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Price Discovery and Integration in U.S. Pecan Markets

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Abstract

The United States is a major supplier in the world pecan market. Using grower-level pecan price data from the 2005–2016 seasons, we estimate pecan market integration patterns among Texas, Oklahoma, Georgia, and Louisiana using causality structures identified through cutting-edge machine-learning methods. Current pecan price received by growers in Texas is a direct cause of those in Oklahoma, Georgia, and Louisiana. Past-period grower-level pecan price in Georgia either directly or indirectly influences the current price in other states. These findings are useful for businesses and the government in order to price and promote marketing of pecan.

Keywords: directed acyclic graphs, machine learning, market integration, pecan markets, price discovery

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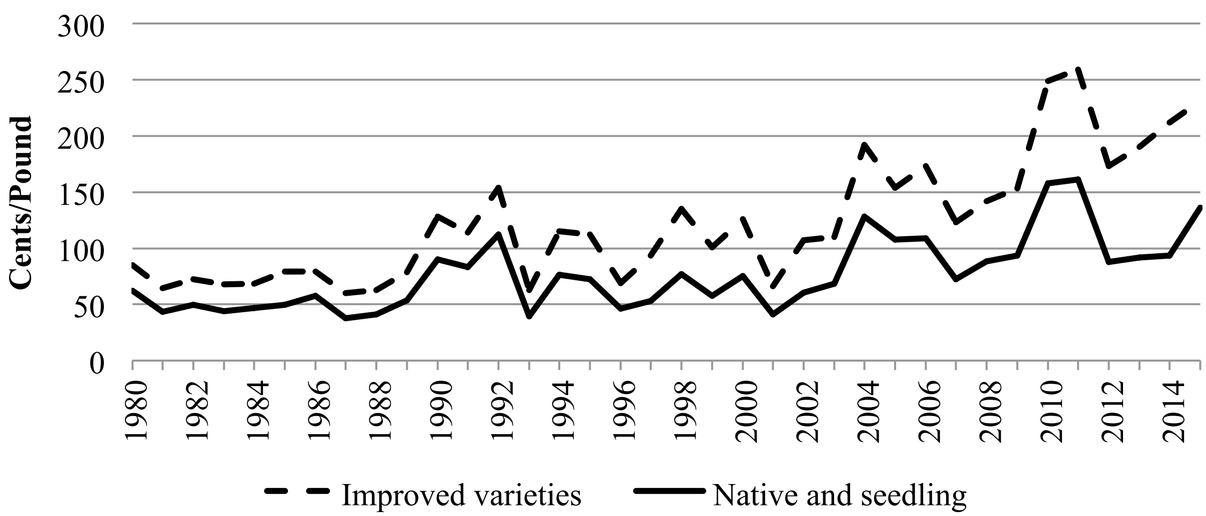
Introduction

The United States is a major worldwide supplier of tree nut products, particularly pecan and almond (International Nut and Dried Fruit Council, 2015; California Almond Board, 2016). The United States supplies about 55% of the world's pecan, while Mexico comes in second at about 38% of market share. However, pecan has lost its share in the U.S. tree nut market, while almond has taken the most of the potential growth since the 2010/11 season. The U.S. pecan market was valued at $560 million in the 2015/16 season (U.S. Department of Agriculture, 2017). Some research with regard to several players in the pecan supply chain is beginning to emerge. Ibrahim and Florkowski (2007) studied sheller-level pecan prices, while Dharmasena and Capps (2017) focused on consumer-level pecan prices. Figure 1 shows season-average pecan prices when growers sell their pecans to shellers/processors. While there is an increasing trend, it fluctuates seasonally due to the alternate bearing character of pecan (Shafer, 1996). In early 2016, the U.S. Department of Agriculture (USDA) approved a federal marketing order, which supports better marketing conditions for fruit, vegetable, dairy, and specialty crop producers and handlers (USDA, 2016). Research on pecan prices was emphasized to help shape current and future U.S. pecan marketing programs.

