatial analysis is used to model factors that explain the price received by pecan growers. Besides the statistical aspect of the study focussing on spatial autoregressive residuals, the economic analysis of the paper identifies linkages between the price for in-shell pecans received by growers and the characteristics of the orchard, production costs and resources, and the orchard location.

I. Introduction

Factors that change economic series are known to persist over time. This implies an economic interpretation of autocorrelation terms in regression models. Economically relevant factors change at particular locations and are likely to permeate over space in a fashion similar to a temporal correlation. The physical connotation of spatial correlation, however, differs from the temporal correlation captured in time-series data. Location or distance become a focus in spatial analysis and are considered a major cause of the observed events. In the presence of spatial correlation, the ordinary least squares (OLS) estimator uses the incorrect variance–covariance matrix for testing, and the estimator is not asymptotically efficient. Most farm level analysis, however, ignores spatial autocorrelation (Kelejian and Robinson, 1995) in the econometric residual.

In price analysis, the spatial autocorrelation term captures the correlation that exists between unobserved factors that explain spatial prices in the economic model. For these applications, new developments in spatial econometrics provide a statistical basis for hypothesis testing. This paper illustrates the statistical and economic significance of using a spatial-correlation estimator in spatial price analysis and identifies economic linkages in price determination at the farm level that cannot be generally identified with aggregate time-series data.

The paper in particular identifies linkages between the price for in-shell pecans received by growers and the characteristics of the orchard, production costs and resources and the orchard location. The focus on in-shell prices is of special relevance to the spatial analysis because growers must sell their unprocessed pecan crop to pecan processors (shellers) operating specialized shelling plants scattered throughout the country. The light but voluminous commodity is transported to buyers at the expense of growers. Between 45–60% of the in-shell shipment is eventually discarded during shelling. Furthermore, in contrast to grain or oil seed farmers, pecan growers do not have readily available on-farm storage facilities. Although pecan storage can benefit growers because intra-annual price differences would often pay premium

* Corresponding author. E-mail: wflorko@griffin.uga.edu

Applied Economics ISSN 0003–6846 print/ISSN 1466–4283 online © 2005 Taylor & Francis Group Ltd
http://www.tandf.co.uk/journals
DOI: 10.1080/0003684042000295340

for storage (Florkowski and Wu, 1990), the existing storage technology cannot be readily used on farm. The inability to store pecans on-farm because of their susceptibility to oxidation (Kays, 1991) forces the sale of the crop during harvest.

Pecans are produced in a volume smaller than most row crops and the marketing infrastructure is less dense. The biology of the pecan tree is complex and not fully understood, but biological scientists recognize the importance of climatic conditions for growing a large crop of quality nuts. Most suitable conditions are prevalent in river valleys in the western USA, particularly Texas and Oklahoma (where pecan is indigenous), and in a small area east of the Mississippi in central Georgia. In the context of spatial correlation, the location of an orchard in an area favouring pecan trees should result in crop volume and quality superior to those in other areas, *ceteris paribus*.

Some growers conduct an intense search for buyers in expectations of high prices. It has been reported that on average a Georgia pecan grower contacted three accumulators and two shellers (Hubbard *et al*., 1998). Large growers contacted up to 15 buyers to inquire about prices. In spite of this observed behaviour, the empirical verification of the relationship between prices received by growers and the orchard location has rarely been conducted due to a lack of data. Indeed, although price changes over time have been a topic of many studies, the spatial price differences at the farm level have seldom been examined. This study establishes factors that influence in-shell pecan prices accounting for the spatial aspect of pecan production. An examination of prices in the spatial context adds to earlier findings that the knowledge of standards for pecan grades was not affected by the location of a grower in Georgia (Florkowski *et al*., 1996) suggesting that if price differences exist, the inadequate knowledge of quality measures is not a determining factor. The empirical analysis uses data from the survey of commercial pecan growers in Georgia.

