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# Economic Benchmark Model and Analysis of the Effects of the Chinese Tariff on the U.S. Pecan Industry


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AMERICAN PECAN COUNCIL

FABA
FORECASTING AND BUSINESS ANALYTICS

# ECONOMIC BENCHMARK MODEL AND ANALYSIS OF THE EFFECTS OF THE CHINESE TARIFF ON THE U.S. PECAN INDUSTRY

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**Abstract:**
This report presents and describes the first economic model of the U.S. pecan industry ever developed. Known as PecanMod, the model replicates the functioning of the pecan industry for analysis of economic issues of importance to the pecan industry. After reviewing past research to analyze economic behavior in the U.S. pecan industry, the report discuss the structure of the U.S. pecan industry, identifies the data needed to model the economic activities of the industry, and evaluates the critical data gaps that exist. After laying out the structure and functioning of PecanMod, the report demonstrates the features and usefulness the model by performing an analysis with the model of the U.S. pecan industry impacts of the Chinese import tariffs in 2017/18 and 2018/19. At the end, the report offers some comments on future uses of PecanMod and the continued evolution of the model required to insure that the model captures the full dynamics of the U.S. pecan industry.

**Acknowledgements:**
We gratefully acknowledge funding for this project from the American Pecan Council and for helping us to understand how the U.S. pecan industry functions. We also are greatly indebted to Loren Burns, AFCERC Program Manager, and student workers for excellent data and administrative support. Nevertheless, findings and conclusions are those of the authors and do not necessarily represent the views of the American Pecan Council or Texas A&M University.

A Limited Liability Company formed in Texas in 2001, FABA was founded on the belief that to utilize information effectively in a decision-making process, real world experience, sound econometric and statistical skills, and advanced analytical ability are necessary. FABA provides a mix of theoretical horsepower and real world experience in designing and implementing research projects for its clients. FABA draws on resources with experience across many different private sector applications, with a common goal of utilizing econometric and statistical tools to create effective forecasting and other analytical tools that enable better decisions. FABA provides complete forecasting and business analytic solutions centering on the development of econometric/statistical models to aid decision-making in the business community in two ways: (1) analyses to better interpret the business, economic, and financial landscape and (2) forecasts to provide a better vision of the future.

## EXECUTIVE SUMMARY

This report presents and describes the first economic model of the U.S. pecan industry ever developed. We first summarize the findings of past research that analyzes economic behavior in the U.S. pecan industry. We then discuss the structure of the U.S. pecan industry, identify the data needed to model the economic activities of the industry, and evaluate the critical data gaps that exist. Next, we briefly discuss the model of the U.S. pecan industry developed to replicate the functioning of the industry known as PecanMod. To demonstrate the features and usefulness of PecanMod, we use the model to perform an analysis of the impact of the Chinese import tariffs in 2017/18 and 2018/19 on the U.S. pecan industry. At the end, we offer some comments on future uses of PecanMod and the continued evolution and uses of the model.

While providing many important insights on the U.S. pecan industry, none of the previous economic research efforts on pecans attempted to develop a viable structural model of the U.S. pecan industry for at least two reasons: (1) a lack of needed data; and (2) the on-off production behavior of pecan trees which tends to swamp the economic forces making statistical efforts to disentangle the economic drivers from the biological drivers in pecan markets quite difficult.

A review of the structure of the pecan industry and available data concludes that while some data related to the pecan industry are available, much data needed to characterize many critical activities in the U.S. pecan industry are not. Missing are historical, consistent, and reliable data on critical activities such as acreage planted and harvested, trees removed by pecan variety, purchases by accumulators, wholesalers, and shellers, purchases by various retailers by type or as a group, purchases by various industrial users by type or as a group, and exports to specifically identified destinations. Price data associated with most of those activities also are not available for analysis. In addition, some of the available data are not useful or reliable for analysis such as exports by destination and terminal prices. Other available data are not specific as to type, such as domestic utilization for which there is no breakdown by retail or industrial uses.

We developed PecanMod as a relatively powerful economic model based on the available data. PecanMod is an econometric simulation model consisting of a set of equations that explain the movement over time of 13 key industry activities, including (1) improved pecan production (in-shell), (2) native pecan production (in shell), (3) total pecan production (in-shell), (4) total pecan production (shelled), (5) pecan import supply, (6) domestic pecan utilization, (7) ending stock demand, (8) export demand, (9) price of improved pecans (in-shell), (10) price of native pecans (in-shell), (11) average producer price of pecans (shelled), (12) import price of pecans, and (13) export price of pecans. Using statistical procedures (econometrics), the relationship between these key industry activities and the drivers that explain the economic behavior of each were determined.

For example, the econometric procedure determined that price is a statistically significant driver of production, import supply, export demand, domestic demand, and pecan stock demand behavior. Even so, the procedure concluded that each of those market activities are price inelastic, that is, not highly responsive to price changes. Various statistical measures confirm PecanMod does an excellent job of tracking the historical functioning of the U.S. pecan industry.

To demonstrate its features and usefulness, we use PecanMod to conduct a counter-factual simulation of the effects of the increased Chinese tariff in 2017/18 and 2018/19 on the U.S. pecan industry. The results indicate that over these two years, the main effect of the tariffs in those years was to reduce U.S. pecan exports and prices with some corresponding increase in domestic use and little or no effect on effect on production. The U.S. price declines plus the decline in exports and the small decline in production all as a result of the tariffs led to sizeable declines in producer and export revenues of $215 million (16%) and $239 million (17%), respectively.

We used the counterfactual simulation results to determine how much of the actual change in industry activities that occurred between 2017/18 and 2018/19 was due to weather and other issues affecting production that year and how much was due to the tariff. The results indicate that nearly all of the declines in producer and export prices and nearly half of the drop in export volume that actually occurred between 2017/18 and 2018/19 were due to the tariff, with the rest of the export decline due to other market forces such as the decline in production in 2018/19. The tariffs were also responsible for about half of the drop in producer revenue and two-thirds of the drop in export revenue with the remainder due to other market forces that year.

PecanMod is a powerful analytical tool that is capable of analyzing the effects of many key economic forces on the U.S. pecan industry. The model is limited by a lack of data for key industry activities and by the consistency and reliability of available data. Like all models, PecanMod will need to evolve over time given changes that occur in the industry. As well, the model will need to expand to better capture the complex and extremely dynamic nature of the pecan industry. The analysis of the 2017/18 and 2018/19 Chinese tariffs on imports of U.S. pecans provides an excellent demonstration of what PecanMod can already do in analyzing the effects of economic events impacting the U.S. pecan industry. The attribution analysis demonstrates some of the additional insights that analysis with PecanMod can provide.

PecanMod is the exclusive property of the American Pecan Council (APC). The model will reside at Texas A&M University to allow researchers to update and refine the model over time. Future analysis using the PecanMod can be carried out but only at the request of APC under separate contracts for the work requested.

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# Economic Benchmark Model and Analysis of the Effects of the Chinese Tariff on the U.S. Pecan Industry

Strategic decision-making in any U.S. crop industry requires good information regarding the effects of changes in U.S. and foreign government policies, weather, macroeconomic conditions, disease issues, and other key market influencers on production, utilization, and prices not only in the domestic market but also in foreign markets. The extensive information and data available on the structure and functioning of major U.S. field crop and livestock markets have enabled both public (USDA) and private groups (FAPRI and others) to develop policy and forecast tools to analyze the impacts of policy shifts or market changes on markets and producer profitability. In contrast, the data and information relating to the structure and functioning of U.S. pecan markets is much more limited. In addition, the off-and-on-year behavior of pecan production has infused considerable year-to-year and long-term variability into U.S. pecan markets which swamps the influence of both economic and policy variables on those markets. With both limited data and a high degree of biologically-induced market variability, little effort has been made in the past to develop reliable economic models for the pecan industry to aid in strategic economic and policy decision-making.

The beginning point in developing a useful economic model for the pecan industry is to determine what relevant research may have already been done. Thus, for this project we first conducted an in-depth review of published pecan industry modeling efforts to gain insights on the state of research efforts, research challenges, and appropriate methodologies. The next step was to define the economic structure of the industry and the data needed to model how the industry functions. Gaps in the data were identified which required adjustments in the specification of the industry model. A database for the major activities in the pecan industry was developed to support the development of a baseline economic model that replicates the structure and functioning of the pecan industry to the extent of the available data. The model developed based on the available data (known as PecanMod) is capable of analyzing impacts on the U.S. pecan industry (production, utilization, price, trade, etc.) from major market changes and policy shifts. The model includes functions that identify the key factors (drivers) that influence U.S. pecan supply, demand, trade (exports and imports), and other supply chain activities as allowed by the data. The model will allow economic analyses of the impacts of various issues facing the U.S. pecan industry.

In this report, we first review past research to analyze economic behavior in the U.S. pecan industry. We then discuss the structure of the U.S. pecan industry, identify the data needed to model the economic activities of the industry and evaluate the critical data gaps that exist. Next, we briefly discuss the model of the U.S. pecan industry developed to replicate the functioning of the industry (PecanMod). A more detailed technical documentation of the model can be provided separately. Then, to demonstrate the features and usefulness of PecanMod, we use the model to perform an analysis of the impact of the Chinese import tariffs in 2017/18 and 2018/19 on U.S. pecan production prices, consumption, inventories, exports, imports, and industry revenue. At the end, we offer some comments on future uses of PecanMod and the continued evolution of the model required to insure that the model captures the full dynamics of the U.S. pecan industry.

## Past Research on Modeling the U.S. Pecan Industry

A number of economic studies have analyzed various components of the U.S. pecan industry. In this section, we provide an overview of the main studies that have been done. A more detailed chronological review of these studies is provided in Appendix 1. Although providing insights on various aspects of the pecan industry, past studies have provided only a fragmented view of the key activities and functions of the U.S. pecan industry.

Jones *et al.* (1932) was the first study to provide basic economic information to assist the development of the pecan industry through a survey focused on production, cost of production, and marketing. Palma and Chavez (2015) provided a more current overview of the pecan industry in the United States and the potential effects on supply and demand from the proposed Federal Marketing Order (FMO) for pecans. Florkowski, Purcell, and Hubbard (1992) surveyed pecan growers from Georgia to provide information about knowledge of and perceived adequacy of pecan quality standards. Wood (1993), Shafer (1996), Reid and Hunt (2000), and Wood (2001) all focused on production relationships for pecans. Onunkwo and Epperson (2000) dealt with the impacts of federal promotion programs on the foreign demand for U.S. pecans. Ibrahim and Florkowski (2005) analyzed the relationship between the pecan price and pecan cold storage inventory behavior. A 2007 study by the same authors examined the relationship between shelled pecan prices and inventories. Moore, Williams, Palma, and Lombardini (2009) conducted an evaluation of the economic effectiveness of the Texas Pecan Checkoff Program in expanding sales of Texas pecans. Kim and Dharmasena (2018) discussed price linkages across pecan producing states, particularly Georgia and Texas. Sumner and Hanon (2018) as well as Williams, Capps, and Salin (2018) considered the potential impacts of retaliatory tariffs on pecans. The majority of previous studies, however, centered attention on the demand for pecans (Lerner, 1959; Dhaliwal, 1972; Wells, Miller, and Thompson, 1986; Florkowski, You, and Huang, 1999; Park and Florkowski, 1999; and Cheng, Dharmasena, and Capps, 2019).

While providing many important insights on the U.S. pecan industry, none of the previous economic research efforts attempted to develop a viable structural model of the U.S. pecan industry for at least two reasons. First, the lack of critical data has made efforts to analyze more than a few aspects of the industry difficult if not impossible. Nevertheless, past studies have failed to address missing data issues for the key components of the pecan industry. Second, the dynamic nature of the pecan industry derived from the on-off production behavior of pecan trees has injected a high degree of variability into pecan markets over the years, which has swamped economic forces making statistical efforts to disentangle the economic drivers from the biological drivers in pecan markets quite difficult.

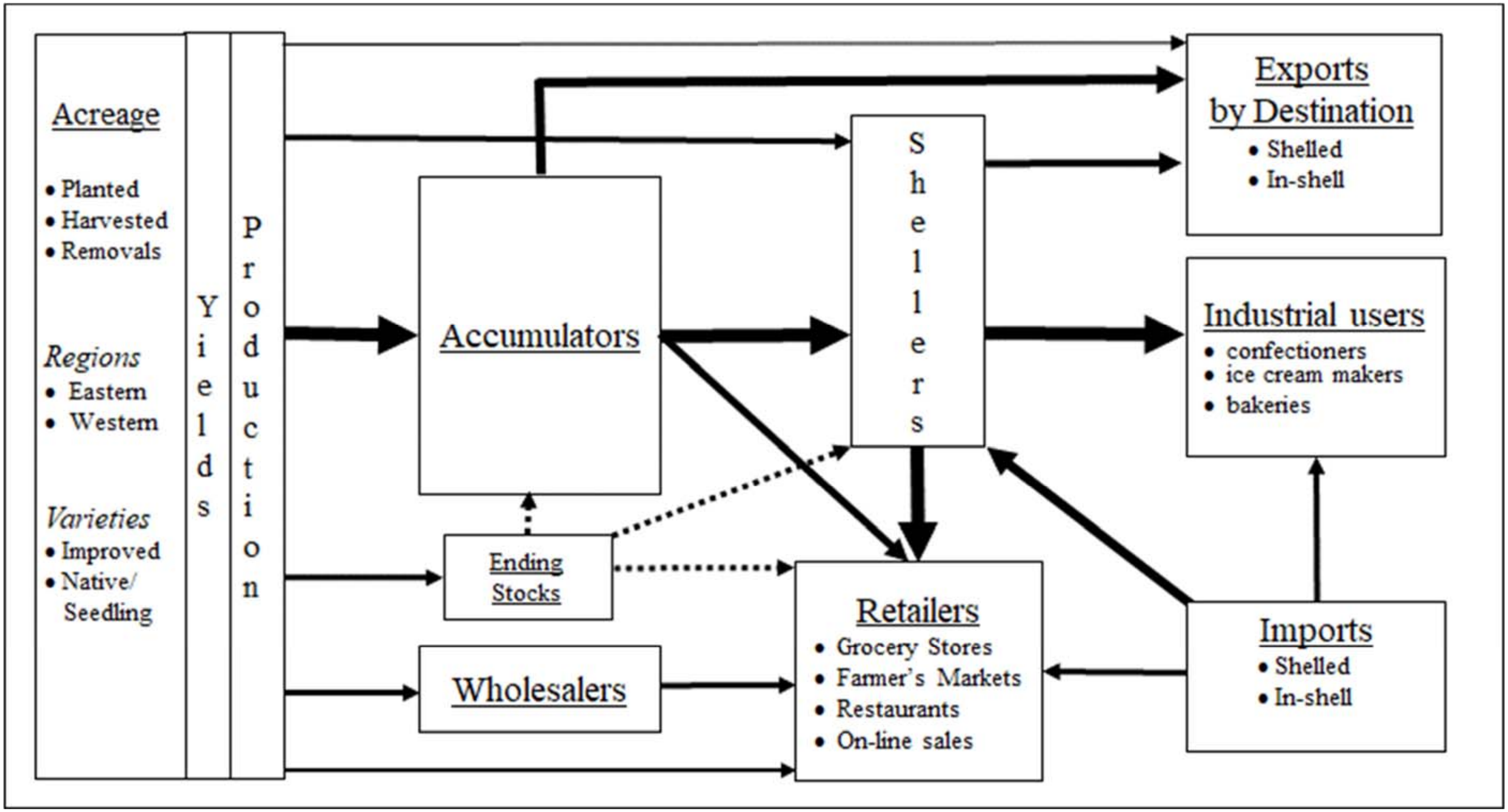
This study bridges the gaps in the economic literature using available data. Specifically, we develop a model of the U.S. pecan industry taking into account production relationships, import supply, export demand, domestic demand, and price linkages consistent with available data. We address data issues and use available data for the period of 1980 to 2018 to conduct an empirical analysis of the key relationships in the industry as allowed by the data. To demonstrate the usefulness of the model, we analyze the effects of the Chinese import tariff on U.S. pecans.

## Structure of the U.S. Pecan Industry

The structure of the U.S. pecan industry is complex as depicted in Figure 1. At the left of that figure, pecan growers across the U.S. Eastern and Western regions plant, remove, and maintain existing pecan trees and harvest both improved varieties as well as native/seedling pecans. Pecan production is highly variable from year to year due to the alternate bearing behavior of pecan trees (on/off production behavior). Alternate bearing is a biological phenomenon where trees bear heavy and light crops in alternate years. The consequence is a high degree of year-to-year variability in U.S. pecan production. The variability in production in transmitted through the supply chain to processing and handling and all the way to end uses and prices.

