U.S. APPLE MARKET RESPONSE TO CHANGE IN PESTICIDE REGULATIONS

A Thesis

presented to

the Faculty of the Graduate School

at the University of Missouri-Columbia

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

Submitted by

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July 2016

The undersigned, appointed by the dean of the Graduate School, have examined the thesis entitled

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and hereby certify that, in their opinion, it is worthy of acceptance.

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ACKNOWLEDGEMENTS

I would first like to express my gratitude to Dr. Wyatt Thompson, for not letting distance interfere with his assistance on this project. I appreciate that you were always available by email or by phone to answer my questions, assure me I was not “stuck”, and to help me keep moving forward. To my committee members, Dr. Francisco Aguilar and Dr. Patrick Westhoff, thank you for taking time out of your busy schedules to offer your comments and insights. This thesis would not have been possible without your guidance. I cannot emphasize enough my appreciation for the support of the FAPRI team. Thank you for your advice and encouragement throughout this endeavor.

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ABSTRACT

Concerns about the future of the pollinator population have led to the possibility of the registration for the neonicotinoid, imidacloprid, not being renewed for pesticide use in the United States. Supply and demand equations are designed to develop a model that projects apple bearing acreage, yield, imports, exports, residual supply, domestic use, and production to solve for market price. The model structure reflects the time it takes supplies to respond for a perennial crop. Four scenarios are used to consider potential effects if this chemical is no longer permitted in the United States, including possible increases in production costs, reduced yields and restricted imports. Results are compared with the baseline estimates. All of the scenarios result in an increase in price during most of the projected years, with higher gross producer revenue, even if yields are lower, and suggest consumers will have to pay more for apples if imidacloprid's registration is not renewed.

INTRODUCTION

In the United States, the different types of fruit grown are as varied as the nation's climate. Apples are one of the fruits the U.S. is most recognized for producing, which is easy to understand considering the U.S. ranks second in world apple production behind China (Perez, 2016). To produce maximum, high-grade yields, most apple producers use chemical-intensive management programs to control pests and diseases that threaten their profitability. Preferred chemicals change over the years as understanding of effectiveness and safety, for both humans and the environment, expands. Neonicotinoids, a class of chemicals approved by the Environmental Protection Agency's (EPA) pesticide program in the early 1990's, quickly gained popularity due to reduced toxicity to mammals when compared with other pesticides used in fruit production (Jentsch, 2013). However, the insect-targeting characteristics that initially made the chemicals desirable have caused controversy with environmentalists, as neonicotinoids have come under scrutiny for jeopardizing the future of the honey bee population. Since 2006, declines in the honey bee population have occurred due to the largely unexplained phenomenon called Colony Collapse Disorder (CCD) that occurs when a hive's queen and immature bees are abandoned by the worker bees that are responsible for providing for the hive (Lu, Warchol, & Callahan, 2012). In April 2013, concerns about neonicotinoids and the honey bee population led the European Commission to enact a two-year ban on three of the seven neonicotinoids used in flowering crop production as well as any imports that were grown using the chemicals. Because U.S. apple producers still use these neonicotinoids in production imports from the U.S. to the E.U. were restricted to organic apples, which barely dents the E.U.'s total apple imports. Prior to the ban, the United Kingdom was the fourth largest export destination of fresh apples from the U.S., importing over 35,000 metric tons valued at over $37 million dollars in 2008 (Lynch, 2010).One of the banned neonicotinoids, imidacloprid, is the top-selling insecticide in the world and of particular interest to this study.

Developed by Bayer Ag as a systemic insecticide, meaning it spreads internally throughout the plant tissues, imidacloprid is classified as highly toxic to honeybees and should only be applied post-bloom to reduce the risk of pollinators coming into contact with the chemical (McGrath, 2014). Even when application guidelines are followed, there is a possibility of bees being exposed when the chemical fails to breakdown completely between applications. While the chemical does not present a long-term residue risk in the environment, it can build up in the plant tissues and remain for extended periods of time (Jentsch, 2013). Supporters of imidacloprid state the chemical is safe when applied at realistic levels during appropriate times. However, recent studies counter these claims with evidence connecting imidacloprid and CCD. Not only is there indication that imidacloprid can contribute to the causes of CCD, but there is also evidence the suggested application levels that are supposed to be low-risk for pollinators are in fact still lethal and connected to CCD even at lower exposure levels (Lu, Warchol, & Callahan, 2014; Lu, Warchol, & Callahan, 2012). If future studies continue to find similar results, the EPA could determine use of the neonicotinoid is no longer safe for use in apple production. What will happen in the U.S. apple market if the EPA does not renew the pesticide registration for imidacloprid?