Overall, results from this study establish the usefulness of the spatial correlation estimator and test the importance of economic factors that may explain the price received by the farmer. Spatial price differences are of relevance for making marketing decisions within a single production year where the interseason selection of annual crop is not applicable because of the perennial nature of an enterprise and the lack of on-farm storage. All members of the pecan industry – including growers, processors, and end users – can potentially gain insights into which factors are confirmed to be relevant by statistical analysis. This knowledge supplements years of personal observations of the market revising the importance of these observations by confirming some and rejecting others. Furthermore, this study supplements earlier studies on pecan prices (Epperson and Allison, 1980; Wells *et al*., 1984; Shafer, 1989; Okunade and Cochrane, 1991; Pena, 1995), inventories (Florkowski and Wu, 1990), and supply response (Elnagheeb and Florkowski, 1993), all based on time-series data.

II. Modelling Spatial Differences of In-shell Pecan Prices

Firms make optimal decisions based on expected rather than realized yield (Pope and Chavas, 1994) in the presence of production risk. Production risk is primarily associated with the weather, but in case of many perennial crops, the important source of risk is the irregular bearing. Many tropical and subtropical crops – for example, coffee or citrus – display the tendency to produce low yields after years of large yields. Although in pecan production there are risks associated with the weather, the foremost uncertainty results from the well-known tendency of pecan trees to bear large and small crops of nuts in an irregular pattern (Sparks, 1992; Worley, 1994). Cultural practices temper the alternative bearing, but have not eliminated this phenomenon (for example, Harris, 1985). Irregular bearing is also observed in the USA in the production of pistachios, for example, despite considerably higher cultivar uniformity than in the pecan industry. The unpredictability of perennial tree-crop production makes the spatial analysis of price differences of particular interest to growers because the prices received by growers are a direct outcome of the local demand and supply conditions. The local supply is determined by the crop size in the absence of on-farm storage facilities carrying over a portion of the previous year's crop.

Pecan production requires standard chemical inputs such as fertilizers and pesticides. Fertilizers and supplements of trace elements enhance yields and compensate for any deficiencies in soil productivity detected through soil and leaf analysis. Pesticides are especially important because pecan trees are attacked by several diseases and are commonly infested by insects that can inflict catastrophic damage to the crop volume and quality. Pecan trees are attacked by fungi such as scab (Latham and Goff, 1991; Sanderlin, 1995), so fungicide treatments must be applied on a regular basis in orchards to control fungal diseases, which could interfere with the photosynthesis responsible for the enlargement and filling of nut kernels. Insecticides are needed to control leaf-feeding insects, such as various species of aphids, or insects feeding on maturing nuts, such as several species of weevils. Pesticide costs are a substantial portion of the annual variable production costs.

In the production of pecans, capital resources (fixed inputs) are defined as the machinery and equipment used for cultural practices and harvesting. The perennial nature of pecan trees, as with other perennial tree crops, demands specialized machinery and equipment. Asset specificity in perennial tree crop production is a major factor limiting reallocation of resources, stressing the importance of location to the economic viability of a farm. In case of pecan trees, their size and the ability to remain productive over a span of several decades – sometimes as much as 100 years (Harris, 1995) – requires spraying or harvesting with highly specialized machinery that cannot be used on other crops. Harvesting calls for shakers and sweepers that have little use in production of other crops. This relatively narrow use of the machinery prohibits smaller pecan operations from acquiring the best equipment, compared to larger operations that tend to focus on pecans as an enterprise commodity. Some owners of small orchards purchase used equipment (Fonsah, 2002) or lease their pecan trees to other growers. These arrangements improve the utilization of physical capital owned by large pecan operations, permitting timely performance of cultural practices and efficient nut harvest.

Harvested pecans, cleaned of debris, are sold after sizable volume has been accumulated. A typical sale transaction involves sampling pecans in the shipped lot and pricing them according to the estimated shell-out ratio, i.e., the content of edible kernels (for details see Florkowski *et al.*, 1992). Nuts are relatively light, so transportation costs are minimized by hauling nuts in large trucks. However, the primary reason for transporting nuts to distant buying points is the expectation of higher prices than at the nearest outlets. This observed behaviour is the response to the less-dense marketing network for pecans than for major agricultural commodities, even in areas of production concentration. It is plausible that growers are willing to travel additional distance if the price difference assures higher profits.