U.S. pecan production is divided into two main groups, native/seedling ("wild") and improved varieties. Native pecans tend to have thicker shells and smaller nuts than improved varieties (Nesbitt, Stein, and Kamas, 2013). The more thin-shelled improved varieties are preferred in commercial use because they are more easily shelled and tend to yield more pecan meat per pound of in-shell nuts. Different pecan varieties tend have varying oil content, which affects the texture and flavor of the pecan kernel (Nesbitt, Stein, and Kamas, 2013). Newly planted pecan trees will become harvestable in five to eight years and can be productive for 100 years or longer (Call, Gibson, and Kilby, 2006). Profit margins are often more narrow for native pecans (Nesbitt, Stein, and Kamas, 2010). Managed native pecan groves tend to produce 500 to 1,000 pounds of nuts per acre per year while native pecans can produce from 1,000 pounds to 2,000 pounds per acre per year, each with high yields one year and low the next.

**Figure 1. Economic Structure of the U.S. Pecan Industry (No Data Gaps)**



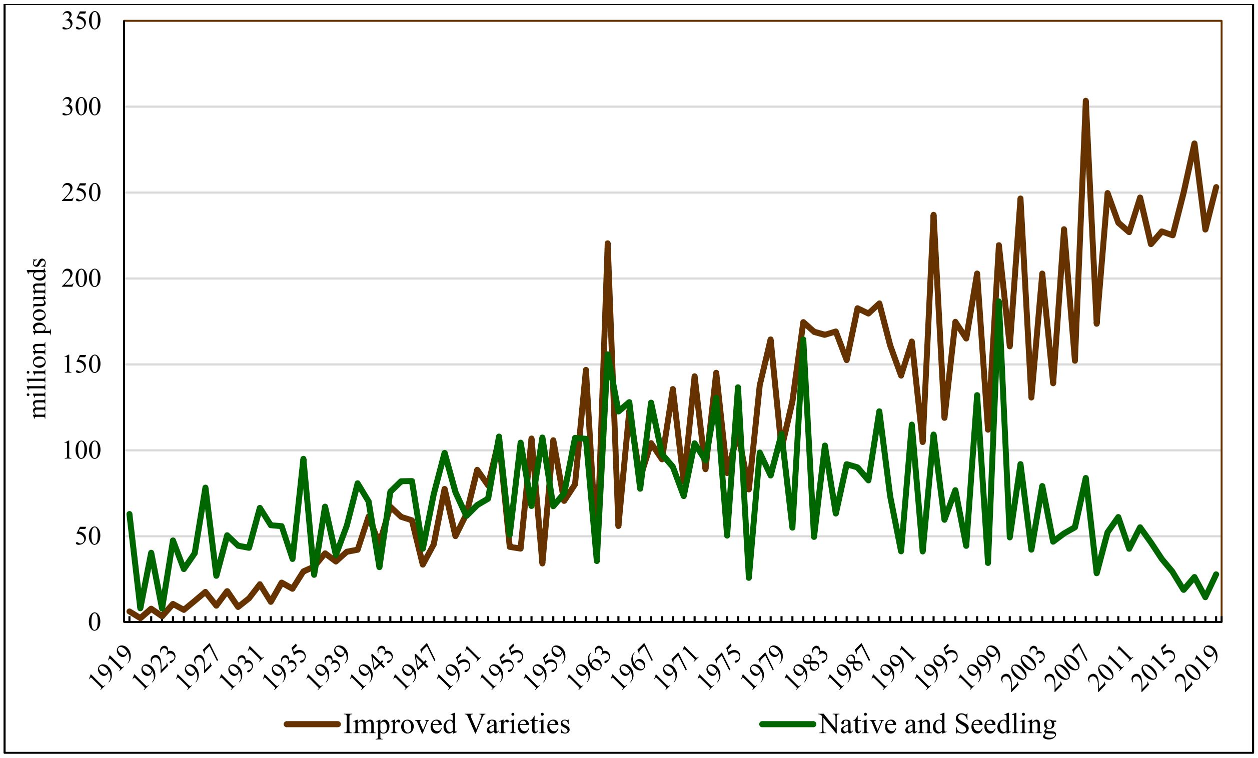
U.S. pecan production was almost equally split between native and improved varieties in the 1940s through the 1960s and 1970s (Figure 2). Since then, however, improved pecan production has continued to grow while that of native pecans has declined precipitously. From a high of 164.5 million in-shell pounds in 1981 (48.5% of U.S. production), native pecan production declined by nearly 92% to only 14.5 million in-shell pounds in 2018 (6.0% of U.S. production). Over the same period, improved pecan variety production grew by 20% to 228.5 million in-shell pounds, about 94.0% of all U.S. pecan production. In 2019, the production of both improved and native varieties recovered somewhat to 253.2 million pounds and 27.8 million pounds, respectively.

The high degree of year-to-year variability of U.S. pecan production over the years resulting from the alternate bearing behavior of pecan tress is evident in Figure 2 for both native and improved varieties and in Figure 3 for all pecans. Despite the sharp decline in native pecan production that occurred over time, the growth in improved pecan variety production more than made up for the native production decline until the last decade (2009 – 2019). Since 2009, total production has demonstrated little trend and a marked decline in variability, varying between about 250 million pounds and 300 million pounds over that period (Figure 3). The average year-to-year variation in production since 2009 was only about 12% compared to nearly 50% between 1990 and 2008.

Three states accounted for about 76% of U.S. pecan production (utilized) on average over the last decade, including Georgia (32.9%), New Mexico (26.8%), and Texas (16.4%) (Figure 4). The top five states (including Oklahoma and Arizona) accounted for nearly 90% over that period. As well as having the largest pecan production, Georgia accounted for the largest share of bearing acreage of any state (29.2%) over 2016 to 2018 followed by Texas (27.3%), Oklahoma (22.5%), New Mexico (10.8%), and Arizona (4.0%), and other states (6.2%) (Figure 5). Although Georgia accounted for the largest bearing acreage and the largest production over that same period, the three states with only improved pecan production accounted for the highest yields per acre including New Mexico (1,965 pounds), Arizona (1,717 pounds), and Georgia (770.0 pounds) (Figure 6). With improved varieties accounting for 58% of its bearing acreage and native/seedling 42%, Texas bearing acres yielded an average of 288.7 pounds per acre over 2016 to 2018. The native/seedling share of bearing acreage in Oklahoma is higher than in Texas at about 77% with only 23% in improved varieties. Consequently, the average pecan yield in Oklahoma was lower at 180.3 pounds per acre over 2016 to 2018.

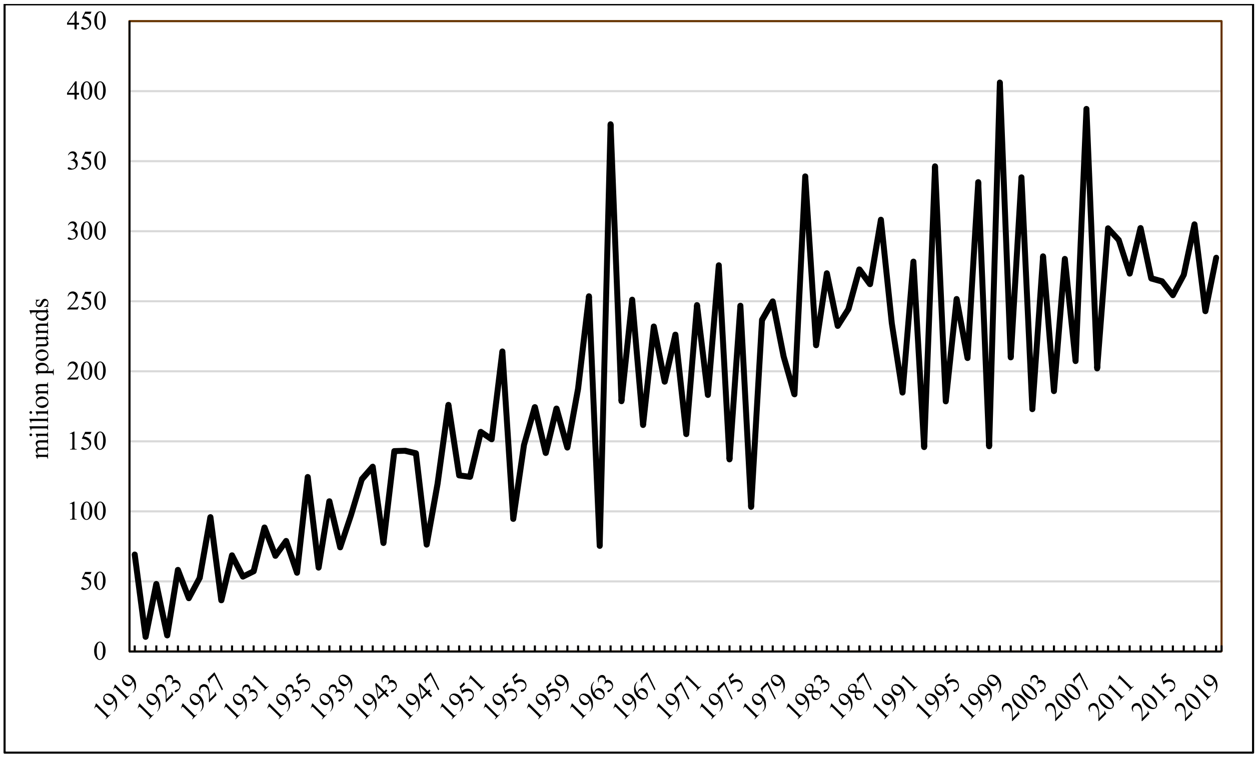
In 2018, U.S. pecan production dropped by 27.4% to 175 million pounds (see Figure 4). At the same time, U.S. pecan production value dropped nearly in half (45.5%). Hurricane Michael severely damaged pecan trees in Georgia, downing trees, breaking tree limbs, and blowing nuts off trees. In addition, USDA reported that wet conditions in the summer months fostered disease

**Figure 2. U.S. In-Shell Pecan Production by Type, 1919 – 2019**



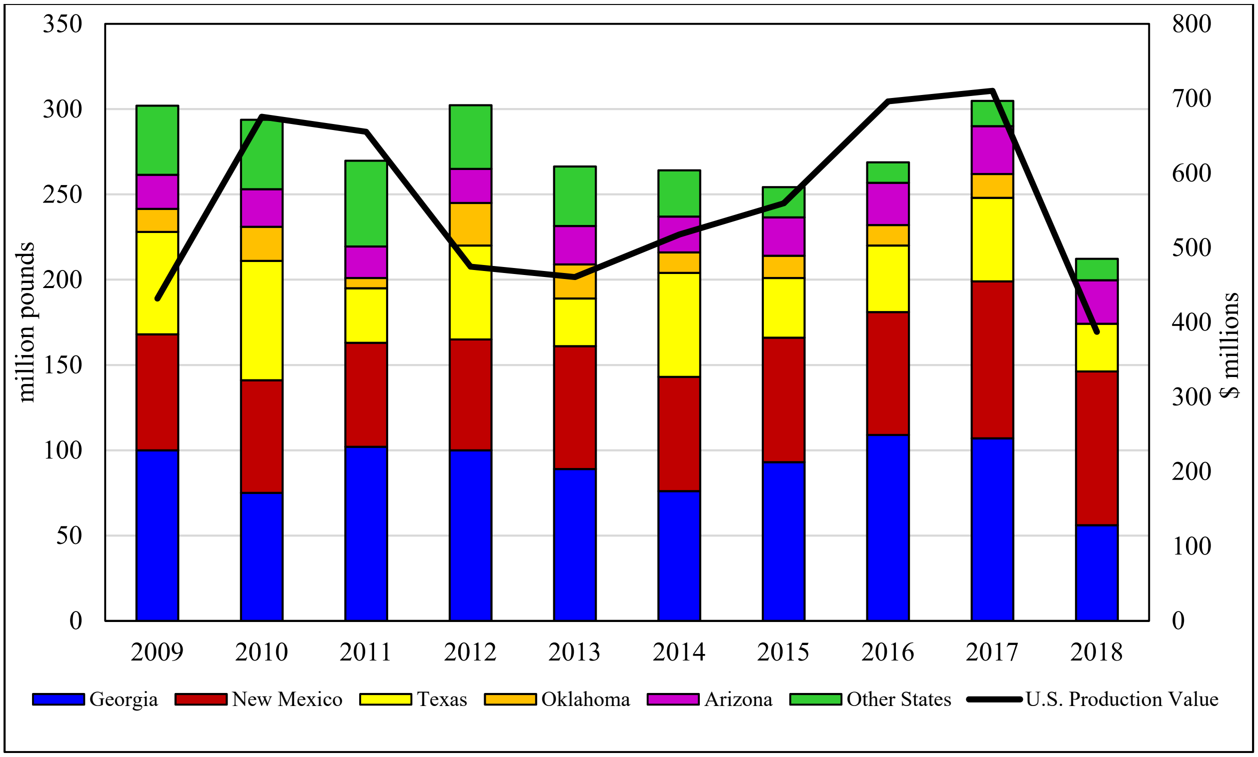

Source: Developed by the authors based on data from USDA (2019a).

**Figure 3. Total U.S. In-Shell Pecan Production, 1919 – 2019**



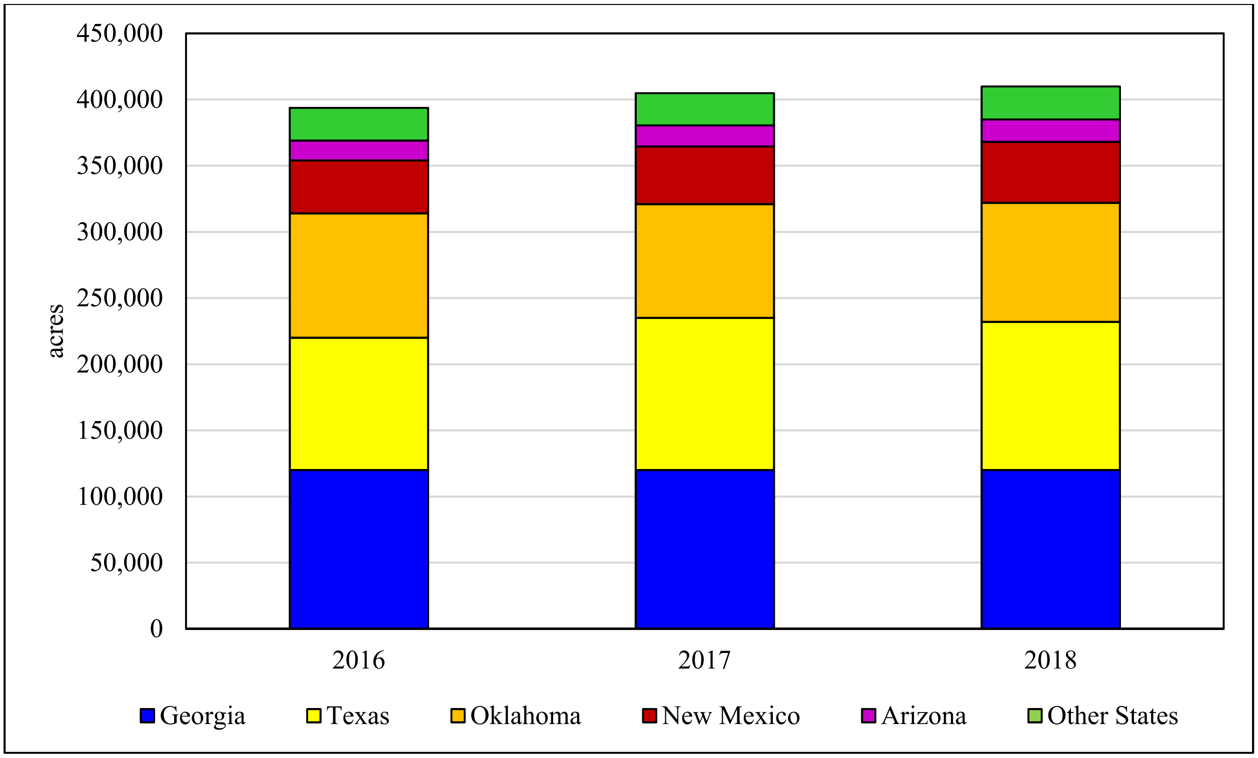

Source: Developed by the authors based on data from USDA (2019a).