Figure 1. In-Shell Pecan U.S. Season-Average Grower Price, 1980–2016



Notes: Estimates discontinued in 1996 for Missouri and Tennessee. Estimates since 2005 include Missouri.

Oklahoma, Texas, and Georgia produce approximately 90% of the pecan production of native varieties, while Georgia, New Mexico, Texas, and Arizona account for about 95% of total production of improved varieties. Given the nature and the location of pecan production in the United States, it is likely that the pecan price in one state affects or is affected by pecan price in another state. Major pecan markets in Texas, Oklahoma, Georgia, and Louisiana might be integrated in some form, affecting price-discovery patterns. Understanding pecan price integration patterns will be imperative for upstream players in the pecan supply chain (such as growers, shellers, and wholesalers) as they attempt to discover pecan price each season.

Using biweekly data from 2005–2016, we investigate pecan price integration patterns among Texas, Oklahoma, Georgia, and Louisiana using causality structures identified through cutting-edge machine-learning methods. We find that pecan price at the grower level in Texas contemporaneously determines pecan price in Oklahoma, Louisiana, and Georgia, making Texas pecan price a common cause. In the current time, Oklahoma, Louisiana, and Georgia only receive price signals, making them strictly endogenous in the price-discovery process. Georgia's past-period price is a common cause for Georgia, Texas, and Louisiana's current-period prices, making Georgia's past-period price strictly exogenous. Also, Louisiana's past-period price affects Louisiana and Oklahoma's current-period prices.

Literature Review

Wood (2001) found that pecan's alternate-bearing characteristic caused significant marketing problems in the U.S. pecan industry and that pecan prices have a much stronger relationship with supply at the national level than at the state level. In addition to the supply side, he found both the prices of substitutable nuts and competition among shellers/processors to influence pecan price.

Shafer (1996) found that expected pecan production in the current season and carry-in stocks from the previous year mainly determine pecan price in each season. He found that relatively high pecan prices in 1990–1995 were caused by lower production and stocks in those years. In addition, he noted a growing trend in international trade in pecan as well as a significant impact on U.S. pecan market prices from pecan import volumes. Ibrahim and Florkowski (2005) analyzed the relationship between pecan price and pecan cold storage inventory by applying seasonal cointegration methods to deal with pecan price seasonality. Ibrahim and Florkowski (2007) found that the price of shelled pecan and its inventories are nonstationary and have long-run relationships.

Dharmasena and Capps (2017) concentrated on the demand side of tree nut products, including pecan. They estimated the own-price elasticity of demand (0.98) and market penetration (7%) for pecan. They concluded that income, age, region, and presence of children are significant drivers of pecan consumption at the U.S. household level. In addition, Moore et al. (2009) analyzed the effectiveness of state-level pecan promotion programs and found that they had a statistically significant impact on increased sales for improved varieties but not for native varieties. Palma and Chavez (2015) studied the potential implications of federal marketing orders on pecan price and concluded that average pecan price at the grower level would increase by $0.063 for improved varieties and $0.036 for native varieties.

Very few studies in the extant literature have examined the movement of U.S. pecan prices. To the best of our knowledge, this article is the first to look at grower-level market integration patterns in the U.S. pecan market. This article investigates the relationships between grower-level pecan prices in four major pecan markets (Georgia, Texas, Louisiana, and Oklahoma) in the southern United States.

Data and Methods

Average grower-level pecan prices in Georgia, Texas, Louisiana, and Oklahoma are obtained from the U.S. Department of Agriculture Agricultural Marketing Service (USDA-AMS). Since grower-level pecan prices are recorded by season, the data usually range from October to February for each year, which is when most pecan growers harvest their crop and sell to shellers/processors. For example, pecan prices from October 2005 to January 2006 are categorized as the 2005 season.