The location of an orchard matters because the optimal climatic conditions vary across production areas. Each orchard location was determined with regard to the area most suited for pecan production in the state. Such a desired area in terms of climatic conditions is Peach county in central Georgia. This area saw growth in pecan planting during the 1990s, whereas other areas experienced stagnation or the decline in pecan tree numbers (Florkowski, 2001). A specific orchard characteristic is the yield from mature trees, a stage reached by pecan trees after 10–20 years. Maturity is important because immature pecan trees bear regularly; the evaluation of a tree's yield potential is therefore postponed until the proper age. In addition, the irregular bearing pattern implies that a yield in a single season does not properly reflect the consistent yield that can be expected from an orchard. The consistency demonstrates good orchard management reducing the troughs in the irregular bearing pattern leading to a higher average yield over time (McEachern, 1991).

Price differences can result from variable quality. Pecans are not indigenous to the southeastern USA; the planted trees are mostly improved (grafted) varieties, selectively bred for yield and quality. Among commercially planted trees, two varieties dominate the production of pecans in the region, accounting for 56% of all trees in Georgia's commercial orchards: the *Stuart* variety, first propagated commercially in the 1880s, and the variety *Desirable*, commercially introduced in 1945 and widely planted in the 1960s (Sparks, 1992). The distinct differences between these two varieties include the size and colour of kernels, shell thickness, and ease of shelling. Kernels of *Desirables* tend to be brighter and larger than do *Stuart* kernels and do not darken over time. It has been noted that *Desirables* tend to bring higher prices than *Stuart* pecans (Sparks, 1992; Florkowski, 1996). A binary variable was introduced in the empirical model and assigned the value of one when the variety was *Stuart*.

The price received by a pecan grower can be modelled in terms of characteristics of his operation by inverting the conditional supply–response function as suggested by the implicit function theorem (Simon and Blume, 1994, p. 337). In particular, the economic model of the in-shell pecan price received by growers is

$$P_t = f(\mathbf{H}_t) \tag{1}$$

where the in-shell pecan price received by the grower t is P_t, and the vector $\mathbf{H}_t$ captures the average yield from pecan operation t and accounts for the irregular bearing pattern, variable inputs price, and fixed inputs.

To estimate Equation 1, the statistical model is specified as,

$$p_t = A'\mathbf{h}_t = v_t \tag{2a}$$

where lower cases imply the transformation of variables in Equation 1 into their logarithmic values. In the statistical model, however, omitted factors are likely to be correlated across space in the econometric residual that explains the price received by growers.

A commonly used structure for spatial correlated residuals is:

$$v = (\mathbf{I} - \rho\mathbf{W})^{-1}\mu \qquad (2b)$$

where $v = (v_t, \mu, v_M)$; $\mu \ldots (\mu_1, \mu, \mu_M)$ for $\mu_t \sim N(0, \sigma^2)$; $\mathbf{I}$ is the identity matrix; $\mathbf{W}$ is a row-standardized matrix with zeros in the diagonal matrix and rows summing to one; and the spatial correlation coefficient is ρ. The spatial correlation structure in Equation 2b, in particular, allows for both spatial correlation and heteroscedasticity (Anselin and Florax, 1995).

Estimator of spatial correlation

For estimation purposes, an alternative representation of Equation 2 is

$$(\mathbf{I} - \rho\mathbf{W})p = (\mathbf{I} - \rho\mathbf{W})a\mathbf{i} + (\mathbf{I} - \rho\mathbf{W})b\mathbf{X} - \mu \qquad (3)$$

where $\mathbf{p} = (p_1, \ldots, p_M)$; $\mathbf{X} = (\mathbf{h}_1, \ldots, \mathbf{h}_M)$; and $\mathbf{i}$ is a vector of ones. Kelejian and Robinson (1995) show that the maximum-likelihood (ML) estimator of Equation 3 is the solution of the following three sets of equations:

$$Q'(\mathbf{I} - \rho\mathbf{W})'(\mathbf{I} - \rho\mathbf{W})\mathrm{E} = 0 \qquad (4a)$$