**Figure 4. U.S. In-Shell Pecan Production by State and Total Production Value, 2009 – 2018**



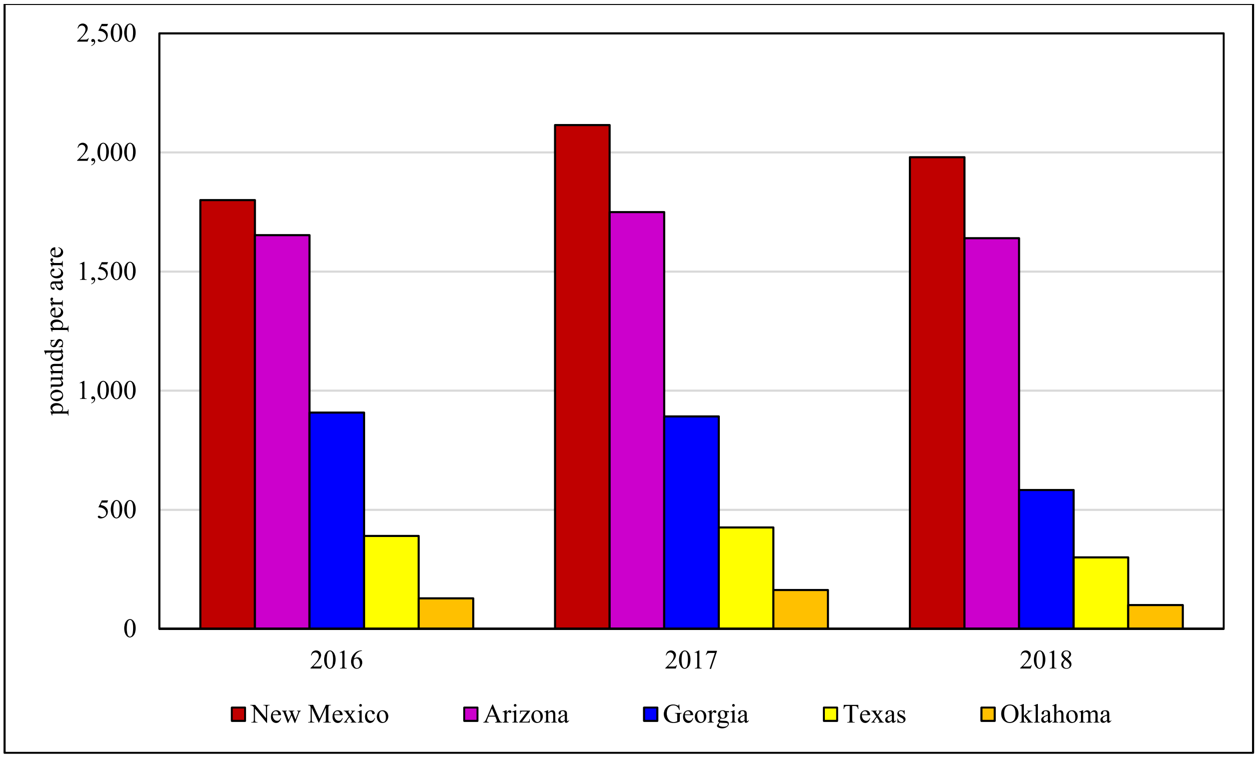

Source: Developed by the authors based on data from USDA (2019a).

**Figure 5. U.S. Pecan Bearing Acreage by State, 2016 – 2019**




Source: Developed by the authors based on data from USDA (2019a).

**Figure 6. U.S. Pecan Yields by State, 2016 – 2019**




Source: Developed by the authors based on data from USDA (2019a).

issues and limited the harvest of nuts blown off trees (USDA, 2019a). As a result, Georgia's production plunged by 47.6% and its share of U.S. production sank from 35.1% in 2017 to 25.4% in 2018. Despite a 2% drop in its production, New Mexico became the top U.S. pecan producing state with 40.7% of the lower U.S. production n 2018. A steep 42.9% decline in Texas pecan production that year was reportedly due to a low alternate-year bearing production cycle yield (NASS, 2019b). Oklahoma also suffered a sharp decline in production that year (35.7%), while Arizona experienced a smaller reduction (8.9%).

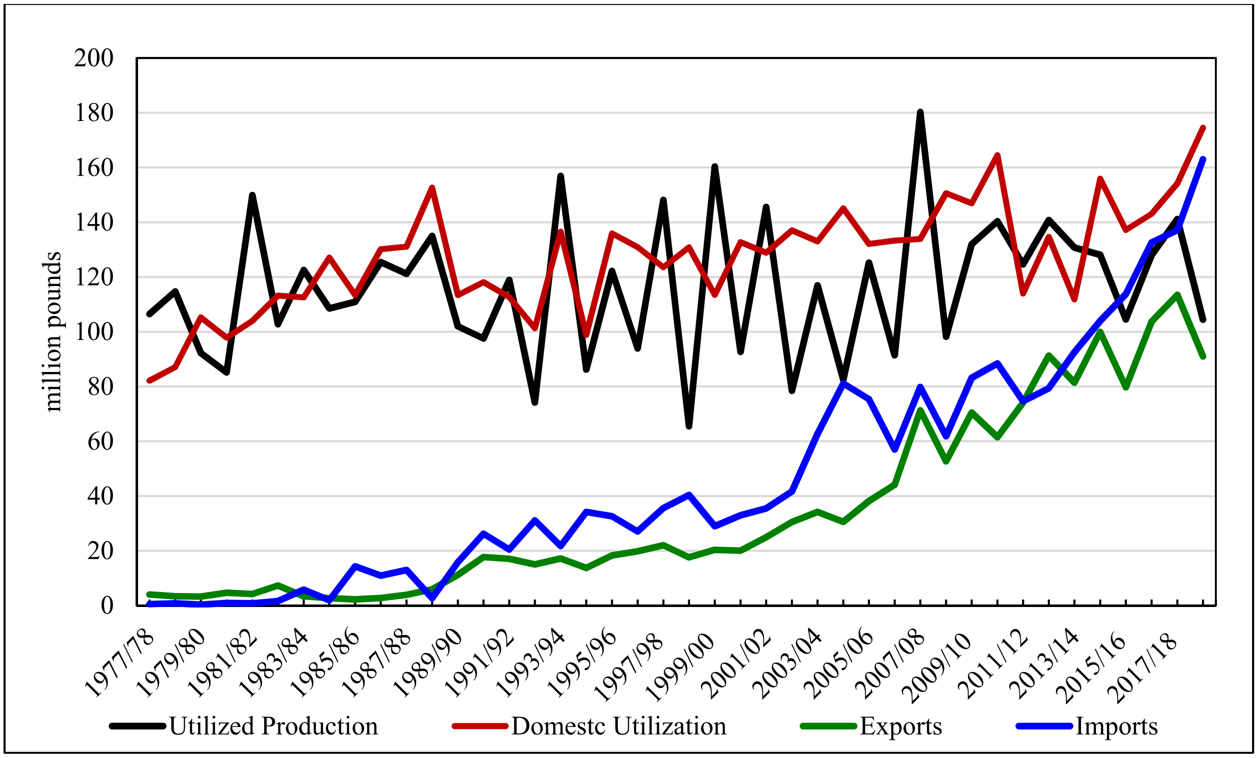
As shown in the center of Figure 1, growers have historically sold the majority of their pecans to accumulators, companies that act as brokers, selling the nuts to shellers and paying the growers a percentage based on the final price they receive for the crop. In recent years, growers have increasingly diversified their sales portfolio to include wholesalers who sell to various users, direct to shellers or exporters, and even direct to retail destinations such as local farmer's markets and on-line sales. Shellers sell the processed (shelled nuts) to end users both in U.S. markets including industrial users (confectioners, ice cream makers, bakeries, and others), retailers (local, regional, and national food/grocery stores, restaurants, and others) and in foreign markets (China, Hong Kong, Vietnam, Canada, Mexico, and the EU among many others) (right-hand side of Figure 1). Unfortunately, little historical, reliable, or consistent data for most of those activities are available.

The domestic utilization of pecans across all end users (retailers and industrial users as shown in Figure 1) has varied substantially over the years with major peaks since 1980/81 occurring in 1988/89 (152.6 million pounds), 2010/11 (164.5 million pounds), 2014/15 (155.9 million pounds), and 2018/19 (174.5 million pounds) (Figure 7). Major lows over that period occurred in 1980/81 (97.8 million pounds), 1992/93 (101.3 million pounds), 1994/95 (98.8 million pounds), 2011/12 (114.0 million pounds), and 2013/14 (111.8 million pounds). Domestic utilization has exhibited a generally upward trend over the last decade, however, from an average of 120.2 million pounds in the 1980s to an average of 143.3 million pounds since 2010/11, an increase of 19.2%. Nevertheless, per capita consumption has varied little over that period, remaining between about 0.40 pounds and 0.50 pounds (Figure 8). Since the low of 111.8 million pounds in 2013/14, U.S. pecan consumption grew by half (56.1%) to a record 174.5 million pounds last year, despite the sharp drop in domestic production that year (Figure 7). The record consumption in 2018/19 was likely facilitated by several factors: (1) a 24.9% decline in the in-shell price of pecans, (2) an associated 19.8% reduction of pecan exports, (3) an increase in imports of 18.9% to a record 163 million pounds, and other factors such pecan promotion efforts under the auspices of the Federal Marketing Order for pecans. While generally considered a negative factor in U.S. pecan markets, the Chinese tariff increase nevertheless was well-timed to reduce export demand in 2018/19 when domestic production was at its lowest level since 2006/07.

With growing demand from both export markets and domestic users and lack of growth in domestic production, shellers and other domestic users have increasingly turned to imports, almost all from Mexico, to meet domestic supply needs (bottom right corner of Figure 1). Imports accounted for 40% - 42% of total U.S. pecan supplies from 2015/16 through 2017/18 but jumped to nearly 47% with the drop in U.S. production in 2018/19 (Figure 7). Imports have exceeded exports in most years over the last several decades. Nevertheless, exports have grown in importance as an outlet for U.S. pecans (top right corner of Figure 1). As a share of the total utilization of pecans, exports have increased from around 10% in the mid-1990s to over 30% in most years since 2011/12 given the general lack of growth in domestic utilization (Figure 7). A combination of the increased tariff on U.S. pecan imports into China and the production drop in 2018/19 helped reduce the export share of total utilization that year to only 26% (Figure7).

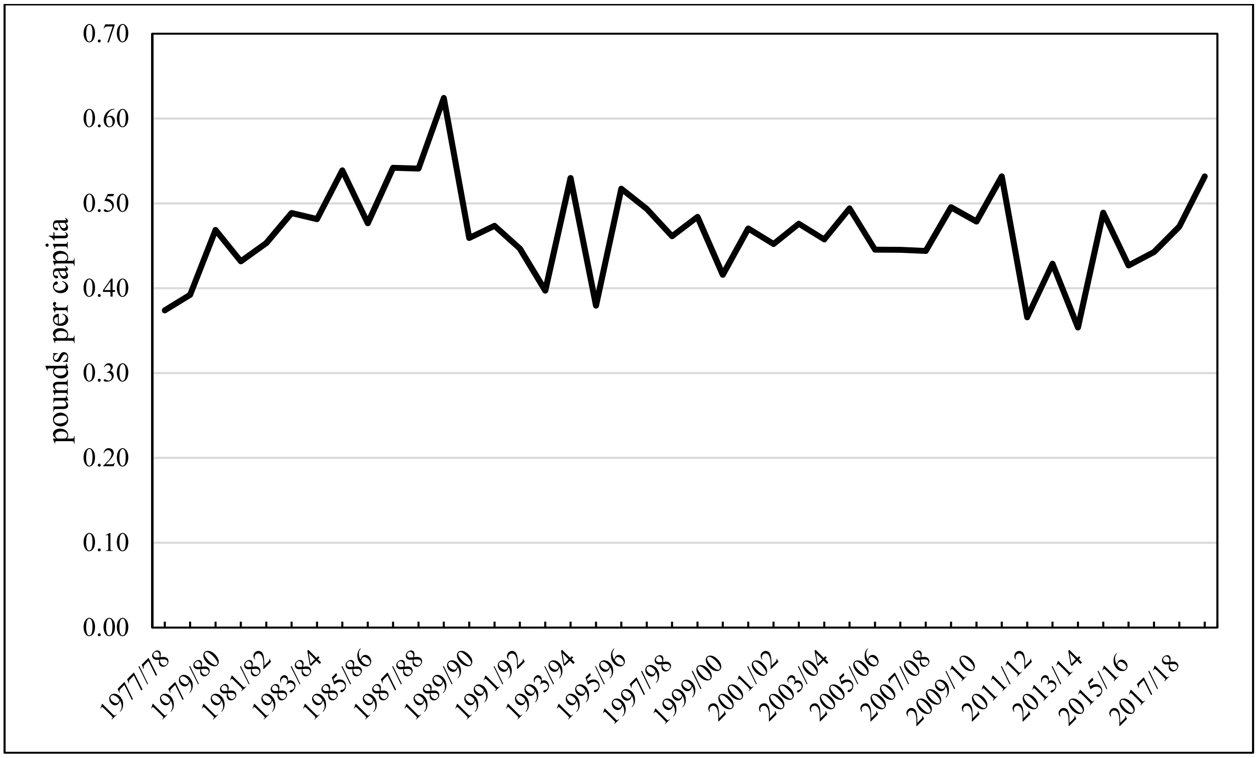
Although the United States exports pecans to numerous countries, generally 75% to 80% have been exported to two groups of countries over the last decade: (1) China, Vietnam, and Hong Kong (CVH) and (2) Mexico (Figure 9). Until last year, CVH accounted for 50% -60% of U.S. pecan exports and Mexico for 20% -25%. Hong Kong has been the largest export market for U.S. pecans although much of the pecans are transshipped to China. The same is likely the case for Vietnam. Because the extent of transshipments to China through Hong Kong and Vietnam is not

**Figure 7. U.S. Pecan Supply and Utilization (Shelled Basis), 1980/81 – 2018/19**



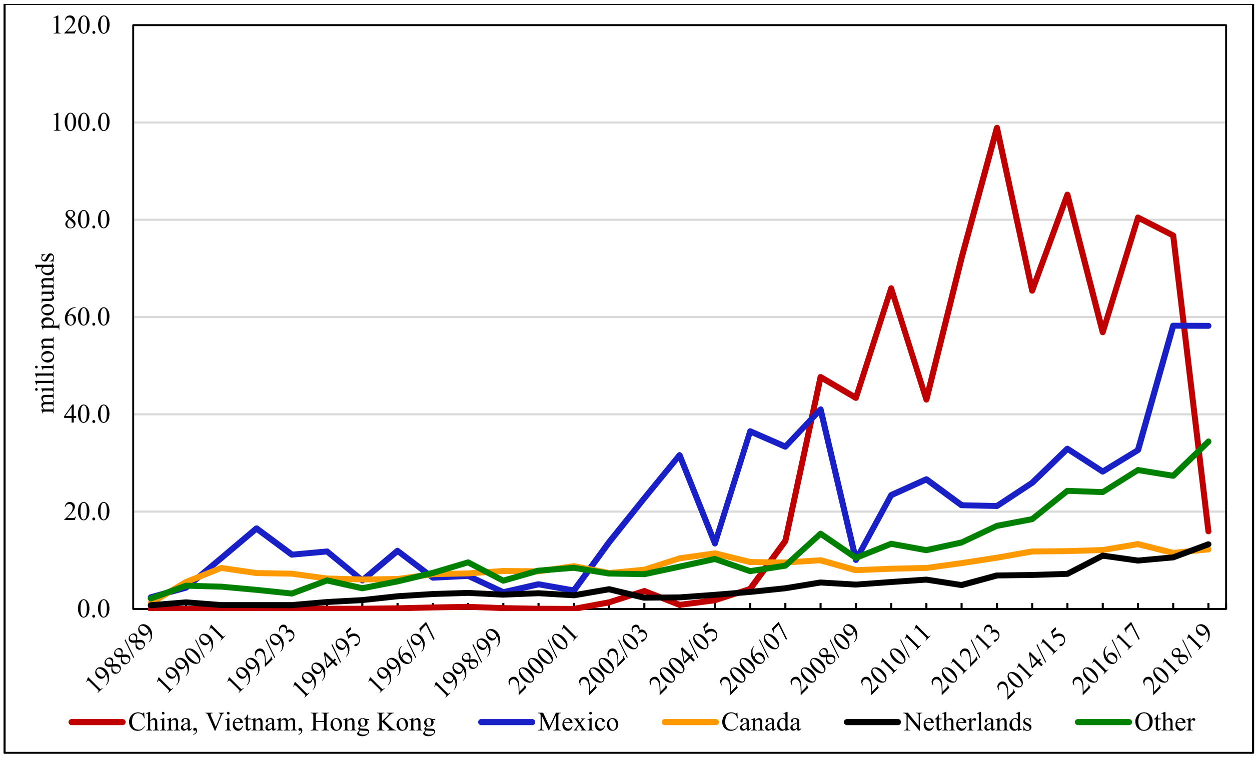

Source: Developed by the authors based on data from USDA (2019b).

**Figure 8. U.S. Per Capita Consumption of Pecans (Shelled Basis), 1977/78 – 2018/19**




Source: Developed by authors based on data from USDA (2019b).