Summary statistics of grower level pecan prices from seasons 2005–2016 are presented in Table 1. A few missing data points in the USDA-AMS report for the 2011, 2012, and 2013 seasons for Texas and Oklahoma were generated by estimating an autoregressive model with one lag. SIMETAR© statistical software (Richardson, 2008) was used to estimate these models. In addition, pecan price is recorded as non-shelled basis until the 2014 season, after which it changed to shelled basis beginning in the 2015 season. Converting non-shelled pecan price to shelled requires knowing the nut-yield percentage—the ratio of shelled to unshelled pecan weight—which determines the weight of actual nut once the shell is removed. There are over 10 varieties of improved pecans, each with a different nut yield. The conversion from non-shelled to shelled price is a linear transformation, which does not affect the correlation among the price variables. Therefore, non-shelled prices are not adjusted for shelled prices in this study. We also use biweekly average per pound price of all varieties of pecan (including improved, natives, blends, and mix budded, which are recorded in shelled basis in dollars per pound). According to Table 1, pecan prices in all four states are comparable: Georgia and Texas have higher prices per pound ($1.49/lb and $1.47/lb) compared to Louisiana and Oklahoma ($0.96/lb and $0.98/lb).

Table 1. Grower-Level Pecan Prices by State ($/lb)

	Georgia	**Louisiana**	**Oklahoma**	**Texas**
Mean	1.49	0.96	0.98	1.47
Standard Deviation	0.55	0.34	0.35	0.48
Minimum	0.55	0.41	0.45	0.57
Maximum	3.47	1.66	2.55	3.11

This study estimates integration patterns among grower-level pecan prices in Texas, Oklahoma, Georgia, and Louisiana using causality structures identified through cutting-edge machine-learning algorithms applied to the underlying variance–covariance matrix (or the underlying correlation matrix) of price variables. Causality structures among price variables are developed using Directed Acyclic Graphs (DAGs), as explained in Pearl (2009). Table 2 presents Pearson correlation matrix that show correlation between current and previous-year pecan prices. Current pecan prices in every state are positively correlated with previous pecan prices in the same and other states. Even though we intuitively assume that previous price affects current price, the correlation matrix itself does not provide clear evidence for causal structures among these prices.

Dharmasena, Bessler, and Capps (2016) used a machine-learning algorithm called Greedy Equivalence Search (GES) to select appropriate predictors to conduct regression analysis as applied to variables determining food insecurity in the United States. GES is a part of TETRAD

Table 2. Correlation Matrix of Pecan Prices

	GA(*t*)	LA(*t*)	OK(*t*)	TX(*t*)	GA(*t* - 1)	LA(*t* - 1)	OK(*t* - 1)	TX(*t* - 1)
GA(*t*)	1.00							
LA(*t*)	0.45	1.00						
OK(*t*)	0.32	0.48	1.00					
TX(*t*)	0.41	0.40	0.32	1.00				
GA(*t* - 1)	0.51	0.60	0.33	0.48	1.00			
LA(*t* - 1)	0.35	0.82	0.52	0.24	0.45	1.00		
OK(*t* - 1)	0.27	0.43	0.72	0.17	0.32	0.49	1.00	
TX(*t* - 1)	0.29	0.45	0.39	0.65	0.41	0.39	0.31	1.00

Notes: GA(*t*), LA(*t*), OK(*t*), TX(*t*), GA(*t* - 1), LA(*t* - 1), OK(*t* - 1), and TX(*t* - 1) represent pecan price received by growers in time periods *t* and (*t* – 1) in Georgia (GA), Louisiana (LA), Oklahoma (OK), and Texas (TX), respectively.

statistical package (Glymour et al., 2014), which searches causal models using artificial intelligence and DAG (see Chickering, 2002, for details). The GES algorithm compares many possible types of directed acyclic graphs (DAG) to search for the optimum graph associated with price variables.