$$\mathrm{E}'(\mathbf{I} - \rho\mathbf{W})'\mathbf{W}\mathrm{E} = \sigma^2\Sigma_t[\lambda_t/(1 - \rho\lambda_t)] \qquad (4b)$$

$$\mathrm{E}'(\mathbf{I} - \rho\mathbf{W})'(\mathbf{I} - \rho\mathbf{W})\mathrm{E} = M\sigma^2 \qquad (4c)$$

where $\mathbf{E} = \{y_1 - (a + bx_1, \ldots, y_M - (\mathrm{a} + bx_\mathrm{M})\}$; $Q = \{(1, x_1), \ldots, (1, x_M)\}$; and $(\lambda_1, \ldots, \lambda_M)$ are the eigenvalues of the matrix $\mathbf{W}$.

In the presence of spatial correlation, the estimator in Equation 4 uses the adequate variance–covariance matrix for hypothesis testing, and the estimator is asymptotically efficient. The OLS estimator, in contrast, uses an incorrect variance–covariance matrix and is inefficient.

III. Data Collection and Description

The application uses microlevel data obtained from the survey of commercial pecan growers in Georgia. The state is the leading pecan producing state in the USA and supplies about 40% of the national crop, on average (USDA-NASS). The survey was conducted in 1998. The first mailing of the survey instrument to 1595 growers included two parts: a sheet recording the number of pecan trees operated by a grower in 1997, and a separate set of questions asking growers to provide information about their production costs, marketing practices, and the average yield of nuts from an acre of a mature orchard. During the course of the survey a number of individuals from the original mailing list were eliminated, leaving a total of 875 commercial pecan growers. The original list consisted of addresses of growers used in the pecan-tree inventory survey ten years earlier and the list of growers identified by the State Pecan Commission. Despite the removal of duplications, the list proved outdated. A number of growers had abandoned their orchards. Some retired and sold parcels of orchards for development, while others found alternative crops more profitable and reallocated land. Also, the 1998 survey defined a commercial pecan grower as one operating a minimum 30 acres of pecan trees because experience showed that smaller growers did not qualify as 'commercial' growers and produced pecans mostly for their own use. The definition was consistent with that adopted by the State Pecan Commission.

It was expected that the initial mailing of the survey instrument would be insufficient to collect information from all growers. Therefore, the mailing was followed by a postcard reminding growers to return the completed questionnaire. Subsequently, one more mailing of the two-part questionnaire (the tree-inventory sheet and the questions about production and marketing practices) was conducted in the spring of 1998. Ultimately, 292 growers provided responses to at least some of the questions, while the final number of identified commercial pecan growers was 875. Although this study focuses on answers from about 37% of all growers (292 respondents), the group as a whole operated almost 56% of pecan trees in commercial pecan orchards in Georgia in 1997.

Given the information required to estimate the statistical model in Equation 2, the model was estimated using 177 observations. This number of growers provided qualitative information on the distance travelled to market pecans, the cost per acre, the value of machinery and equipment used in pecan production, and the average yield of a mature orchard over a span of five years preceding the survey. Table 1 provides a summary of descriptive statistics of the variables used in the empirical model.

The travel distance was defined as a binary variable assuming the value of one if a grower shipped his pecans to a buying point located more than 15 miles from the orchard. The distance was chosen arbitrarily given the observations of the industry practices. Buying points are scattered throughout Georgia and are mostly operated by pecan shellers or on behalf of shellers. Although some are next to shelling plants, many are seasonal. Their proximity to commercial orchards reflects buyers' desire to accommodate growers, while enabling the purchase of the crop and the protection of its quality. Also, the chosen

Table 1. Descriptive statistics

Variable	Units	Mean	Variance
Price	c/lb	0.78	0.23
Travel	1–15 miles or more	0.55	–
Location	1–optimal area	0.15	–
Capital	1–US50 K or less	0.53	–
Expected yield	Lb/ac	731	482
Variety	1–*Stuart*	0.28	–
Cost per acre	US$	198	209

Notes: Travel, location and capital variables are binary variables. Specifically, the three binary variables represent 55%, 15%, and 53% of sample growers, respectively. The variable representing the variety shows that 28% of pecan trees were *Stuart* variety.

distance appears to have been chosen by about one-half of growers – 45% of growers travelled less than 15 miles to sell their crop.