**Figure 9. U.S. Pecan Exports by Country (Shelled Basis), 1988/89 – 2018/19**

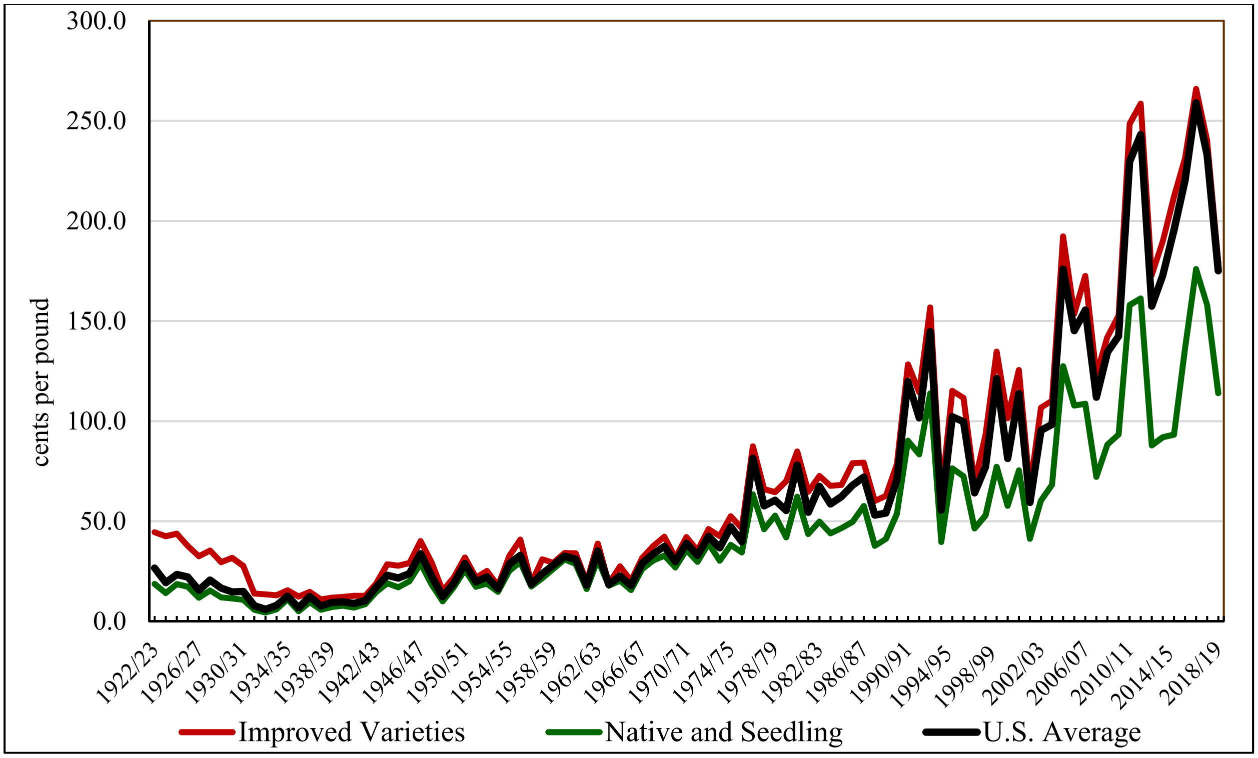



Source: Developed by the authors based on data from USDA (2019c).

known, the export volumes for the three countries are added together as a single importing group in Figure 9. With the drop in U.S. pecan supplies available for export in 2018/19 and the increase in the Chinese tariff on U.S. pecans, exports to CVH dropped from 76.8 million pounds in 2017/18 to just 16 million pounds in 2018/19, a drop of nearly 80%. Other major countries importing U.S. pecans (with 2018/19 percentages of total imports) include the Netherlands (11.6%), Canada (10.7%), Israel (5.2%), United Kingdom (4.8%), France (2.2%), and Japan (0.8%) (Figure 9).

Although Figure 1 depicts the flow of pecans from production to end use, along with that flow are prices at each point along the value chain. At the production end are prices received by producers (in-shell) for native/seedling and improved varieties from each state (Figure 10). From an average of 98.5 cents/pound in the 1990s, the U.S. price of all pecans increased to an average of 206.0 cents/pound over the last decade (2009-2018) with an all-time high of 259.0 cents/pound in 2016. Improved variety prices have been above the average while prices of native pecans have traded at levels below the average. As the production of native pecans has declined over time, the average U.S. price and the price of improved varieties have become nearly the same.

**Figure 10. Pecan Prices (In-Shell) Received by Producers by Type, 1922/23 – 2018/19**

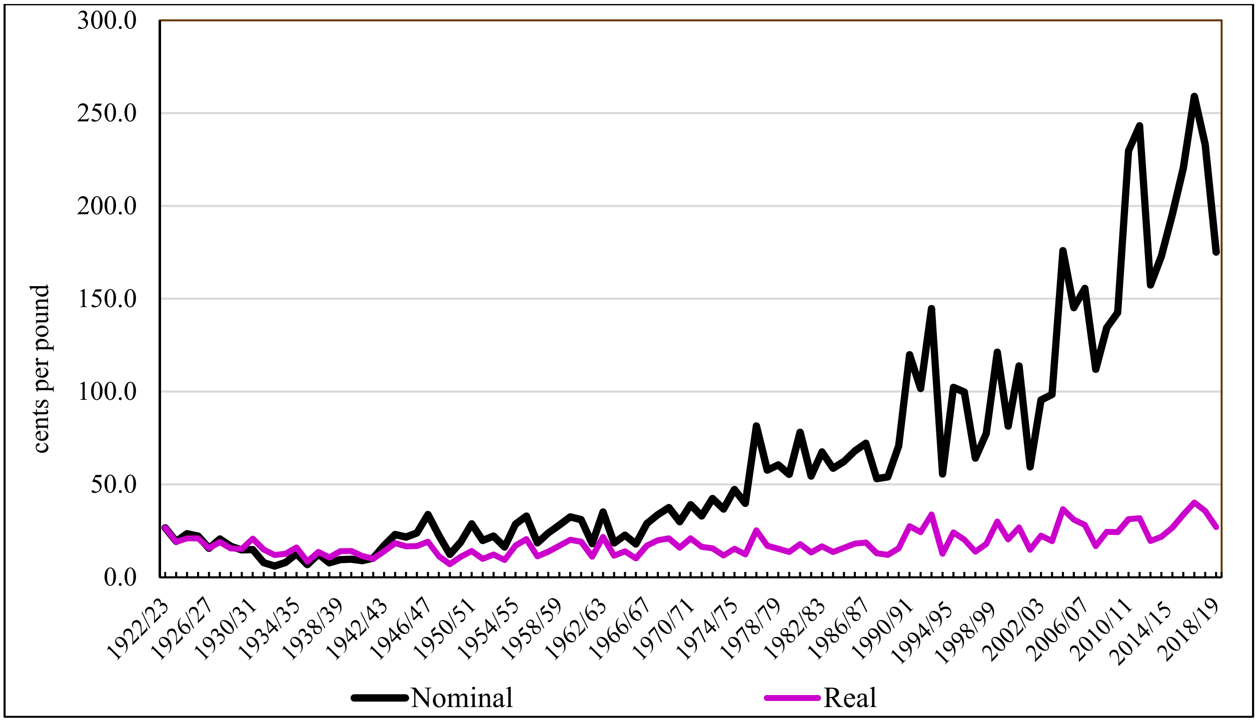



Source: Developed by the authors based on data from USDA (2019b).

Although the increase in pecan prices over time appears impressive, when adjusted for inflation, the average price of pecans has changed little since the early 1920s (Figure 11). In fact, the inflation-adjusted (1922=100) price of pecans in 2018/19 (27.0 cents/pound) was nearly identical to the price of pecans in 1922 (26.6 cents/pound). In other words, the dollars earned from the sale of a pound of pecans in 2018 resulted in about the same purchasing power as the dollars earned from a pound of pecans in 1922. While the nominal price of pecans was increasing over time, the nominal prices of all other goods were increasing at about the same rate over time. That is, the price of pecans has increased at about the rate of inflation over time.

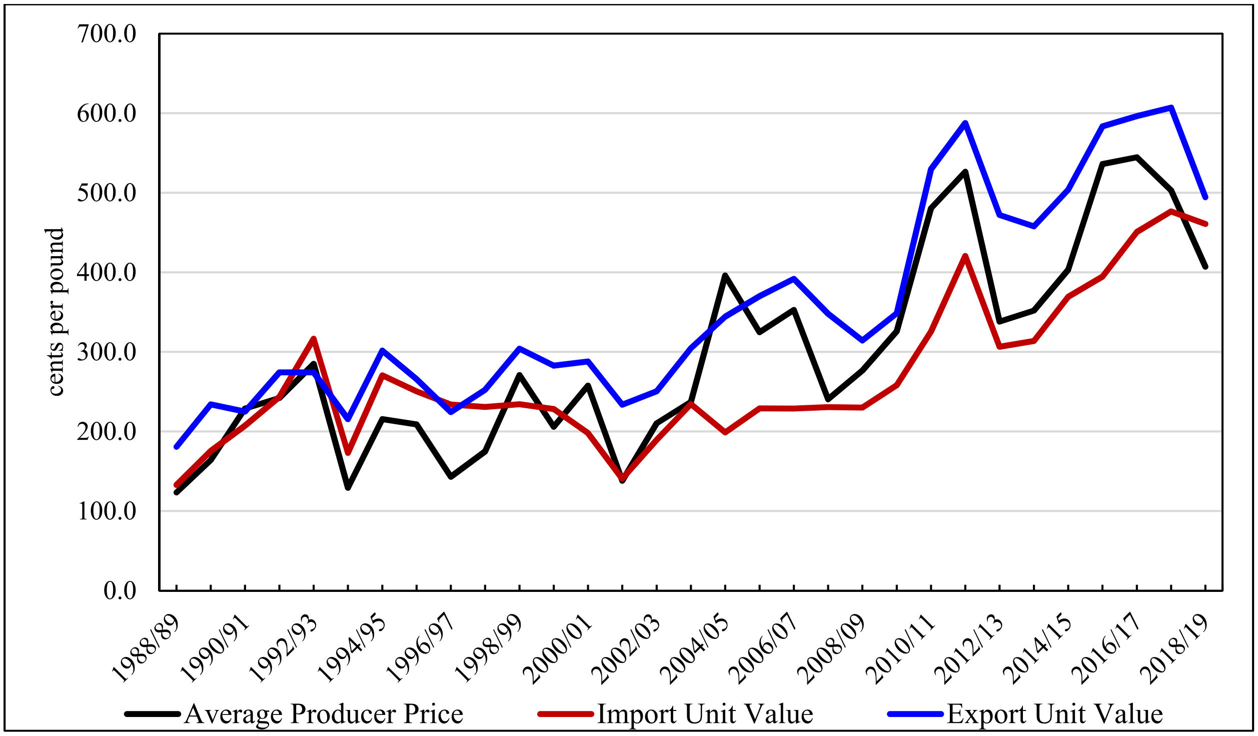
Few other reliable, consistently available prices for pecans over a sufficiently long period of time to support empirical analysis are available at any level of the value chain. The Agricultural Marketing Service of USDA collects prices at various U.S. terminals (USDA 2019d). Those data are available only back to 1998 and are not well correlated with farm prices. Export prices and import prices for pecans are not available either. As proxies for those prices, export and import unit values can be calculated from export and import volume and value data (Figure 12). The pecan export unit value has been consistently higher than and closely correlated with the average U.S. pecan price received by producers on a shelled basis over time. The pecan import unit value

**Figure 11. Nominal and Inflation-Adjusted (1922=100) Pecan Price Received by Farmers (In-Shell), 1922/23 – 2018/19**




Source: Developed by the authors based on data from USDA (2019b) and USDL (2019).

**Figure 12. Pecan Prices (Shelled Basis): Producer, Export, and Import, 1988/89 – 2018/19**



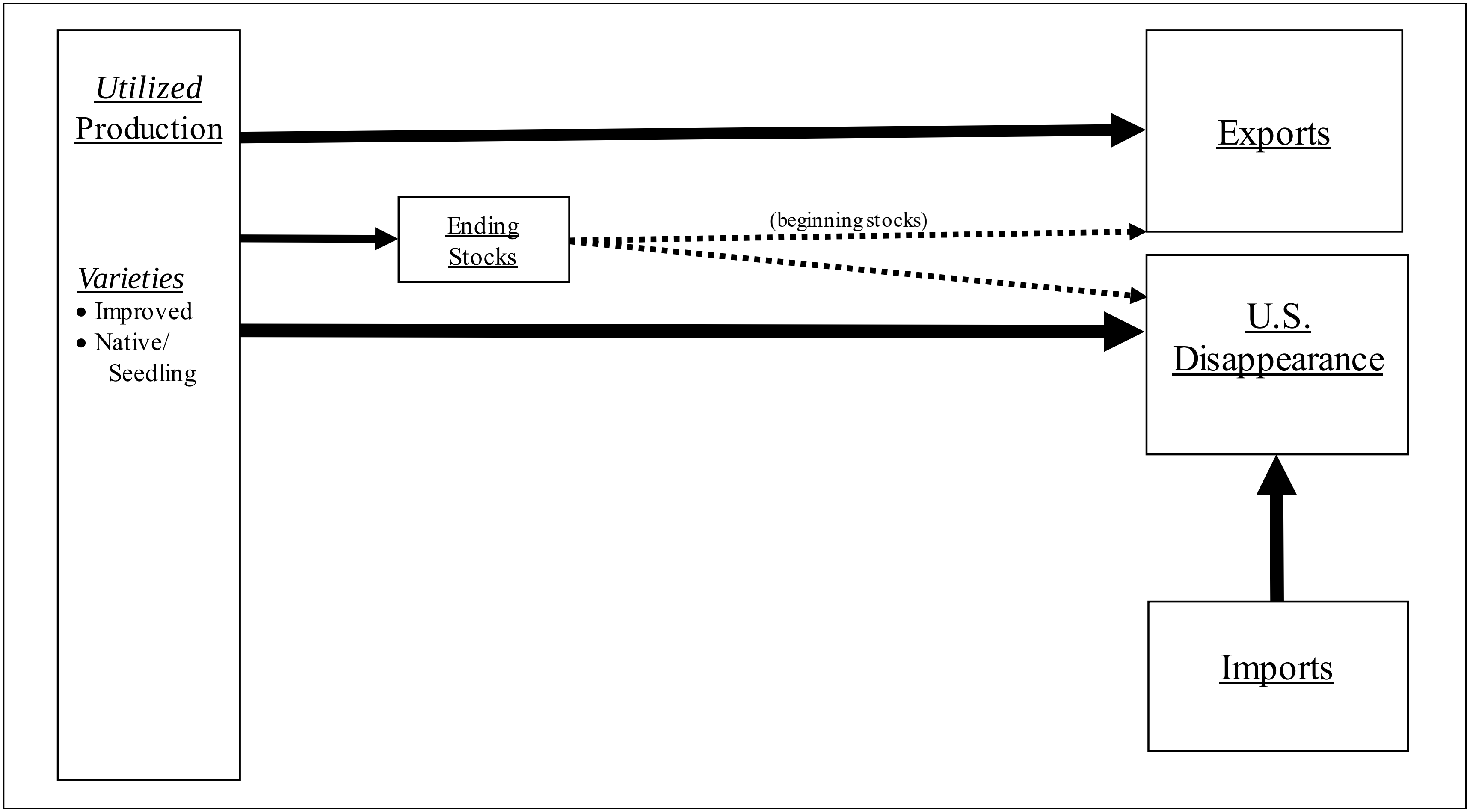

Source: Developed by the authors based on data from USDA (2019b,c).

(shelled basis) has been consistently lower than but still highly correlated with the producer price. While the producer price and the export unit value declined in 2018/19, the import unit value declined by less. In fact, the import unit value in 2018/19 was above the U.S. producer price for the first time since 2001/02 and approached the export unit value of U.S. pecans. Some of the support for the import price of pecans likely resulted from the demand by shellers and processors for imports to meet domestic pecan demand in a low domestic production year. However, some of the support may be due to Chinese demand for Mexican pecans as China's pecan buyers shifted their purchasing habits to Mexico in the face of the increased cost to them of U.S. pecans due to the 47% tariff placed by the Chinese government on imports of U.S. pecans. According to one report, Mexico's pecan exports to China increased by more than 3,000% in 2018 relative to the previous year (Produce Report, 2019). Mexican pecan exports to China are assessed only the 7% most favored nation (MFN) tariff.

The preceding discussion demonstrates that while data related to the pecan industry are available, much data needed to characterize many critical activities in the U.S. pecan industry as depicted in Figure 1 are not available. Missing are historical, consistent, and reliable data on, for example, acreage planted and harvested, and trees removed (removals) by pecan variety or even by native and improved types, purchases by accumulators, wholesalers, and shellers, purchases by various retailers by type or as a group, purchases by various industrial users by type or as a group, and exports to specifically identified destinations. Price data associated with most of those activities also are not available for analysis. USDA has begun to collect data on pecan acreage and yield. However, given the long lag between the year when a pecan tree is planted and when that tree begins to produce, many years of acreage and yield data will need to be collected before those data are useful for empirical analysis. In addition, some of the available data are not useful or reliable for analysis such as exports by destination and terminal prices. Other available data are not specific as to type, such as domestic utilization for which there is no breakdown by retail or industrial uses.