The first challenge in addressing this question comes from the difficulties of modeling perennial crops such as apples, as producers of these specialty crops do not start each year with the “clean slate” of an empty field like annual crop producers (French & Matthews, 1971). Rather, their production choices must be made several years in advance of when they expect to see any returns on their investment. Over the years, there have been various studies of the U.S. apple market regarding the modeling of both fresh and processed apples (Willett, 1993). Other research has measured the supply response to loss of pesticides in other produce markets (Rozankski, 1997). Research focusing on the chemical costs and the market effects of pesticide cancellations is also done just after neonicotinoids enter the market (Roosen, 1999). Almost all perennial crop research and models this project studies run into the issue of insufficient data for variables that, had the data been available, would provide a more accurate reflection of the actual market. Diverse approaches are utilized to handle the complication, from substituting general assumptions to focusing on specific regional data. While the existing studies do not incorporate data relevant to the neonicotinoids and CCD time period, they provide elasticities and equations that are beneficial references for creating an updated and more in-depth model that is capable of incorporating and reflecting the changes in the apple market should imidacloprid’s registration not be renewed and it be removed from the production system in the coming years.

PROBLEM STATEMENT

Chemicals are not removed from the production system without thorough research and evidence supporting the need for elimination. To enter the market, the high costs of evaluating and registering these chemicals must be outweighed by the benefits chemical manufacturers expect to gain in sales. At the same time, producers must evaluate the marginal benefits of increased yields with the marginal costs of applying new or additional chemicals. How will apple yields be affected if imidacloprid’s registration is cancelled? Apprehensions about the chemical’s effects should not be ignored. A threat to the honey bee population could eventually become a threat to apple production as a whole as the industry relies so heavily on the use of these pollinators. Already, the decreased supply of bees has caused the cost of pollinating an acre of apple trees to be more than twice what it was before CCD emerged (Lynch, 2010). Based on Europe’s experience with banning several of the neonicotinoids for use in flowering crops, producers rely heavily on the chemicals to maintain adequate production levels. Without them, producers have been forced to revert to older chemicals with higher toxicity to mammals or do without, and production levels in the EU have declined as a result (Randall, 2015). While previous studies have examined apple markets, this research is important because it is able to utilize more recent data that provides a more relevant timeframe and better understanding of the pollinator issue. A model designed to incorporate the chemical costs in the production function and measure market effects should imidacloprid be banned is important for properly evaluating the effects on returns for apple producers and costs to consumers. Once a model is set up to reflect the current market conditions and projections, the model is then shocked to demonstrate how removing the chemicals would alter the market path.

MARKET OVERVIEW

Prior to understanding how the apple market is expected to move in future years, it is important to understand the foundations and background of the market. The only apple variety native to the U.S. is the crab apple, and it was not until the 1500s that the fleshier apples of today were introduced by European settlers. In 1625, the first U.S. apple orchard was planted on Boston's Beacon Hill by William Blackstone (U.S. Apple Association, 2016). Since then, the varieties and locations of apples grown in the U.S. have expanded. Today, apples are grown in all 50 states and over 2,500 varieties are found in the U.S. While many of them are heirloom varieties grown on personal orchards, over 100 apple varieties are grown commercially in 32 states (Geisler, 2013). The most popular apple variety grown in the U.S. today is the Red Delicious, which originated in Iowa in the late 1870s. High demand for Red Delicious apples led to selective breeding for early reddening and thicker skin, traits that negatively affected the apples' quality and consumers' demand by the late 1990s (Perez, 2016). Early reddening led to harvest of under ripe apples, and the thicker skin that improved durability for harvesting and transport made it difficult to determine when internal damage occurred to fruit (Lynch, 2010). With the decreased demand for what had become the most widely produced apple variety, consolidation occurred within the apple market as less efficient producers exited the market and those remaining shifted to growing higher value apple varieties. The change in consumer preferences led to Gala apples becoming the top variety sold in the U.S., with Red Delicious coming in second (Perez, 2016). The restructuring of the production system increased the U.S.'s competitiveness in the international market by the late 2000s. In particular, Washington's apple growers export over 30% of the state's fresh apples, almost twice the national average of 16 percent (U.S. Apple Association, 2016).