The value of machinery and equipment was divided fairly evenly into those who reported owning no more than US$50 000 worth of specialized equipment (53% of respondents) and those who owned equipment in excess of US$50 000. Capital was defined as a binary variable assuming the value of one if the value of machinery and equipment is less than US$50 000. Because of the long existence of the majority of orchards, the value of the equipment tends to be low because it has been depreciated over the course of orchard operation. The cost per acre includes the cost of fertilizer, pesticides, fuel, repairs and maintenance. The long productive life of pecan trees makes other costs (e.g., land) less important in grower calculations. The expected yield is the average of yields from an acre of a mature orchard during the five years preceding the survey. The five-year span accounted for the irregular bearing and the reasonable record keeping.

Selection of weight functions

To specify the weights of the row-standardized matrix in Equation 4, this study uses information on the county where each orchard was located. In particular, for the spatial-correlation matrix in Equation 3, the w_{ij} element of the matrix **W** for all firms located in county i is $1/r_i$ where r_i equals the number of pecan operations located in same county i, and $w_{ij} = 0$ if the grower $\{i,j\}$ is not located in county i. While other weight matrices could be considered (Anselin and Florax, 1995), the survey only contains information on the county in which each grower is located. Under the chosen weight matrix, spatial correlation between the pecan operation i and the pecan operation j is the $\{i,j\}$ element of $(\mathbf{I}-\_\mathbf{W})^{-1}$. To estimate Equation 3, a grid search over _ is used.

Table 2. Estimated coefficients with and without spatial correlation

Variable	OLS estimates (*t*-statistics)	ML estimates (*t*-values)
Constant	−0.85*	−0.95*
	(−4.77)	(−5.22)
Travel	−0.02	−0.04*
	(−1.57)	(−2.15)
Location	−0.03	−0.07*
	(−0.46)	(−1.74)
Capital	−0.16*	−0.13*
	(−3.13)	(−2.92)
Expected yield	0.11*	0.12*
	(−4.01)	(−4.64)
Variety	−0.06**	−0.07*
	(−1.73)	(−2.01)
Cost per acre	1.5×10^{-3}	-3.8×10^{-6}
	(−0.17)	(−0.03)
Spatial correlation coefficient	NA	0.10*
		(−4.07)
R-squared	0.54	NA

Notes: * Denotes 5% significance level.
** Denotes 10% significance level.
Expected yield and costs per acre expressed in logs.

IV. Results

Table 2 shows estimates of Equation 2 for in-shell pecan price differences. The significance of the spatial-correlation coefficient suggests the existence of markets influenced primarily by local supply and demand conditions. Prices discovered at such markets apply to a limited area and change quickly in response to changing supply of pecans during harvest. Growers from outside the market area may be attracted by a high price, but the time needed to prepare and transport a shipment puts them at a disadvantage. By the time their shipment arrives, growers from the nearby orchards may have already responded by supplying their nuts, altering market conditions and causing the price to decrease. Consequently, growers located farther away from a given local market may receive a price that is even lower than the price paid by a closer buyer, and they incur a higher transportation cost.

Comparison of the OLS estimates and the ML estimates further illustrates the relevance of spatial correlation. In particular, both the distance travelled by a grower to market his in-shell pecans and the proximity of the pecan orchard to the optimal production area were not significant when using the OLS estimator (Table 2). However, each of these two variables was found to be significant in explaining the price received by growers when the ML estimator with spatial correlation was applied. Consistent with these differences, the spatial-correlation coefficient is significant at the 5% level.