If we strip all activities of the pecan industry out of Figure 1 for which historical, consistent, and reliable quantity and price data are not available, then Figure 1 devolves to Figure 13. The result is a simplified depiction of the pecan industry. Note that much of what happens along the industry value chain between production and final utilization is missing from the picture. Major components of this smaller, more data-supported economic structure of the U.S. pecan industry include primarily utilized production (by improved and native/seedling varieties) and imports (by country of origin) on the supply side and ending stocks, U.S. disappearance, and exports on the demand side. Export data do not support an analysis of foreign demand by China specifically. Domestic utilization data do not support anything more than a crude analysis of total use other than exports and ending stocks.

**Figure 13. Reduced Data-Supported Economic Structure of the U.S. Pecan Industry Due to Data Gaps**



## PecanMod - A U.S. Pecan Industry Economic Benchmark Model

Despite the general lack of data available for modeling and conducting a detailed economic analysis of the complete U.S. pecan industry, we developed a relatively powerful economic model of the industry based on the available data, referred to as PecanMod. Building from Figure 13, reorganizing, and adding price linkages, the Structure of PecanMod is depicted in Figure 14. In the model, the supply-side activities (utilized native and improved variety pecan production (in-shell and converted to a shelled basis), beginning stocks, and imports) at the top of Figure 14 interact with demand-side activities (domestic utilization, export demand, and ending stocks) at the bottom of Figure 14 to determine producer prices (U.S. average, native, and improved) as well as export and import prices in a given year in the middle of Figure 14. The producer prices in that year then affect the production of improved and native pecans in the following year (dotted lines represent time lags). Together with import supplies and beginning stocks in the following year (which are ending stocks in the previous year), production in the following year interacts with demand activities in that year to determine prices in that year which then impact production in the following year and so on. Because no retail price of pecans is available (red box in Figure 14), we use the producer price (shelled basis) as a proxy assuming that the two prices are positively correlated to some extent.

The schematic representation of PecanMod in Figure 14 can be laid out as a corresponding set of 13 equations in Figure 15. Each equation represents one of the 13 boxes in Figure 14. The variable names are defined in Figure 16. The relationships between the ten variables representing industry activities are represented in equations (1) and (2) (improved and native pecan production), equation (5) (pecan import supply), equation (6) (domestic pecan utilization), equation (7) (ending stock demand), and equation (8) (export demand) in Figure 14. Equations (10) through (13) represent the various price linkages in the model. The relationships between the variables on the left hand side of each equation (the industry activities) and the various drivers that explain the behavior of the respective industry activity on the right-hand side of each equation are determined through the use of a statistical procedure known as econometric analysis.

Three of the equations in the model represented in Figure 15 are identities to link various activities such as the addition of native and improved in-shell pecan supplies into a total in-shell pecan supply in equation (3) and the conversion of total in-shell supply to shelled supply in equation (4). Equation (9) is a market clearing condition requiring that total supply of shelled pecans equal the total demand for shelled pecans in each year. In the other ten equations, the econometric procedure identifies statistically significant drivers of each market activity and the statistical relationship between them. The estimated coefficients (structural parameters) provide measures of the change in each market activity in the model from a change in the respective explanatory (driver) variable.

**Figure 14. PecanMod Structure**

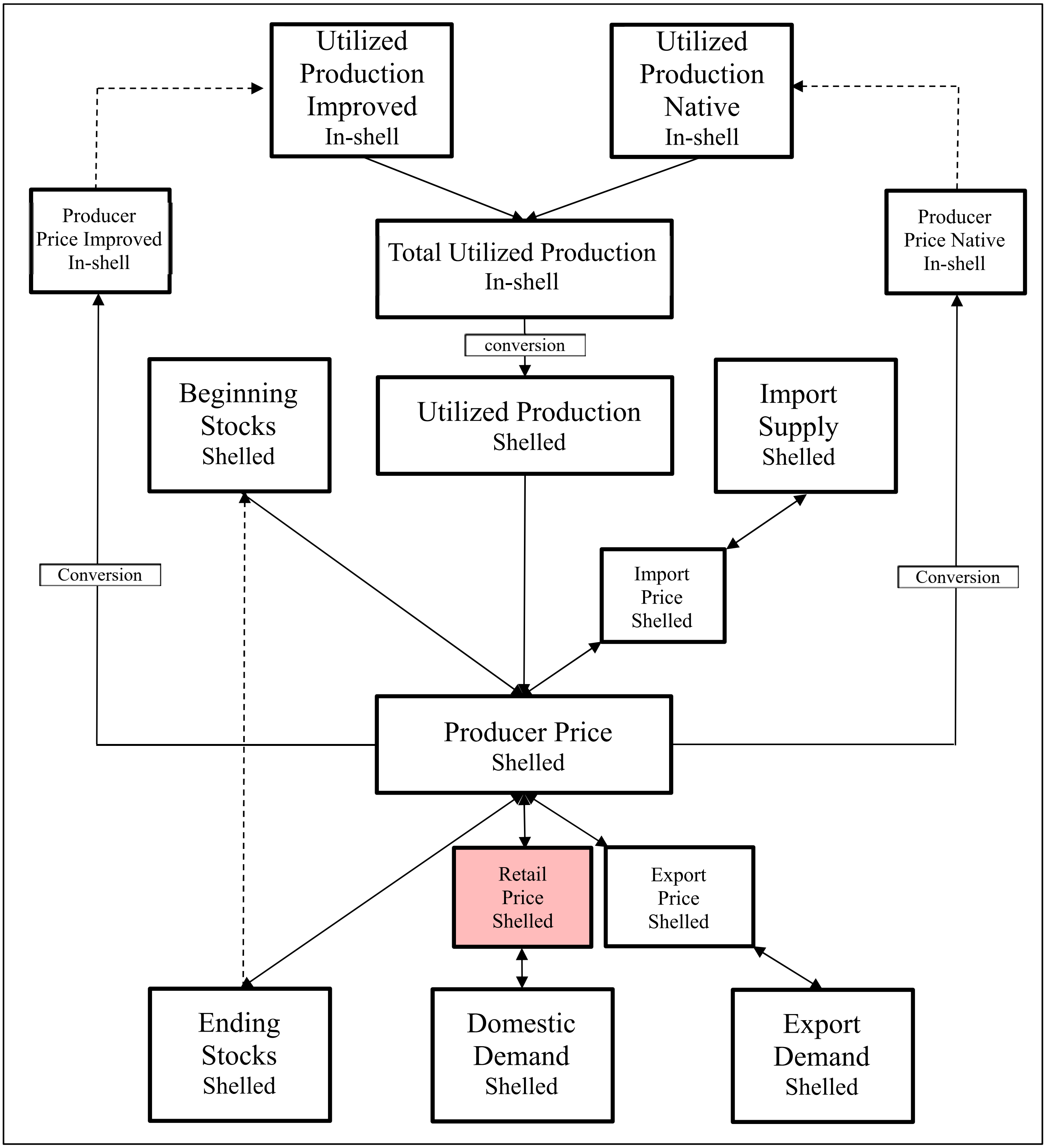


**Figure 15. PecanMod Equations**

| | | |
|---|---|---|
| (1) | $S_i = S_i (P^e_i, \alpha_{si})$ | Improved pecan production (in-shell) |
| (2) | $S_n = S_n (P^e_n, \alpha_{sn})$ | Native pecan production (in-shell) |
| (3) | $S_p = S_i + S_n$ | Total in-shell pecan production identity (in-shell) |
| (4) | $S_u = Ø*S_p$ | Total utilized production (in-shell conversion to shelled identity) (Ø = conversion rate) |
| (5) | $S_m = S_m (P_m, \alpha_{sm})$ | Import pecan supply (shelled) |
| (6) | $D_u = D_u (P_u, \beta_{du})$ | Domestic pecan utilization (shelled) |
| (7) | $E_u = E_u (P_u, \beta_{eu})$ | Ending stock demand for pecans (shelled) |
| (8) | $D_x = D_x (P_x, \beta_{dx})$ | Export demand for pecans (shelled) |
| (9) | $E_{ut-1} + S_u + S_m = D_u + D_x + E_u$ | Market clearing condition (shelled) |
| (10) | $P_i = P_i(P_u/ Ø, \theta_{pi})$ | Price linkage ($P_{improved}$ to $P_{shelled\ market}$) |
| (11) | $P_n = P_n(P_u/ Ø, \theta_{pn})$ | Price linkage ($P_{native}$ to $P_{shelled\ market}$) |
| (12) | $P_m = P_m(P_u, \theta_{pm})$ | Price linkage ($P_{import}$ to $P_{shelled\ market}$) |
| (13) | $P_x = P_x(P_u(1+\tau), \theta_{px})$ | Price linkage ($P_{export}$ to $P_{shelled\ market}$) |

13 unknowns: $S_{i,}$ $S_n$, $S_p$, $S_u$, $S_m$, $D_u$, $E_u$, $D_x$, $P_i$ , $P_n$, $P_m$, $P_x$, $P_u$

**Figure 16. PecanMod Variable Definitions**

**Endogenous Variables:**

$S_i$ = U.S. improved pecan production (in-shell)

$S_n$ = U.S. native pecan production (in-shell)

$S_p$ = U.S. total in-shell production

$S_u$ = U.S. total utilized production (in-shell converted to shelled)

$S_m$ = U.S. pecan import supply (shelled)

$D_u$ = U.S. domestic pecan utilization (shelled)

$E_u$ = U.S. ending stock demand for pecans (shelled)

$D_x$ = U.S. export demand for pecans (shelled)

$P_i$ = U.S. producer price of improved pecan varieties (in-shell)

$P_n$ = U.S. producer price of native pecans (in-shell)

$P_m$ = U.S. price (import unit value) of imported pecans

$P_x$ = U.S. price (export unit value) of exported pecans

$P_u$ = U.S. average producer pecan price (shelled)

**Exogenous Variables:**

Ø = conversion rate (in-shell to shelled)

$\alpha$ = drivers (shift variables) of the respective supply equations, including variables like inflation, prices of competing crops, technological change, etc.

$\beta$ = drivers (shift variables) of the respective demand equations, including variables like income, prices of other nuts, population, inflation, etc.

$\theta$ = drivers (shift variables) of the respective price equations, including variables like exchange rates, transportation costs, etc.

$\tau$ = Chinese pecan import tariff rate

*The Statistical Model*

In this report, we provide a summary of the estimated relationships previously discussed. The details of the full econometric model and parameters can be made available. The econometric model represents key industry activities such as improved and native pecan production, pecan import supply, domestic pecan utilization, ending stocks, and pecan export demand. The remaining equations represent the various price linkages in the model as well as identities.

The model does an excellent job of tracking the historical functioning of the U.S. pecan industry. Appendix 2 provides the statistics normally used to gauge the reliability of an econometric model, including the goodness-of-fit statistics ($R^2$ and adjusted $R^2$), the within-sample mean absolute percent error (MAPE), and the Theil U2 statistics. Goodness-of-fit refers to the ability of any model to explain the variability in industry activities. The $R^2$ statistics are close to 1, indicating that the model explains most of the variability in improved and native pecan production, pecan import supply, domestic pecan utilization, ending stocks, pecan export demand, and the various price linkages in the model. In addition, the MAPE statistics range from 1.89% to 19.76%, another indicator of excellent performance. In fact, most of the MAPE statistics are below 10%. Finally, a necessary condition for model validation is for Theil U2 statistics to be less than 1. This condition is met for each equation in the model as shown in Appendix 2. Hence, the set of estimated econometric equations mimics the actual behavior of key relationships in the pecan industry.

The key drivers of in-shell production of native and improved pecans were found to include inflation-adjusted grower prices, past production (a lag of two years for native pecans and lags of six and seven years for improved pecans). Key Influential factors associated with export demand of pecans were found to include inflation-adjusted export prices, inflation-adjusted world income, trend, and previous exports (a lag of two years). Similarly, key drivers of total U.S. imports were found to include inflation-adjusted import prices, trend, and the level of imports in the previous year. Domestic pecan utilization was found to depend on inflation-adjusted pecan prices, inflation-adjusted almond prices, inflation-adjusted U.S. income, and previous domestic pecan utilization (a lag of two years). Almonds and pecans were found to be substitutes. Pecans were found to be “normal” goods in that pecan consumption increases as income increases. Ending stocks were found to be dependent on inflation-adjusted producer prices of pecans, utilized production, and ending stocks in the previous year. The price linkage equations in the model reveal that import and export unit values of pecans as well as producer prices of native and improved pecans are all functions of the weighted average U.S. producer price of pecans.

Table 1 provides the estimated short-run and long-run indicators of price responsiveness in terms of elasticities. An elasticity is the percentage change in a given market variable from a one percent

**Table 1. PecanMod Short-Run and Long-Run Price Elasticities**

| Dependent Variable | Variable Symbol | Time Period (Annual) | Short-Run Elasticities | Long-Run Elasticities |
|---|---|---|---|---|
| Native Production (In-Shell) | $S_n$ (1,000 lb) | 1960 to 2018 | 0.134 | 0.196 |
| Improved Production (In-Shell) | $S_i$ (1,000 lb) | 1960 to 2018 | 0.000 | 0.323 |
| Import Supply (Shelled) | $S_m$ (1,000 lb) | 1980 to 2018 | 0.516 | 0.646 |
| Domestic Use (Shelled) | $D_u$ (1,000 lb) | 1979 to 2018 | -0.148 | -0.180 |
| Ending Stock Demand (Shelled) | $E_u$ (1,000 lb) | 1980 to 2018 | -0.215 | -0.320 |
| Export Demand (Shelled) | $D_x$ (1,000 lb) | 1990 to 2018 | -0.625 | -0.745 |
| Improved Price (relative to Shelled Producer Price) | $P_i$ (cents/lb) | 1980 to 2018 | 0.955 | 0.955 |
| Native Price (relative to Shelled Producer Price) | $P_n$ (cents/lb) | 1980 to 2018 | 1.010 | 1.010 |
| Import Price of Pecans (relative to Shelled Producer Price) | $P_m$ (cents/lb) | 1980 to 2018 | 0.443 | 0.827 |
| Export Price of Pecans (relative to Shelled Producer Price) | $P_x$ (cents/lb) | 1980 to 2018 | 0.658 | 0.658 |

**Identities**

Total In-Shell Pecan Production = Improved Pecan Production (In-Shell) + Native Pecan Production (In-Shell).

Total Utilized Production (In-Shell Conversion to Shelled Identity = Conversion Factor * Total In-Shell Production.

Market Clearing Condition (Shelled): Beginning Stocks + Domestic Production + Imports = Domestic Use + Exports + Ending Stocks.

change in the associated driver. The elasticities presented in Table 1 reveal that improved, native, and, hence, total pecan production are not very sensitive to price changes. For example, a 1% change in their respective prices lead to a 0.13% change in native pecan production and no response of improved pecan production over the short-run. (The short-run is the period over which pecan trees cannot or cannot fully respond to price changes). The same 1% change in their respective prices, however, leads to a 0.20% change in native pecan production and a 0.32% change in improved pecan production over the long run. Further, a 1% percent change in the prices of imports and exports results in 0.52% and a -0.62% changes in the import supply and in the export demand for pecans, respectively, in the short-run and 0.65% and -0.75%, respectively in the long run. Finally, a 1% change in the price of pecans leads to a -0.15% change in the domestic utilization of pecans in the short run and -0.18% in the long run. In summary, production relationships, import supply, export supply, and domestic utilization are not highly responsive to changes in prices in the short run or long run.

In addition, the procedure quantifies the impacts of real (inflation-adjusted) income and real almond prices on the domestic utilization of pecans in terms of elasticities. A 1% change in real U.S. income leads to a 0.44% change in the domestic utilization of pecans meaning that pecans are necessities because the income elasticity is positive and less than one. At the same time, a one percent change in the real almond price leads to a 0.05% change in the domestic utilization of pecans meaning that pecans and almonds are considered to be substitutes by consumers. Also, a 1% change in real (inflation-adjusted) world income increases export demand for pecans by 9.56%, indicating that changes in real world income play a major role in affecting the export demand for U.S. pecans.

*Using PecanMod for Analysis – Counterfactual Simulation*

The process of analyzing the effects of economic events on markets using an econometric model such as PecanMod is referred to as counter-factual simulation. The “simulation” of a model is simply the mathematical solution of a set of equations, such as the 13 equations of PecanMod. A *baseline* simulation is the simulation of the model to determine how closely the model replicates the actual, historical values of the variables in the model, such as the supply, demand, trade, and price variables in PecanMod, over the time period of the simulation. A number of statistical measures (known as validation statistics) are used to determine how closely the model comes to tracking the actual values of such market activities. A baseline simulation of PecanMod was conducted over the period of 1980/81 through 2018/19. As mentioned previously, the associated validation statistics for the baseline simulation indicate that the model does an excellent job of tracking the historical functioning of the U.S. pecan industry (see Appendix 2).