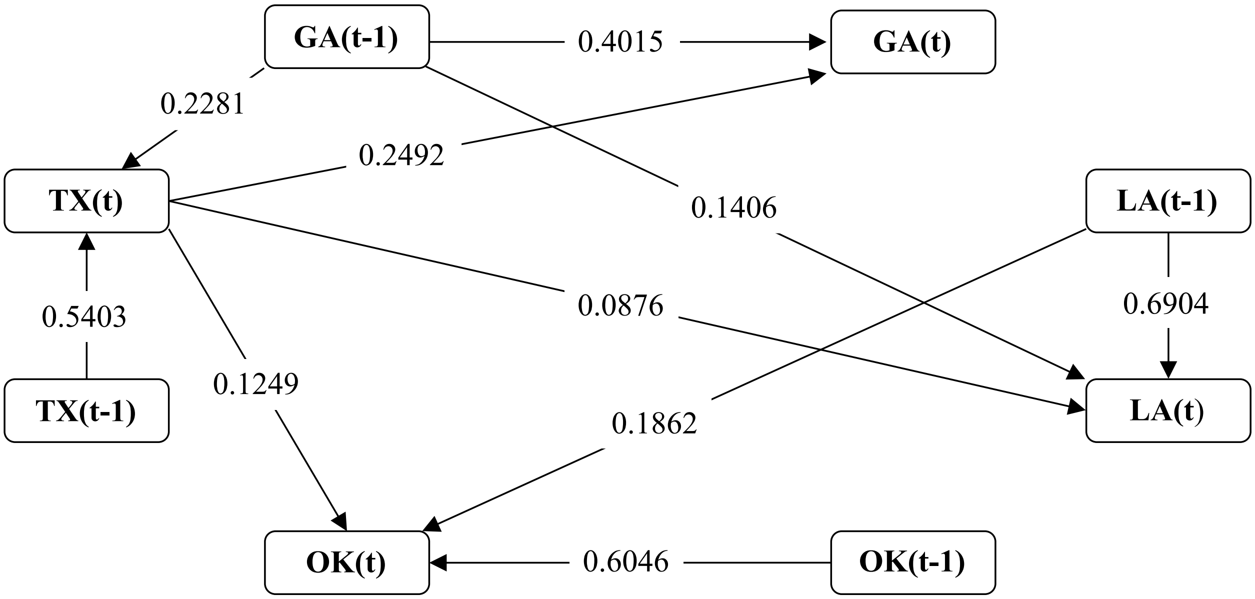
Empirical Results

Figure 2 shows the DAG associated with current and previous grower-level pecan prices in Texas, Georgia, Louisiana, and Oklahoma. Each edge with direction determines the predictor and predicted variables in the regression model. Each number on an edge is the estimated slope coefficient of the predictor variable when arrow-received variable (dependent variable) is regressed on every causing variable (independent variable). For example, the current Texas pecan price can be explained by Texas and Georgia's previous pecan prices. When TX(*t*) is regressed on TX(*t* - 1) and GA(*t* - 1), the slope coefficients for the two independent variables are 0.5403 and 0.2281, respectively. Table 3 shows slope coefficients and p-values for each estimated edge.

Texas's current pecan price is a common-cause variable for current prices in Georgia, Louisiana, and Oklahoma. Even though current Texas pecan price blocks the path, if included in the regression model, the previous Texas price also indirectly influences current pecan price in Georgia, Louisiana, and Oklahoma in a causal chain relationship. A higher current Texas pecan price drives pecan prices in Oklahoma, Georgia, and Louisiana to increase at the grower level. As shown in Table 3, the current pecan price in Georgia has the highest slope coefficient (0.2492) and Louisiana has the lowest (0.0876) with respect to Texas being a common cause variable.

Current-period pecan price in Georgia is affected by both current price in Texas and its own previous period price. Current Texas pecan price is the only current factor that directly affects Georgia's price. Considering the large amount of pecan production in Georgia, it is interesting

Figure 2. Directed Acyclic Graph (DAG) of Current and Past Pecan Prices



Notes: GA(*t*), LA(*t*), OK(*t*), TX(*t*), GA(*t* - 1), LA(*t* - 1), OK(*t* - 1), and TX(*t* - 1) represent pecan price received by growers in time periods *t* and (*t* – 1) in Georgia (GA), Louisiana (LA), Oklahoma (OK), and Texas (TX), respectively.