The ML estimates (Table 2) show that growers travelling a greater distance to market pecans expected to receive a lower price than growers who travelled to market pecans within a 15-mile radius from their operation. Observations of the pecan sector suggest that over time, growers and buyers develop personal relationships, and because a pecan orchard remains productive for many decades – longer than a working life of a grower – the tight relationships between buyers and growers is based on experience. A pecan buyer became familiar with the grower's management practices, varieties planted in the orchard; and the consistency in delivery of clean, quality nuts. The risk of buying a shipment of uneven quality nuts was noticeably reduced by knowledge of the pecan operation, which could be verified on a nearby site. The risk reduction works to the advantage of a grower who is able to negotiate a higher price with a neighbouring buyer than with a remote pecan buying outlet.

Consistent with the interaction of the supply and demand in a local market, ML estimates show that growers whose orchards were located closer to the optimal pecan-producing area received lower prices than did growers in other parts of Georgia: the larger the local production, the lower the price. This inverse relationship is measured in this study by the proxy variable associating an abundant supply with orchards located in the area of the most favourable climate to the pecan tree growth. This result is also consistent with the observed increased production of pecans in the optimal growing area in Georgia (Florkowski, 2001). Growers tend to ignore the role of local market conditions and focus on other local markets that may offer higher prices, interpreting the price differences as induced by buyers. Ignoring the underlying economic forces that shape the offered price at a specific location, some growers feel that the obtained price is below the prevailing market price exclusively due to the buyer's control.

The economic analysis also addresses the issue of whether there is a positive partial correlation between the value of capital equipment used on the farm and the price received by growers (Table 2). Accounting for price heterogeneity at the farm level in terms of the capital resources available to the farm is generally ignored due to lack of data and measurement problems. Interestingly, this investigation found that the effect of resources available to a grower – i.e., the value of the capital equipment and machinery – had a statistically significant, positive effect on the received price. The ownership of the highly specialized equipment is justified by growers in terms of the size of an operation, the length of orchard existence allowing the accumulation of machinery, and the age-dependent tree size requiring larger or more powerful equipment the older (and therefore bigger) the trees. Indirectly, then, the value of machinery and equipment indicates the ability of a grower to negotiate a higher price. This direction in the partial correlation between the price received by growers and the equipment underscores the existence of some level of price-bargaining power, where growers with more resources received a higher price for their in-shell pecans than did those with less equipment.

The higher the yield from the mature pecan orchard, the higher the price received by a grower. This effect was expected because it is consistent with a high level of orchard management. With proper and sustained management a perennial plant such as a pecan tree provides yields that even in the off-year in the irregular bearing pattern are higher than yields from poorly managed orchards. Growers who achieve high yields are likely to produce quality nuts sought after by the buyers.

Nut quality is to a large extent determined by the genetic makeup of a tree. A binary variable, which assumed a value of one when a variety was *Stuart*, showed statistically significant and negative influence. Growers, who delivered lots of *Stuart* pecans could expect a lower price in comparison to those supplying *Desirables*. This result is supported by observations of slow, steady shift away from *Stuart* variety towards *Desirables*. The share of the *Desirable* variety in commercial orchards of Georgia has been increasing during the last two decades, reflecting the price differences. The change has been slow because of the perennial nature of the crop.

V. Implications

The focus of research on the temporal correlation among economic variables, including agricultural commodity prices, is facilitated by the availability of data and the needs to make annual planting and marketing decisions. In regions specializing in major row crops, farmers could expect prices to differ in the amount equal to transportation costs. In the production of perennial crops, such as pecan nuts, where resources cannot be easily re-allocated to raising another crop, the spatial aspects become relatively more important. Orchards are located on specific sites and the perennial plant yields a crop every year. Instead of a crop offering the promise of high returns, a grower of pecans could select a buyer offering the highest price.

Results show the statistical and economic significance of modelling spatial correlation in the determination of in-shell pecan prices received by growers. The addition of the spatial correlation led to a substantial improvement of the significance of results. By ignoring the spatial correlation, researchers may be adopting an unsuitable modelling approach, leading to less-than-robust estimation results even though the specification may have included all relevant variables. The magnitude of the spatial correlation coefficient in this study indicates the existence of very localized markets (the coefficient value of 0.1 is small) where price effects are not easily transmitted across locations. Pecan growers are therefore highly dependent on the local supply and demand conditions in the price discovery process. This result supports earlier findings that price information obtained from even a large number of inquires may not improve the grower's bargaining position at a local market.