To use PecanMod for measuring the industry effects of some economic event, a *counterfactual* simulation analysis is conducted with the model. A counterfactual simulation analysis actually requires two simulations of the model to analyze two scenarios. The first scenario simulation assumes that nothing has changed over the time period of analysis, that is, nothing in the market is different than what actually occurred over history. This simulation is actually just the *baseline* simulation generated to determine the validity of the model. In the context of a counterfactual analysis, the baseline simulation is referred to as the "with" simulation because the simulated values of the industry variables (supply, demand, price, etc.) include the effects of the event being analyzed (such as the effect of the Chinese tariff). Thus, the *with* scenario represents actual history, that is, the level of supply, demand, prices, trade, etc. in the U.S. pecan industry that include any effects on those markets of the event being analyzed.

The second scenario simulated with the model in a counter-factual analysis is the counterfactual simulation referred to as the *without* scenario analysis and is conducted by setting the value of some exogenous model variable (representing the event to be analyzed such as the Chinese import tariff) at a level different than its historical value and then simulating the model again over the same time period to generate new values for the industry variables (production, consumption, trade, prices, etc.). Because the changes in the industry model variables in the *without* scenario are generated by changing only the level of one (exogenous) variable representing an event like the Chinese import tariff, they represent the changes in the industry that would have occurred over history if changes in the event (like changes in the level of the Chinese tariff) had occurred. In the case of a Chinese tariff, the *without* scenario could simulate the effects of a zero Chinese import tariff in one period or over several periods. The simulated levels of the industry variables (supply demand, prices, etc.) in this example would represent the levels of those variables that would have occurred over time if there had been no Chinese import tariff.

Differences in the simulated levels of the industry variables in the model (supplies, demand, prices, trade, etc.) in the *with* scenario from those in the *without* scenario are then taken as direct measures of the effects of the event being analyzed, such as the effects of the Chinese tariff. Because no other exogenous variable in the model (e.g., level of inflation, exchange rates, income levels, agricultural and trade policies, etc.) other than the event being analyzed is allowed to change in either scenario, this process effectively isolates the effects of the event of interest on the industry. That is, the simulated differences between the values of the endogenous (industry) variables from the *with* scenario and from the *without* scenario provide direct measures of the historical effects of the event being analyzed (and only that event).

## Demonstration of the Use of PecanMod: Economic Effects of the Chinese Import Tariffs

To demonstrate the usefulness of PecanMod, we used the model to analyze the U.S. pecan industry effects of the Chinese tariff on imports of U.S. pecans following the counter-factual simulation process described in the previous section. We first provide some background on the Chinese tariff and then outline the theoretically expected effects of a Chinese tariff on U.S. pecan imports. A discussion of the counterfactual simulation of the tariff and the results of that simulation are followed by some concluding comments.

*Background on the Chinese Import Tariff*

On April 2, 2018, China announced tariffs on imports of a variety of U.S. products, including pecans, as countermeasures to the U.S. Section 232 tariffs on steel and aluminum product imports imposed on China by the United States. The trade dispute is important to the U.S. pecan industry because China had become the top foreign market destination for U.S. pecans.

Actually, Chinese tariffs on imports of U.S. pecans are not a new phenomenon. Before 2007, pecans were rarely seen in China (Jun et al., 2013). However, the Chinese appetite for pecans exploded in 2007 when the price of walnuts jumped, making pecans a good substitute and a great bargain. China's pecan boom continued in following years as China's emerging middle-class consumer base, familiar with walnuts, found pecans to be similar to walnuts but more nutritious (Jun et al., 2013). At the time, China classified pecans as "other nuts" and assessed imports of U.S. pecans at the most favored nation (MFN) tariff rate of 13% (Table 2). As pecan imports began to increase, however, China increased the MFN tariff rate to 24% in 2008 and left it at that level through 2014. At the request of domestic industry in China, the government lowered the pecan MFN tariff rate to 10% where it remained until January 2018 when China again reduced the rate to 7%. Following the U.S.-China trade dispute in early 2018, however, the Chinese government subsequently added a new 15% tariff on April 2, 2018, bringing the total tariff to 22% for pecans of U.S. origin (Table 2). On July 6, 2018, China tacked an additional 25% onto the existing 22% tariff bringing the total tariff to 47%. On September 1, 2019, as part of the continuing U.S.-China trade dispute, China bumped up the tariff on imports of U.S. pecans by another 10%, increasing the total tariff facing Chinese buyers of U.S pecans to 57%. In a matter of about a year and a half, the tariff charged on imports of U.S. pecans into China rose from 7% to 57%. The incremental Chinese tariffs were not applied to pecans originating from other pecan exporting countries like Mexico, South Africa, and Australia.

*Expected Effects of the Chinese Import Tariff*

China is the largest importer of in-shell pecans so any changes in China's pecan trade policies have major implications for the U.S. pecan industry. In the short run (the year in which the tariff was imposed in this analysis, 2018/19), the 57% tariff on in-shell pecans had little effect on U.S. pecan production given that producers are unlikely to remove trees from production given a price decline which they hoped to be of short duration. The 2018/19 production reduction was more likely the effect of Hurricane Michael and a low, off-year, alternate-year bearing production cycle yield that

**Table 2. Chinese Tariffs on Imports of U.S. Pecans, 2007 – 2019**

| Year | MFN[a] Tariff | Tariff Added | Total Additional Tariff | MFN + Additional Tariff |
|---|---|---|---|---|
| | % | | | |
| 2007 | 13 | | | 13 |
| 2008 | 24 | | | 24 |
| 2009 | 24 | | | 24 |
| 2010 | 24 | | | 24 |
| 2011 | 24 | | | 24 |
| 2012 | 24 | | | 24 |
| 2013 | 24 | | | 24 |
| 2014 | 10 | | | 10 |
| 2015 | 10 | | | 10 |
| 2016 | 10 | | | 10 |
| 2017 | 7 | | | 7 |
| Jan – March 2018 | 7 | | | 7 |
| Apr – Dec 2018 | 7 | 15 | 15 | 22 |
| Jan – May 2019 | 7 | | 15 | 22 |
| June – Aug 2019 | 7 | 25 | 40 | 47 |
| Sept – Dec 2019 | 7 | 10 | 50 | 57 |

[a] MFN = most favored nation

year. If the tariff remains in place for over a prolonged period, however, the effects of the tariff on U.S. plantings, removals, and harvest could be substantial. Nevertheless, the short-run effect of a tariff included a reduction in the U.S. producer price for pecans to some extent, along with a dropin both exports and export revenue. How much the tariff contributed to the price and export decline experienced in 2018 depends on the price responsiveness of U.S. pecan export supplies and of the Chinese import demand for U.S. pecans as illustrated in Figures 17, 18, and 19.

In Figure 17, the price and quantity of U.S. pecans exported to China before the imposition of the retaliatory tariff by China are shown as $P_0$ and $Q_0$, respectively. The export supply curve (ES) in Figure 1 represents the quantity of U.S. pecans available at various prices. The curve is upward sloping because the U.S. is willing to supply more pecans to the world market only at higher prices. The export demand curve ($ED_{\text{without tariff}}$) in Figure 17 represents the prices that importing countries are willing to pay for each level of U.S. pecans they import. This curve is downward sloping

**Figure 17. Effect of a Chinese Import Tariff on U.S. Pecan Export Quantity and Price**

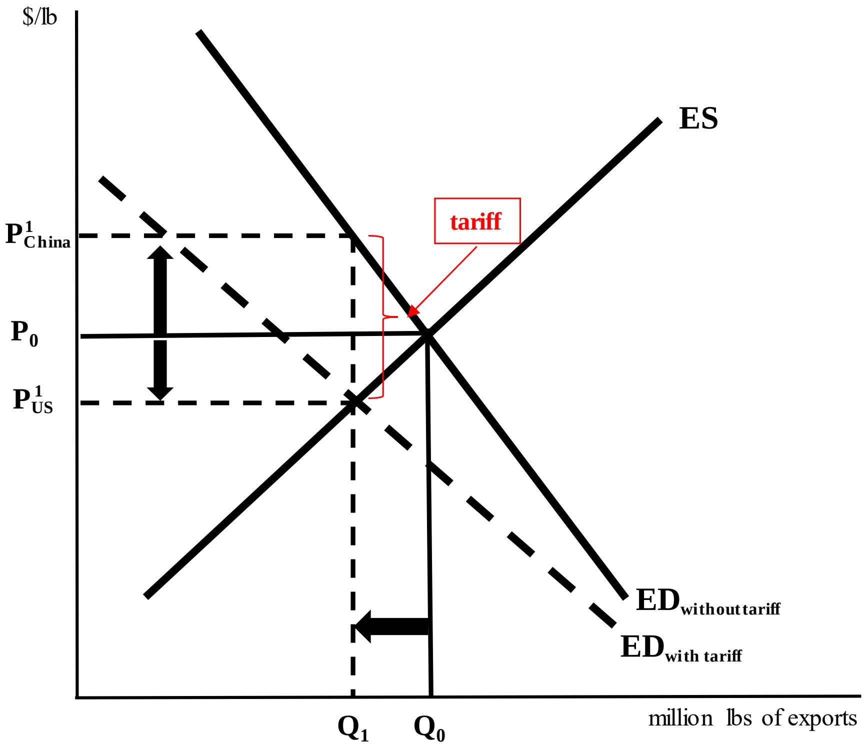



**Figure 18. Effect of a Chinese Import Tariff on U.S. Pecan Export Quantity and Price Given an ELASTIC Export Supply of U.S. Pecans**

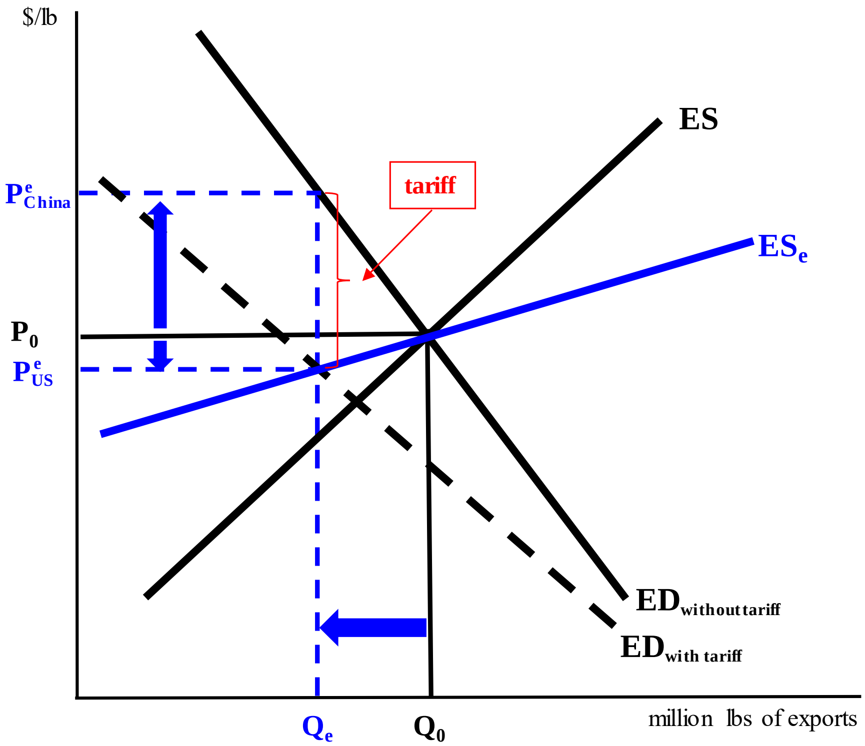
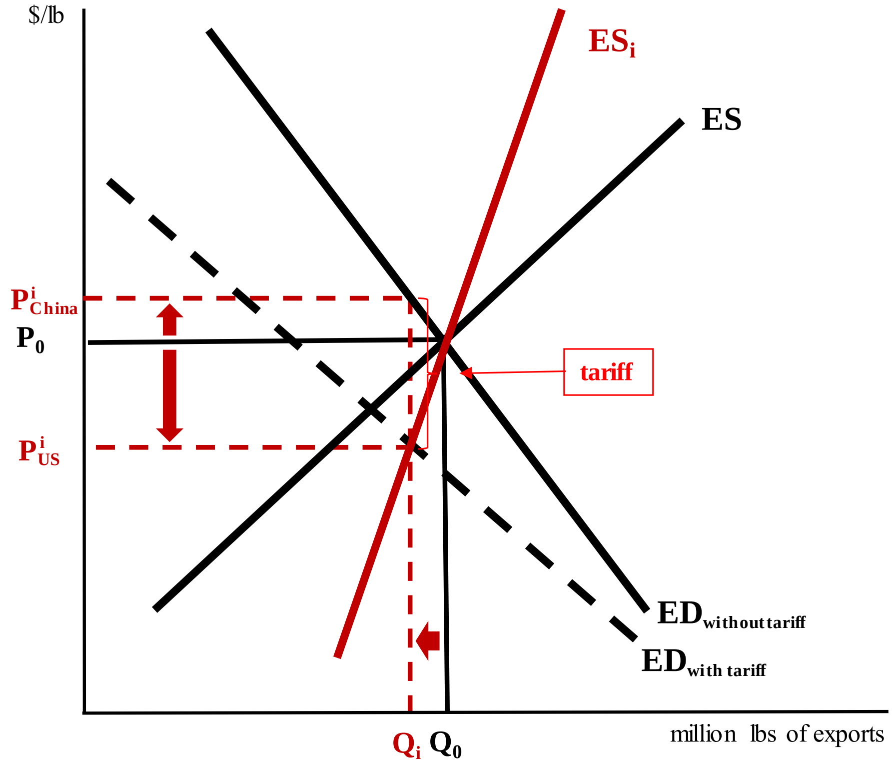


**Figure 19. Effect of a Chinese Import Tariff on U.S. Pecan Export Quantity and Price Given an INELASTIC Export Supply of U.S. Pecans**




because the lower the price, the greater the quantity of U.S. pecan exports foreign importing countries are willing to buy. The effects of a tariff on U.S. pecan exports are illustrated with a lower ED demand curve ($ED_{with\ tariff}$) because the tariff leads to lower prices paid by importers for each level of pecan imports. Given the lower ED curve because of the tariff, the result is a reduction in exports to $Q_1$ and a decline in the U.S. export price of pecans to $P^1_{US}$. Adding the 57% tariff to the lower U.S. pecan price ($P^1_{US}$ x 1.57) gives the price of pecans in China ($P^1_{China}$) which is higher because of the tariff. The U.S. price is lower because China imports fewer pecans, dampening the demand for U.S. pecans. The reduced level of imports of pecans by China results is a reduction in supplies available on the Chinese market which raises the price of U.S. pecans in that market.

Note from Figure 17 that the tariff effects are shared by both the U.S. and China because the tariff acts as a wedge between their prices – raising price in China and lowering price in the United States. Thus, the U.S. pecan price does not drop by the full 57% of the tariff. While some of the tariff is paid by the U.S. in the form of a lower price on a smaller level of exports, China pays for part of the tariff in the form of a higher price on that lower level of exports. Thus, the tariff is the difference between the higher price in China ($P^1_{China}$) and the lower U.S. price ($P^1_{US}$). The result is also a lower volume of U.S. pecan exports ($Q_1$) at a lower price ($P^1_{US}$) and, therefore, lower pecan export revenue. How far the volume and price of U.S. pecan exports drop as a result of the import tariff depends on the elasticities (that is, price responsiveness) of both U.S. pecan export supply (ES) and the Chinese demand for U.S. pecan exports (ED) as shown in the Figures 18 and 19. Figure 18 demonstrates that if the U.S. export supply of pecans is relatively responsive (elastic) to price ($ES_e$), the same Chinese import tariff leads to a relatively smaller decline in the U.S. pecan export price to $P^e_{US}$ and a relatively larger decline in the volume of U.S. pecan exports to $Q_e$. The extent of the subsequent drop in export revenue depends on how far both the price and quantity exported drop. Note that in this case China pays most of the tariff because the price of pecans in the U.S. declines relatively less than the price of U.S pecans in China increases. In this case, economists say that China bears the burden of the tariff.

Figure 19 demonstrates that the opposite is the case for the same tariff with a less responsive (inelastic) U.S. export supply of U.S. pecans ($ES^i$). In this case, the Chinese tariff leads to a relatively larger decline in the U.S. price of pecans to $P^e_{US}$ and a relatively smaller decline in the volume of U.S. pecan exports to $Q_i$. Given the lack of price response of U.S. exports to the tariff, most of the effects of the tariff are manifest as a decrease in the price of U.S. pecans with relatively less effect on U.S. exports of pecans. In this case, the U.S. bears the burden of the tariff because U.S. pecan price drops by more than the price in China increases. U.S. pecan exports are little affected by the Chinese import policy in this case.