The marketing year for apples runs from August 1st through July 31st, with harvest occurring between August and November. While apples have an extended cold storage shelf-life of 2-7 months compared to other fruits, minimal fruit is available to be considered for stocks at the end of the marketing year (Plattner, Perez, & Thornsbury, 2014). The share of imports into the U.S. market has remained small and predominantly counter-seasonal with the U.S. remaining a net exporter of fresh apples. However, U.S. import volumes of fresh apples have climbed over 350 million pounds between the early 1980s and the early 2000s (ERS, 2015). The predominant reason for the increase is a shift in the origin of apples imported into the U.S. Whereas previously Canada and New Zealand had been the primary suppliers to the U.S., development of Chile's fruit industry in the 1990s has since caused the country to become the main supplier of U.S. apple imports (Perez, 2016).A majority of the apples imported into the U.S. arrive during the months of May, June, and July with over 60% of total fresh apple imports coming from Chile (Lynch, 2010). Extended release of harvested apples onto the market has also allowed for moderation of seasonal price fluctuations that often occur in fresh fruit markets (Plattner, Perez, & Thornsbury, 2014). At the same time, export demand for U.S. apples has climbed as foreign consumer preferences and trade policies have expanded global market access for U.S. producers.

While the U.S has remained a net exporter of fresh apples, the same cannot be said when processed apple products are considered. Table 1 outlines the net exports of apples and apple products of the U.S. since the 1980s. Collected from the G tables of the USDA's ERS Supply and Utilization Yearbook of Fruit and Tree Nut Dataset, the traded products are reconverted from product weight into fresh weight for uniformity of measurements, explained further in the Methods section. Canned apples do not have export data; consequently the net exports reported here are simply the negative of the U.S. imports. Also, data collections on dried apple products are discontinued after 2011, so the time series is non-continuous (ERS, 2015). Juice imports are the main reason the U.S. is a net importer of apples and apple products. Because apples destined for juicing do not have the same high quality standards as those for canning or fresh consumption, the price growers receive is often lower (Lynch, 2010). The U.S imports a large amount of apple juice from countries such as China where production costs are lower, but the quality of apples grown has suffered from the government's focus on expanding planted area rather than quality improvement (Perez, 2016). Another factor in domestic juice production being edged out by foreign imports is that several states require juice processing firms to negotiate prices annually with growers. These prices are often much higher than prices paid in other states or overseas (Lynch, 2010). The increase in lower priced apple juice imports has put downward pressure on U.S. processed production, widened the price gap between fresh and processed apples, and increased participation in the fresh market as producers found better profit potential there (Perez, 2016). While China dominates the world market in overall apple production due to the large amount of area in the country devoted to producing the fruit, the U.S. excels in efficient production of high-quality apples and is the leading world apple produce in terms of value (Perez, 2016). In fact, apples are the second most valuable fruit produced, for fresh utilization, in the U.S. behind oranges (UI Extension, 2016).

Unlike commodity crops that are considered a homogenous product, the heterogeneity of apples creates different market allocations and variety demand within each segment. Price changes between the different market sectors affect which types of apples producers grow and where those apples are sold (Willett, 1993). Even with their higher price, U.S. apples have found a niche in the world market as consumers with rising incomes have sought more quality and variety. The diversity of U.S. production proves particularly beneficial in China where Fuji is the variety grown predominately and consumers are willing to pay for what they consider to be higher-quality, safer apple imports from the U.S (Perez, 2016).

Table 1 U.S. Net Apple Exports
Source: NASS, 2016

U.S. Net Exports of Apples and Apple Products, from USDA ERS Yearbook												
Million Lbs. Fresh Weight												
	1980	**1983**	**1986**	**1989**	**1992**	**1995**	**1998**	**2001**	**2004**	**2007**	**2010**	**2013**
Fresh	539	320	150	546	823	834	1144	992	1076	1103	1493	1389
Canned	-4	-4	-9	-7	-1	-18	-39	-53	-81	-110	-149	-218
Juice	-841	-1742	-2747	-2247	-2367	-2526	-3489	-4160	-5586	-6979	-6935	-5237
Dried	-7	-23	-22	-34	-31	-35	-27	-59	-70	-128	-76	-