The comparison of results obtained using two estimation methods indicated statistically significant and positive influence of yield obtained by a grower and the value of specialized machinery and equipment. Yield improvement is a knowledge-intensive process because it is the result of a number of cultural practices – specifically in the case of pecan orchards, the protection of trees from fungal diseases and insect outbreaks, which either directly or indirectly lead to the loss of nuts or lower their quality. The best managers typically represent only a small portion of producers and this is likely to be true in the pecan industry. Research into all aspects essential to the improvement of the productivity of pecan trees will help growers, but most important is the prioritization of issues in terms of their contribution to yields. Improvements in disease resistance through breeding are highly desirable, but the progress is slowed by the long period before a tree reaches a full bearing potential. The observed loss of disease resistance of some varieties demonstrates the need for continuing efforts in this area. The current behaviour of growers plays a pivotal role and requires a diligent, timely, and consistent application of all cultural practices.

Growers who do not specialize in pecan production cannot expect to receive high prices. As is the case with many agricultural commodities, marginal enterprises bring marginal results. Without adequate equipment, a grower is unable to complete cultural practices determining the yields. Because orchard management in the southeastern USA is complicated by climatic factors, such as high humidity during most of the growing season, and the presence of insect pests, the lack of necessary equipment is a severe limitation. Growers may overcome some needs for equipment by trying the low-input management approach. In recent years, substantial progress has been made in the monitoring of conditions conducive to insect or disease development, leading to the use of pesticides on as-needed basis. However, it appears that in order for growers to remain in business, savings from the lower input use must be large enough to offset the likely lower prices growers may receive if the quality is compromised or their lower revenues if yields decline.

The advantage of accounting for spatial correlation resulted in the confirmed importance of the distance a grower travels to market his pecans. Growers selling pecans within a 15-mile radius expected higher prices than those travelling farther distances. This outcome is attributed to the buyer's ability to observe orchard management during a number of years resulting in the thorough knowledge of cultural practices and of kernel quality. Such knowledge reduces the uncertainty associated with buying a large volume of a commodity based on a test result from a small sample. This plausible interpretation is consistent with the observed close relationships between individual growers and pecan buyers. However, because the spatial-correlation coefficient suggests the existence of isolated markets, growers who have been attracted by higher prices at distant markets arrived there too late to take advantage of them. High prices likely attracted suppliers located closer to buying points, altering local supply and demand conditions causing prices to adjust rapidly.

Future work may consider the relevance of additional spatial factors including measures of weather conditions during the growing season. Such measures include the number of sun-hours, relative humidity, precipitation and temperature thresholds affecting the crop. In addition, incorporating site-specific disease information is desirable (Bertrand *et al.*, 1999). Expanding the geographical scope of the analysis will allow factors influencing price differences to be examined in other major pecan-producing regions. Improvements in data availability by continuous collection of information and maintaining reports in a consistent format will advance the empirical investigations and raise the level of accuracy.

References

Anselin, L. and Florax, R. J. G. M. (1995) *New Directions in Spatial Econometrics*, Springer Verlag, New York.

Bertrand, P. F., Brenneman, T. B. and Stevenson, K. C. (1999) Disease assessment and uniformity in rating methods, in *Pecan Industry: Current Situation and Future Challenges* (Eds) B. McCraw, E. H. Dean and

B. W. Wood, USDA, ARS, Washington, DC, pp. 124–32.

Elnagheeb, A. H. and Florkowski, W. J. (1993) Modelling perennial crop supply: an illustration from the pecan industry, *Journal of Agricultural and Applied Economics*, **25**, 187–96.

Epperson, J. E. and Allison, J. R. (1980) Price futures for the United States pecan industry, *HortScience*, **15**, 475–8.

Florkowski, W. J. (1996) Nuts, in *Quality of US Agricultural Products* (Ed.) L. D. Hill, CAST, Task Force Report 126, Des Moines, Iowa, pp. 111–38.