Table 3. Parameter Estimates for Each Edge

From	To	Slope Coefficient	p-value
GA(*t* - 1)	GA(*t*)	0.4015***	0.0001
GA(*t* - 1)	LA(*t*)	0.1406***	0.0005
GA(*t* - 1)	TX(*t*)	0.2281***	0.0014
LA(*t* - 1)	LA(*t*)	0.6904***	0.0000
LA(*t* - 1)	OK(*t*)	0.1862**	0.0185
OK(*t* - 1)	OK(*t*)	0.6046***	0.0000
TX(*t* - 1)	TX(*t*)	0.5403***	0.0000
TX(*t*)	GA(*t*)	0.2492**	0.0280
TX(*t*)	LA(*t*)	0.0876**	0.0355
TX(*t*)	OK(*t*)	0.1249**	0.0127

Notes: GA(*t*), LA(*t*), OK(*t*), TX(*t*), GA(*t* - 1), LA(*t* - 1), OK(*t* - 1), and TX(*t* - 1) represent pecan price received by growers in time periods *t* and (*t* – 1) in Georgia, Louisiana, Oklahoma, and Texas, respectively. Single, double, and triple asterisks (*, **, **) denote statistical significance at the 10%, 5%, and 1% levels, respectively.

that Georgia's price is not a common-cause variable for other states. However, the previous-period Georgia price has direct causal relations with its own current price as well as the current price in Texas and Louisiana, making it a common cause. Past pecan price in Georgia also indirectly affects current pecan price in Oklahoma via Texas in a causal chain relationship.

Current pecan price in Louisiana is affected by its previous price, the previous pecan price in Georgia, and current pecan price in Texas. Current pecan price in Louisiana does not directly affect current prices of other states. Previous pecan price in Louisiana also affects current price in Louisiana and Oklahoma.

Current pecan price in Oklahoma is affected by current price in Texas and previous prices in Louisiana and Oklahoma. Oklahoma and Louisiana have the smallest pecan production among the states in this study; thus, we expect them not to be common-cause variables. Unlike that of Louisiana, previous pecan price in Oklahoma only affects its current price.

Conclusions

To summarize, among the four southern states considered in this study, Texas pecan price is weakly exogenous, meaning there are arrows coming into current Texas price (from past-period Texas and Georgia prices) as well as arrows going out (to current Oklahoma, Louisiana, and Georgia prices). Texas is the price leader in the current pecan market at the grower level since it directly causes current-period pecan prices in the other three states considered. However, past pecan price in Texas only affects its current price.

Current pecan price in Georgia does not affect any other states directly or indirectly, making Georgia strictly endogenous with regard to grower-level pecan price. However, past pecan price in Georgia is a common cause for current pecan price in Georgia, Texas, and Louisiana, making past-period pecan price in the largest pecan-growing state strictly exogenous. Past pecan prices in Georgia and Louisiana also affect the current pecan price in Oklahoma in a direct and indirect way, respectively. Thus, Georgia has the most influential past pecan prices affecting current price. In contemporaneous time, the Texas pecan price is the leader in determining grower-level pecan price. However, in lagged time, Georgia pecan price leads grower-level pecan price in Texas, Oklahoma and Louisiana.

Even though New Mexico produces approximately 30% of improved pecan, this study does not include the state due to the absence of consistent data. If those data had been available, it would have been possible to develop more refined graphical causal structures showing price information from New Mexico.

This study shows direct and indirect causal relationships among pecan prices from four southern U.S. states estimated using machine-learning algorithms and directed acyclic graphs. It establishes market integration patterns in the current and lagged-period pecan market with historical data from 2005 to 2016. These findings are expected to be useful to promote pecan marketing and design state-level pecan marketing programs.

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