Thus, in general, the more responsive (elastic) the U.S. export supply of pecans is to the U.S. price of pecans, the more the cost of the tariff falls on China given the relatively large increase in their pecan price and the large drop in their imports of U.S. pecans. On the other hand, the more unresponsive (inelastic) the U.S. export supply of pecans is to the U.S. price, the greater the share of the cost of the tariff is borne by the U.S. pecan industry given the relatively large drop in the U.S. price of pecans. However, the drop in the volume of U.S pecan exports is relatively smaller, which limits the decline in export revenue as a result of the tariff. This case is most representative of the U.S. pecan industry in the short-run. Remember that the short-run is generally the period over which supply cannot change much given a price change. As discussed in connection with Table 1, the domestic demand, export demand, and ending stock demand are quite unresponsive to price (inelastic) and the production of pecans is unresponsive to price in the short-run. Thus, because any price change from a tariff would have only a small effect on production, the supplies available for export would not be much affected over that period either. Thus, the main effect of a tariff that is in place for only a year or two would be a decline in the price of pecans during that period since a change in the production of pecans would not occur much until after five to eight years as producers make tree removal decisions. If producers expected the tariff to be reduced for only a short period of time, little change in production over the short-run or long-run would likely occur. If the tariff persisted for some time, however, then U.S. pecan production would tend to decline over time and reduce the availability of U.S pecan supplies for exports, which, in turn, would tend to limit the price decline from the tariff over time.

*Simulation Analysis of the Effects of the Chinese Import Tariff*

Using PecanMod, we analyzed the effects of the increased Chinese tariff in 2017/18 and 2018/19, assuming that if the Chinese had not increased their tariff on U.S. pecan imports then the Chinese tariff would have remained at the 7% MFN level that was in existence before April 2018 when China began the retaliatory increase in their pecan import tariff (see earlier discussion). In 2017/18, the tariff was at the MFN level from October 2017 through March 2018 (see Table 2). An additional 15% was added to the existing 7% tariff for a total tariff of 22% starting in April 2018, which remained through the end of that crop year (September 2018). Thus, the 15% increase in the Chinese tariff only affected the second half of the 2017/18 crop year.

The 7% MFN tariff with the added 15% (total of 22%) continued from the beginning of the 2018/19 crop year in October 2018 through May 2019. In June 2019, an additional 25% was added to the 7% MFN tariff and the previously added 15%, a total tariff of 47%, which remained until August 2019. In the final month of the 2018/19 crop year (September 2019), an additional 10% was added for a total Chinese tariff on imports of U.S. pecans of 57% in that month and then on into the 2019/2020 crop year. Thus, the added Chinese tariff of 15% was in effect for the first eight months of 2018/19 and the next increase of 25% (a total increase of 40% above the 7% MFN) was in place for the next three months. Only in the last month of 2018/19 was the additional 10% added for a total increased tariff of 50% above the 7% tariff.

In this counterfactual simulation analysis, the *with* simulation is represented by actual history with the Chinese import tariffs at the levels set in both 2017/18 and 2018/19 as previously discussed (also see Table 2). The *without* or counterfactual simulation assumes that the import tariff was set at the 7% MFN level in both crop years. In other words, we analyzed only the effects of the increase in tariffs above the 7% MFN during those two crop years. The simulated differences between the values for the U.S. pecan industry (supply, demand, exports, prices, etc.) are measures of the effects of the increases in Chinese tariffs in those two years. In other words, the results of the analysis indicate how the increases in the Chinese tariff on U.S. pecan imports affected the U.S pecan industry in those two years.

The results of the analysis are shown in Table 3. Replicating economic behavior in the pecan industry, the counterfactual simulation with PecanMod results in little effect of the tariff increases

**Table 3. Effects of Chinese Import Tariff Increases on U.S. Pecan Industry in 2017/18 and 2018/19**

| | 2017/18 | | 2018/19 | | Two Year Effects | |
|---|---|---|---|---|---|---|
| | **Change** | **%** | **Change** | **%** | **Change** | **%** |
| **U.S. Pecan Supply (mil. lb)** | | | | | | |
| Utilized Production (in-shell) | | | | | Two-Year Totals | |
| *Native/Seedling* | -1.2 | -4.3 | -2.8 | -16.4 | -4.0 | -9.0 |
| *Improved Varieties* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Total* | -1.2 | -0.4 | -2.8 | -1.2 | -4.0 | -0.7 |
| Imports (shelled) | -1.3 | -0.9 | -3.1 | -1.9 | -4.4 | -1.5 |
| **U.S. Pecan Use (shelled) (mil. lb)** | | | | | | |
| Domestic Use | 1.9 | 1.2 | 4.5 | 2.6 | 6.4 | 2.0 |
| Exports | -5.2 | -4.4 | -12.7 | -12.2 | -17.9 | -8.1 |
| Change in Stocks | 1.5 | 17.0 | 3.8 | n.d | -5.4 | 75.0 |
| **Revenue ($ millions)** | | | | | | |
| Producer | -69.8 | -9.0 | -145.5 | -25.5 | -215.3 | -15.9 |
| Export | -75.5 | -9.9 | -163.1 | -26.6 | -238.6 | -17.3 |
| **U.S. Pecan Prices (cents/lb)** | | | | | | |
| Producer Prices (in-shell) | | | | | Two-Year Ave. | |
| *Native/Seedling* | -15.7 | -9.0 | -41.0 | -26.4 | -28.3 | -17.2 |
| *Improved Varieties* | -23.0 | -8.7 | -60.0 | -25.1 | -41.5 | -16.5 |
| *U.S. average* | -21.9 | -8.6 | -57.2 | -24.6 | -39.6 | -16.2 |
| Export Price (shelled) | -36.9 | -5.7 | -96.8 | -16.4 | -66.8 | -10.8 |
| Import Price (shelled) | -20.7 | -4.2 | -53.9 | -10.5 | -37.3 | -7.4 |

n.d. = a percentage change from a negative to a positive number which is undefined (cannot be calculated).

on production because pecan production cannot change much in such a short period of time to price changes, particularly the production of improved varieties. In addition, producers were not likely to have removed trees within those two years in response to the price decline given that most observers assumed that the trade war with China was temporary and soon would be resolved so that the Chinese import tariffs would be lifted. The simulation results indicate that over the two years, native pecan production declined slightly by 4.0 million pounds (in-shell) (9.0%) as a result of the tariff increases given that native pecan production tends to be more price responsive in a shorter period of time than are improved varieties. The tariffs had no effect on the production of improved pecans over those two years.

Because pecan production cannot respond quickly to price changes, the major consequences of the increases in the Chinese import tariff were declines in U.S. pecan prices as in the case illustrated by Figure 19 (the case of an export supply that is highly unresponsive to price changes in the short-run). The tariff pushed native/seedling and improved variety prices (in-shell) down by 15.7 cents/lb (9.0%) and 23.0 cents/lb (8.7%), respectively, in 2017/18 and by 41.0 cents/lb (26.4%) and 60.0 cents/lb (25.1%), respectively, in 2018/19. The U.S. export price (shelled) declined by 36.9 cents/lb (5.7%) in 2017/18 and by 96.8 cents/lb (16.8%) in 2018/19 as a result of the tariff increases. The import price of pecans (shelled) declined by 20.7 cents/lb (4.2%) and 53.9 cents/lb (10.5%) in the two years, respectively, primarily because reduced exports as a result of the tariff increased the supplies available in the U.S. market which reduced the demand for imports.

Over the two years, the tariffs reduced pecan exports by 17.9 million pounds (8.1%) (Table 3). The export decline was limited despite the Chinese import tariff due to increases in U.S pecan exports to other countries. The tariff-induced price declines boosted domestic use by 6.4 million pounds (2.0%). The reduction in exports, however, led to lower domestic demand for imports by 4.4 million pounds (1.5%) and a stock build-up of 5.4 million pounds despite the tariff-induced lower prices. The U.S. price declines as a result of the tariff plus the decline in exports and the small decline in production as a result of the tariffs led to sizeable declines in producer and export revenues. Over the two crop years, the Chinese import tariffs reduced producer revenues by a total of $215.6 million (15.9%) and export revenue by $238.6 million (17.3%).

A common misperception is that a tariff of a given percentage should reduce the price in the exporting country by the same percentage. However, as discussed earlier, the tariffs insert a wedge between the prices of the importing and exporting countries. That is, the tariff drives up the price in the importing country and drives down the price in the exporting country down. The tariff is the percentage difference between the lower exporting country price and the higher importing country price. Thus, the percentage change in price is shared between the two countries. The exporting country price does not decline by the full amount of the tariff nor does the price in the importing country increase by the full amount of the tariff.

There are other reasons that prices in an exporting country do not appear to decline the full amount of a tariff, such as in the case of the Chinese tariff on imports of U.S. pecans. For example, China is not the only country that imports pecans from the United States. Recall that China, Hong Kong, and Viet Nam together have accounted for only about 50% of U.S. pecan exports. Thus, when pecans exports dropped as a result of the tariff in 2017/18 and 2018/19, U.S. exports to other pecan importing countries increased, reducing the export impact and the price effect of the tariff. In addition, the tariffs were not constant but rather changed during each crop year. In 2017/18, the additional 15% tariff that was added in that crop year was only added in the last six months of the crop year. Consequently, over the full crop year, the implied tariff increased by only 7.5% (half of 15%). Then in 2018/19, the tariff was only 15% above the 7% MFN for eight months, 40% above the 7% MFN for only three months, and 50% above the 7% MFN for only one month. Thus, the implied tariff addition to the 7% MFN for the full 2018/19 crop year was only 24.167%[1].

The 2018/19 crop year was unusual not only because of the Chinese tariff on U.S. pecans that year but also because of Hurricane Michael, wet weather, and disease issues that negatively impacted pecan production that same year. How much of the change in industry activities (production, consumption, prices, and trade, etc.) was due to the weather and other issues affecting production that year and how much was due to the tariff? We used the counterfactual simulation results to analyze the contribution of the tariff to industry changes that occurred between the 2017/18 and 2018/19 crop years. In essence, we calculated the simulated changes in the industry due to the tariff for each industry activity between 2017/18 and 2018/19 as percentages of the changes in the corresponding activities that actually occurred between those ow years. The results are in Table 4. Columns 1, 2, and 3 of Table 4 indicate actual outcomes for those two years. The last column indicates the share of the change that actually occurred between 2017/18 and 2018/19 that was due to the Chinese import tariff based on the counter-factual simulation results. For example, column three indicates that total U.S. utilized pecan production actually declined by 61.9 million pounds (in-shell) from all events in 2018/19. The last column indicates that very little (about 4.6%), all from a decline in native pecan production, was due to the tariff.  The rest was due to weather-related issues, a low alternate-year bearing production cycle yield in several states that year, and possibly other market forces. In addition, the results in Table 4 indicate that of the 20.4 million pound increase in U.S. domestic pecans use, about 22% was due to the tariff.  The rest was likely due to other positive forces boosting consumer demand for pecans in 2018/19 over 2017/18 like the promotion efforts under the Federal Marketing Order for pecans, increasing consumer incomes, a relatively larger drop in the prices of other nuts (like walnuts), etc.

The results in Table 4 also indicate that the tariff accounted for about half of the drop in exports, with the remainder due to other forces like the drop in pecan production that year. Almost all (nearly 100%) of the declines in the export and producer prices of pecans that occurred between 2017/18 and 2018/19 was also due the tariff. The results provide some additional insight on the tariff effects on the volume of pecan imports, indicating that the tariff pushed pecan imports down slightly (about 3 million pounds) but forces like the drop in production and the increase in domestic demand overwhelmed the negative tariff effect and resulted in a higher level of pecan imports in

[1] 24.167= (8*0.15+3*0.4+0.5)/12

**Table 4. Contribution of Tariff to Changes in the Pecan Industry from 2017/18 – 2018/19**

| | 2017/18 | 2018/19 | Change from 2017/18 to 2018/19 | Percent of Change due to Tariff |
|---|---|---|---|---|
| **U.S. Pecan Supply (mil. lb)** | | | | |
| Utilized Production (in-shell) | | | | |
| *Native/Seedling* | 26.3 | 14.5 | -11.8 | 11.2 |
| *Improved Varieties* | 278.6 | 228.5 | -50.1 | 0.0 |
| *Total* | 304.9 | 242.9 | -61.9 | 2.2 |
| Imports (shelled) | 137.1 | 163.0 | 25.9 | -5.6 |
| **U.S. Pecan Use (shelled) (mil. lb)** | | | | |
| Domestic Use | 154.2 | 174.5 | 20.4 | 10.3 |
| Exports | 113.5 | 91.0 | -22.5 | 26.2 |
| Change in Stocks | 10.6 | 1.9 | -8.7 | -20.5 |
| **Revenue ($ millions)** | | | | |
| Producer | 710.3 | 425.4 | -284.9 | 23.6 |
| Export | 688.8 | 450.0 | -238.9 | 31.5 |
| **U.S. Pecan Prices (cents/lb)** | | | | |
| Producer Prices (in-shell) | | | | |
| Native/Seedling | 158.0 | 114.0 | -44.0 | 43.3 |
| Improved Varieties | 240.0 | 179.0 | -61.0 | 45.7 |
| U.S. average | 233.0 | 175.1 | -57.9 | 45.9 |
| Export Price (shelled) | 607.0 | 494.5 | -112.6 | 42.2 |
| Import Price (shelled) | 476.6 | 460.9 | -15.7 | 159.9 |

2018/19.The tariff also created conflicting effects on the price of imports. While declining like other prices due to the tariff, the import price was supported by other forces such as the increased demand by China for pecans from Mexico. For that reason, perhaps, the import price of pecans declined by less than the producer and export prices between 2017/18 and 2018/19.

Finally, about half of the drop in producer revenue and over two-thirds of the drop in pecan export revenue from 2017/18 to 2018/19 were due to the tariff (Table 4). The rest was due to other market forces like the weather-related drop in production in 2018/19.

In summary, the main effect of the tariff was to reduce U.S. pecan exports and prices with some increase in domestic use and little or no effect on effect on production. Most of the price decline experienced in 2018/19 from 2017/18 was the result of the tariff and about half of the decline in exports and in producer revenue. The rest of the changes in those variables between 2017/18 and 2018/19 was due to other forces, including the production decline that occurred in 2018/19.

## Final Comments

PecanMod is a powerful tool for analyzing the effects of economic and policy issues relating to the U.S. pecan industry. The intention is to continue developing PecanMod to become even more inclusive of activities relating to the U.S. pecan industry and to capture more robustly the dynamics and variability of the industry. Even so, PecanMod already can provide useful analyses of the effects of numerous types of events on the U.S. pecan industry such as the pecan checkoff program, the USDA Trade Aid package benefits to the industry through the Food Purchase and Distribution Program, exchange rate changes, U.S. economic growth and growing consumer incomes, and much more. In addition, the model can be customized to analyze the effects of various other economic events.

Importantly, PecanMod is a tool for analyzing *economic* and not *biologic* events related to pecans. For example, even though pecan scab is the most economically significant disease of pecan trees in the southeastern United States, PecanMod is not designed to determine the biologic effects of the disease on U.S. pecan production. However, working with pecan tree pathologists and other pecan horticultural experts to develop an estimate of the effects of the disease on pecan production, PecanMod then can be used to determine the overall economic effects of an outbreak of the disease on the pecan industry, including the effects on price, consumption, exports, imports, ending stocks, producer revenue, and other key industry measures not only in the short-run but over time as well. The same is true for other biologic and other non-economic issues such as the short-run and long-run effects of hurricane damage and other weather events and new production technologies, among many others.

The model is limited in its ability to analyze the full set of activities in the pecan industry not only by a lack of data for key industry activities but also by the consistency and reliability of available data. Nevertheless, PecanMod replicates well the behavior of the U.S. supply, demand, and prices of pecans. Like all models, PecanMod will need to evolve over time given changes that occur in the pecan industry and the availability of data. As well, the model will need to expand to better capture the complex and extremely dynamic nature of the pecan industry. The analysis of the 2017/18 and 2018/19 Chinese tariffs on imports of U.S. pecans provides an excellent demonstration of what PecanMod can already do in analyzing the effects of economic events impacting the U.S. pecan industry. The contribution analysis demonstrates some of the additional insights that analysis with PecanMod can provide.

PecanMod is the exclusive property of the American Pecan Council (APC). The model will reside at Texas A&M University to allow researchers to update the database used to build and simulate the model and to refine and enhance the model over time. Future APC requests for analysis using the model can be carried out but only at the request of APC under separate contracts for the work requested.

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# APPENDIX 1
## Chronological Review of Past Economic Research on the U.S. Pecan Industry

This appendix provides a more detailed, chronological review of past economic research on U.S pecan markets.

***Jones, Childs, Washburn, Thibodeaux, Park, and Rutland (1932)***
"An Economic Study of the Pecan Industry." U.S. Department of Agriculture, Technical Bulletin No. 324, September 1932.