Florkowski, W. J. and Wu, X.-L. (1990) Simulating impact of pecan storage technology on farm price and growers' income, *Southern Journal of Agricultural Economics*, **22**, 217–22.

Florkowski, W. J., Purcell, J. C. and Hubbard, E. E. (1992) Importance for the US pecan industry of communicating about quality, *HortScience*, **27**, 462–64.

Florkowski, W. J., Crocker, T. F. and Humphries, G. (2001) *Commercial Pecan Tree Inventory*, *Georgia 1997*, Research Report 678, November, University of Georgia College of Agricultural and Environmental Sciences, Georgia Agricultural Experiment Station, Athens, GA, 63pp.

Fonsah, G. E., Harrison, K. and Mitchell, B. (2002) Pecan enterprise cost analysis, AGECON-02-077, September, Cooparative External Service, College of Agriculture and Environmental Science University of Georgia, Athens, GA, 22pp.

Harris, M. K. (1985) Pecan phenology and pecan weevil biology and management, in *Pecan Weevil: Research Perspective* (Ed.) W. W. Neel, Quail Ridge Press, Inc., Brandon, MS, pp. 51–8.

Hubbard. E. E., Purcell, J. C. and Florkowski, W. J. (1988) Issues that have surfaced in Marketing Pecans in Georgia, Research Report 564, November, The Georgia Agricultural Experiment Stations, College of Agriculture, The University of Georgia.

Kays, S. (1991) Post harvest quality, in *Pecan Husbandry: Challenges and Opportunities* (Eds) B. W. Wood and J. A. Payne, USDA, ARS, Washington, DC, pp. 194–228.

Kelejian, H. and Robinson, D. (1995) Spatial correlation: a suggested alternative to the autocorrelation model, in *New Directions in Spatial Econometrics* (Eds) L. Anselin and R. J. G. M. Florax, Springer Verlag, New York.

Latham, A. J. and Goff, W. D. (1991) Pecan scab: a review and control strategies. in *Pecan Husbandry: Challenges and Opportunities* (Eds) B. W. Wood and J. A. Payne, USDA, ARS, Washington, DC, pp. 89–93.

McEachern, G. R. (1991) Keys to profitability for commercial pecans, in *Pecan Husbandry: Challenges and Opportunities* (Eds) B. W. Wood and J. A. Payne, USDA, ARS, Washington, DC, pp. 40–6.

Okunade, A. A. and Cochran, M. J. (1991) Functional forms and firm-level demand for pecans by variety, *Southern Journal of Agricultural Economics,* **23**, 95–102.

Pena, J. G. (1995) The 1993 pecan/tree nut marketing season: an overview of production, prices and the pecan market collapse, in *Sustaining Pecan Productivity into the 21st Century* (Eds) M. W. Smith, W. Reid and B. W. Wood, USDA, ARS, Washington, DC, pp. 88–109.

Pope, R. D. and Chavas, J. P. (1994) Cost function under production uncertainty, *American Journal of Agricultural Economics*, **76**, 196–204.

Sanderlin, R. S. (1995) Effect of nut scab on pecan yield and quality components, in *Sustaining Pecan Productivity into the 21st Century* (Eds) M. W. Smith, W. Reid, and B. W. Wood, USDA, ARS, Washington, DC, pp. 45–9.

Shafer, C. E. (1989) Price and value effects of pecan crop forecasts, 1971–1987, *Southern Journal of Agricultural Economics*, **21**, 97–103.

Simon C. P. and Blume, L. (1994) *Mathematics for Economists*, Norton & Company, New York.

Sparks, D. (1992) *Pecan Cultivars*, Pecan Production Innovations, Watkinsville, GA.

Wells, G. J., Miller, S. E. and Thompson, C. S. (1984) Farm level demand for pecans reconsidered, *Southern Journal of Agricultural Economics*, **16**, 157–60.

Worley, R. E. (1994) Pecan physiology and composition, in *Pecan Technology* (Ed.) C. R. Santerre, Chapman and Hall, New York, NY, pp. 39–48.

USDA-NASS, *Agricultural Statistics*, various issues, Washington, DC.