This study is the earliest known economic analysis of the U.S. pecan industry. Conducted by the USDA Bureau of Agricultural Economics (now known as the Economic Research Service) in cooperation with various State agencies, the study covers the period of 1928-1930. The study reports the results of a survey focused on three basic pecan market activities: (1) production, which included estimates of the size of the pecan crop, a survey of the number of pecan trees by age groups and geographic distribution, and varieties grown; (2) cost of production, which dealt with practices and costs in the development of pecan orchards of improved varieties and in the operation of bearing orchards; and (3) marketing, which included a description of marketing practices in producing areas as well as a presentation of price and distribution data. The survey also included information on pecan-marketing conditions from the viewpoint of the retailer and consumer and a discussion of the competition of pecans with other nuts. The study provides data but no development of a U.S. pecan model.

***Lerner (1959)***
"An Econometric Analysis of the Demand for Pecans with Special Reference to the Demand Interrelationships among Domestic Tree Nuts." Ph.D. thesis, Oklahoma State University.

This study is the first known attempt to investigate demand interrelationships of various tree nut products examining pecans, walnuts, filberts, and almonds using annual time-series data from 1927-1955, excluding the war years of 1942-1946. Using ordinary least squares regression, the estimated own-price elasticities were -1.19 for native pecans, -1.80 for walnuts, -23.04 for filberts, and -0.86 for almonds. The estimated income elasticities were 2.32 for pecans, 2.40 for walnuts, 20.12 for filberts, and 2.53 for almonds. Pecans and walnuts were found to be gross complements. Pecans and filberts, pecans and almonds, and walnuts and almonds were found to be gross substitutes. Although estimating demand relationships, the study does not consider production, price, or other pecan industry activities.

***Dhaliwal (1972)***
"An Econometric Investigation of Demand Interrelationships among Tree Nuts and Peanuts." Ph.D. thesis, Oregon State University.

This study examined single equation demand interrelationships among eight tree nuts, including almonds, filbert, pecans, walnuts, pistachios, Brazil nuts, and cashews using annual time-series data from 1947-1968. The estimated own-price elasticities for each type of nut were substantially lower than reported by Lerner in 1959. The price elasticities estimated by Dhaliwal were -0.91 for pecans, -0.29 for walnuts, -1.93 for filberts, and -0.55 for almonds. Pecans and walnuts, pecans and Brazil nuts, and Brazil nuts and cashews were found to be gross substitutes; almonds and filberts as well as pecans and pistachios were found to be gross complements.

***Wells, Miller, and Thompson (1986)***

"Farm level demand for pecans reconsidered." *Journal of Agricultural and Applied Economics* 18(1): 157-160.

This study estimated farm-level demand for pecans using annual data from 1970-1982 based on a price-dependent demand function. The own-price flexibility of pecans at the farm level they estimated was -0.97, similar to the estimate by Dhaliwai (1972).

***Florkowski, Purcell, and Hubbard (1992)***

"Importance for the U.S. Pecan Industry of Communicating about Quality." *Hortscience* 27(5): 462-464.

The authors of this study surveyed pecan growers from Georgia to provide information about knowledge of and perceived adequacy of pecan quality standards. Logit models were used to identify variables influencing knowledge of pecan grades and their perceived adequacy. Larger and more experienced growers were more familiar with the USDA standards for grades than were smaller growers. The geographical location of growers within Georgia did not significantly affect the results.

***Wood (1993)***

"Production Characteristics of the United States Pecan Industry." *Journal of the American Society of Horticultural Science* 118(4): 538-545.

This study as well as those by Epperson and Allison 1980: Swink, 1991; Wood, 1991; and Young, 1991concludes that past efforts to forecast in-shell nut production and expanding domestic and export markets has been difficult. Forecasting-related problems have been largely associated with the alternative bearing tendency of the crop. This study characterized the cyclic, alternate bearing and correlative aspects of U.S. produced pecans and assessed the feasibility of solely using in-shell nut production to forecast future production based on stepwise autoregressive techniques. Univariate models will generally not be capable of satisfactorily forecasting production for the pecan industry. Past models, in general, failed to take into account the cyclic (alternate bearing) characteristic of pecan production.

***Shafer (1996)***

"Pecan Production and Price Trends 1979–1995." Faculty Paper 24019, Department of Agricultural Economics, Texas A&M University.

A major conclusion of this study is that expected pecan production in the current season as well as beginning stocks affect pecan prices in each season. Relatively high pecan prices over the period from 1990 to 1995 were attributed to lower production and stocks in those years. In addition, the study notes a growing trend in international trade in pecans as well as a significant impact on U.S. pecan market prices from pecan import volumes.

***Florkowski, You, and Huang (1999)***

"Consumer's Selection of Retail Outlets in Buying Pecans." *Journal of Food Distribution Research* 30(2): 34-43.

This study identified differences in consumer characteristics and the selection of the type of a retail outlet in pecan purchases using a multinomial logit model. Data were collected through a nationwide survey. The report concluded that age, household income, and household size are among the important consumer characteristics that influenced the selection of a retail outlet. Employment and the timing of pecan purchases also influenced the use of a specific type of retail outlet. In particular, mail-order purchases were made by older persons with higher incomes and from larger households in comparison to purchases at grocery stores or other outlets. The study also provided information needed to improve marketing strategies for different outlets and suggested that various strategies can be developed to reach different groups of pecan buyers by type of retail outlet.

***Park and Florkowski (1999)***
"Demand and Quality Uncertainty in Pecan Purchasing Decisions." *Journal of Agricultural and Applied Economics* 31(1):29-39.

The authors of this study estimated a generalized Heckman model of purchase decisions incorporating perceived consumer quality attributes, ease of purchase, and familiarity with marketing outlets as factors influencing pecan purchases. A nationwide mail survey examining the purchases of raw, unprocessed pecans (shelled or unshelled) was conducted in the summer of 1993 based on a randomly drawn sample of consumers provided by marketing representatives from the pecan industry. The study concludes that marketing efforts encouraging consumers to spend more on nut products increased both the probability of pecan purchases and the amount purchased. They also found that consumers who used all types of nuts in a wider variety of foods tended to purchase pecans more frequently. In addition, a diverse set of marketing outlets were found to provide consumers with convenient sources of purchasing pecans and had a significant influence on the probability of pecan purchases but not on the amount of pecans purchased.

***Onunkwo and Epperson (2000)***
"Export Demand for U.S. Pecans: Impacts of U.S. Export Promotion Programs." *Agribusiness* 16(2): 253-265.

In this study, the impacts of federal promotion programs on the foreign demand for U.S. pecans on a shelled basis were estimated over the period of 1986 to 1996. Attention was centered on Asia and the European Union, which together accounted for about 27% of U.S. pecan exports during that period. The own-price elasticities of export demand for pecans were estimated as -0.72 for Asia and -0.73 for the European Union. The returns per dollar of promotion expenditure for pecans were found to be $6.45 for Asia and $6.75 for the European Union.

***Reid and Hunt (2000)***
"Pecan Production in the Northern United States." *HorTechnology* 10(2): 298-301.

This study finds that more than 93% of pecans produced in the United States are grown in the southeastern and southwestern states. However, the native range of the pecan tree extends northward into Kansas, Missouri, and Illinois. Reid and Hunt (2000) noted that in these northern states, commercial pecan production was expanding as additional acres of native trees were brought under cultivation, and orchards of short-season, cold-hardy cultivars were established. Native nut production dominated the northern pecan industry accounting for over 95% of nuts produced in the region. Cultural practices for native pecans had been developed for northern groves that feature low inputs and good yields.

***Wood (2001)***
Wood, B. W., "Production Unit Trends and Price Characteristics within the United States Pecan Industry." *HortTechnology*, (2001) 11(1):110–118.

A major finding of this study was that pecan's alternate-bearing characteristic causes significant marketing problems in the U.S. pecan industry. The study also finds that pecan prices have a much stronger relationship with supply at the national level than at the state level. As well, the supply of pecans on-hand at the beginning of the season, plus the supply from the current season's crop, plus the price of walnuts together accounted for 80% of the price variation of U.S. pecan prices.

***Ibrahim and Florkowski (2005)***
"Testing for Seasonal Co-integration and Error Correction: The US Pecan Price-Inventory Relationship." Selected Paper Presented at the Southern Agricultural Economics Association, February 5–9, Little Rock, Arkansas.

This study analyzed the relationship between pecan price and pecan cold storage inventory by applying seasonal co-integration methods. Monthly data over the period 1991 to 2002 were used in this analysis. Inventories were found to be a driver of pecan prices.

***Ibrahim and Florkowski (2007)***
"Forecasting U.S. Shelled Pecan Prices: A Co-Integration Approach." Selected Paper Presented at the Southern Agricultural Economics Association, February 4–7, Mobile, Alabama, 2007.

The study examined the relationship between shelled pecan prices and inventories using monthly data over the period January 1992 to December 2004. Engle-Granger and Johansen co-integration tests found evidence of a long-run relationship between pecan prices and inventories.

***Moore, Williams, Palma, and Lombardini (2009)***
"Effectiveness of State-level Pecan Promotion Programs: The Case of the Texas Pecan Checkoff Program." *HortScience* 44(7): 1914-1920.

This study evaluates the economic effectiveness of the Texas Pecan Checkoff Program in expanding sales of all Texas pecans and on sales of improved and native Texas pecan varieties. The analysis indicated that the Texas Pecan Checkoff Program had effectively increased sales of improved varieties of Texas pecans but had no statistically measureable impact on sales of native varieties of Texas pecans. A benefit-cost analysis determined that the additional sales revenues generated was relatively large compared to the dollar value invested in promoting pecans.

***Palma and Chavez (2015)***
"Economic Analysis of the Implementation of a Federal Marketing Order for Pecans." Unpublished Manuscript, Department of Agricultural Economics, Texas A&M University.

The study provided an overview of the U.S. pecan industry and the potential effects on supply and demand from the proposed Federal Marketing Order (FMO) for pecans. The assessment under consideration was $0.02-$0.03 per pound of improved pecan varieties in shell to be collected from handlers and $0.01-$0.02 per pound for native/seedling varieties. The chief conclusion was that pecan prices at the grower level would increase by $0.63 for improved varieties and by $0.036 for native varieties due to the proposed FMO for pecans. This study described the economic and marketing state of the pecan industry using available secondary data. In addition, this study described the costs and benefits of the proposed FMO for pecan producers and handlers using a risk-based simulation model.

***Kim and Dharmasena (2018)***

"Price Discovery and Integration in U.S. Pecan Markets. "*Journal of Food Distribution Research* 49(1): 39-47.

Given the nature and the location of pecan production in the United States, the study postulates that the pecan price in one state likely affects or is affected by the pecan prices in other states. Using grower-level pecan price data on a biweekly basis from the October 2005/January 2006 through the October 2015/January 2016 seasons, pecan market integration patterns were estimated for Texas, Oklahoma, Georgia, and Louisiana using causality structures identified through machine-learning methods. Current pecan prices received by growers in Texas were found to be a direct cause of grower prices in Oklahoma, Georgia, and Louisiana. Past-period grower-level pecan prices in Georgia either directly or indirectly influenced current prices in other states.

***Sumner and Hanon (2018)***

"Economic Impacts of Increased Tariffs that have Reduced Import Access for U.S. Fruit and Tree Nuts Exports to Important Markets." University of California Agricultural Issues Center and Department of Agricultural and Resource Economics, University of California, Davis, August.

This report summarized potential impacts of higher tariffs facing major U.S. fruits and tree nuts, particularly almonds, pecans, pistachios, walnuts, apples, oranges, raisins, sour cherries, sweet cherries, and table grapes. The loss in revenue due to declines in U.S. prices resulting from tariff increases in affected markets (Hong Kong and China, Vietnam, India, Mexico, and Turkey) was found to be about $3.4 billion. Importantly, among tree nut commodities, almonds alone accounted for roughly $1.6 billion in losses, while pistachios, walnuts, and pecans faced losses of roughly $384 million, $315 million, and $224 million, respectively.

***Williams, Capps, and Salin (2018)***

"Effects of the Chinese Retaliatory Tariff on U.S. Pecan Exports." White paper to the American Pecan Council.

The study considered the potential impacts of recent retaliatory tariffs on pecans. Commercially produced in 14 states, pecans are the only native tree nut grown in the United States. The study finds that the likely impacts of the Chinese 47% tariff on U.S. in-shell pecans are as follows: (1) Chinese imports of U.S. in-shell pecans will fall substantially; (2) exports of U.S. pecans to the European Union (EU) and to other countries likely will rise; (4) globally exports of U.S. pecans will fall but the rise of exports to the EU and to other countries will not cover the loss in exports experienced in China; (5) Mexico, South Africa, and Australia likely will capture more of the Chinese market but will not cover the loss in exports from the United States; and (6) exports of pecans from U.S. competitors to the EU and to the ROW likely will decline. As a consequence, U.S. pecan prices will drop and production likely will decline over time and led to a decline in producer revenues and profitability.

***Cheng, Dharmasena, and Capps (2019)***

"Demand Interrelationships of Peanuts and Tree Nuts in the United States." Working Paper, Department of Agricultural Economics, Texas A&M University, 2019.

Cheng, Dharmasena, and Capps (2019) conducted a demand system analysis for peanuts and tree nuts in the United States. Monthly observations from 2004 through 2015 derived from the Nielsen Homescan Panel data were used. The nut categories in this analysis corresponded to peanuts, pecans, almonds, cashews, walnuts, macadamia nuts, pistachios, and mixed nuts. All of the own-price elasticities were statistically different from zero, ranging from -0.67 to -2.81. Income elasticities also were statistically different from zero, varying from 0.23 to 0.87, indicating that peanuts and tree nuts were necessities. In particular, the own-price elasticity for pecans was estimated to be -1.07, and the income elasticity for pecans was estimated to be 0.65. In addition, the issue of substitutability and complementarity of peanuts and tree nuts was examined in this analysis. Most nut types were found to be substitutes for each other. Specifically, pecans were found to be substitutes for peanuts, almonds, walnuts, macadamia nuts, pistachios, and mixed nuts. Pecans and cashews were found to be complements.

# APPENDIX 2
## PecanMod Baseline Simulation Validation Statistics[1]

| Name of Dependent Variable | Time Period (Annual) | $R^2$ | Adjusted $R^2$ | DW | RMSE | MAE | MAPE | Theil Decomposition Statistics: Bias Proportion | Theil Decomposition Statistics: Variance Proportion | Theil Decomposition Statistics: Covariance Proportion | Theil U2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $S_n$ (1,000 lb) | 1960 to 2018 | 0.925268 | 0.913311 | 2.041073 | 10,603.930 | 8,008.906 | 14.47 | 0.000029 | 0.021728 | 0.978243 | 0.1555 |
| $S_i$ (1,000 lb) | 1960 to 2018 | 0.881114 | 0.862092 | 1.934235 | 22,209.920 | 18,310.550 | 13.78 | 0.000651 | 0.050615 | 0.948735 | 0.2340 |
| $S_m$ (1,000 lb) | 1980 to 2018 | 0.989127 | 0.986227 | 2.500473 | 4,215.100 | 3,306.466 | 19.76 | 0.000064 | 0.003094 | 0.996842 | 0.5193 |
| $D_u$ (1,000 lb) | 1979 to 2018 | 0.866537 | 0.836400 | 1.978798 | 6,187.479 | 5,010.276 | 3.99 | 0.000027 | 0.047910 | 0.952063 | 0.3238 |
| $E_u$ (1,000 lb) | 1980 to 2018 | 0.862908 | 0.831951 | 1.768442 | 7,403.773 | 5,519.689 | 13.03 | 0.000013 | 0.043848 | 0.956140 | 0.2379 |
| $D_x$ (1,000 lb) | 1990 to 2018 | 0.983503 | 0.978004 | 2.57888 | 4,521.947 | 3,432.311 | 9.60 | 0.000001 | 0.002938 | 0.997061 | 0.5123 |
| $P_i$ (cents/lb) | 1980 to 2018 | 0.998229 | 0.998078 | 2.469824 | 2.558 | 2.116 | 1.89 | 0.000000 | 0.000443 | 0.999557 | 0.0789 |
| $P_n$ (cents/lb) | 1980 to 2018 | 0.994715 | 0.993914 | 2.154009 | 2.714 | 2.137 | 2.99 | 0.000000 | 0.001325 | 0.998675 | 0.1235 |
| $P_m$ (cents/lb) | 1980 to 2018 | 0.931914 | 0.923904 | 2.006546 | 27.342 | 20.650 | 8.40 | 0.001395 | 0.000004 | 0.998601 | 0.5581 |
| $P_x$ (cents/lb) | 1980 to 2018 | 0.987525 | 0.962605 | 1.918434 | 24.094 | 18.107 | 5.60 | 0.000000 | 0.008253 | 0.991747 | 0.4972 |

**Identities**

Total In-Shell Pecan Production = Improved Pecan Production (In-Shell) + Native Pecan Production (In-Shell)

Total Utilized Production (In-Shell Conversion to Shelled Identity = Conversion Factor * Total In-Shell Production

Market Clearing Condition (Shelled): Beginning Stocks + Domestic Production + Imports = Domestic Use + Exports + Ending Stocks

[1] See Figure 16 for variable definitions.