Because of the delay between when a tree is planted and when it first starts producing fruit, the apple industry is not quick to respond to changes in market conditions. Bearing acreage does not vary a great deal from year-to-year, as most production decisions are made several years in advance. Since 1980, apple bearing acreage peaked in 1989 at over 480 thousand acres and has declined to just under 322 thousand acres in 2014 (NASS, 2015). Even though acreage and the number of apple producers in the U.S. has declined, the remaining producers have maintained and even increased production levels with the introduction of dwarf apple trees. Figure 1 shows the drop-off in bearing acreage that occurred after shifts in consumer preferences caused declines in producers’ prices and the production rebound that occurred as a result of incorporating dwarfs ((ERS, 2015). Dwarf apple trees involve taking a standard tree variety and grafting it on to a rootstock chosen for dwarfing traits, shortening the turnaround time for new plants to begin producing and ensuring high quality fruit. As shading is reduced when dwarfs are utilized, the apples are more exposed to the sun and the fruit has higher sugar content (Lynch, 2010). The smaller tree size also ensures easier harvest, reducing the amount of apples that are unable to be harvested before their quality declines too much to be marketable. The use of dwarf trees in apple production has almost tripled the volume of trees that can be planted on an acre of land from 200 trees per acre in the mid-1980s to 562 trees per acre by 2011 (Plattner, Perez, & Thornsbury, 2014). Although the dwarf trees produce fewer apples per tree, the increased tree density means that per acre yields increased drastically from over 21 thousand pounds to almost 36 thousand pounds. Peak production of over 11.5 billion pounds did not occur until five years after peak bearing acreage, though the improved yields have kept average total production near past peak levels even though bearing acreage has declined (ERS, 2015).

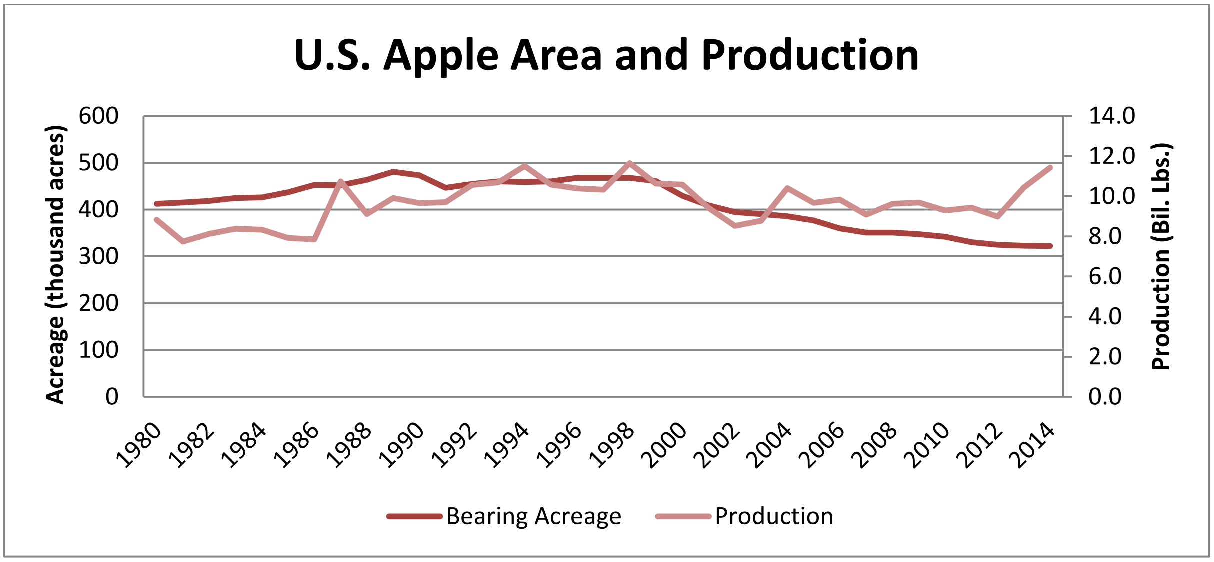

Figure 1. U.S. Apple Area and Production, 1980-2014
Source: NASS, 2016

While maturation of the fruit industry in Southern Hemisphere countries has expanded U.S. access to counter-seasonal apple imports, it has also limited growth in domestic consumption of U.S. produced fruits such as apples. Increased availability, shipping and storage techniques have increased U.S. consumption of tropical fruits not produced in the U.S. (Perez, 2016). Even though overall fruit demand in the U.S. has increased, these imported fruits are composing a greater share of the market and apple producers are not benefiting from the additional demand. In fact, fresh apple consumption has changed little over the last three decades with per capita consumption growing from 19.2 pounds in the early 1980s, peaking at 21.2 just prior to the 1990s, and falling to just over 15 pounds in recent years (NASS, 2015). The stagnated domestic demand has increased the importance of export markets for U.S. apple producers.

LITERATURE REVIEW

Before delving into the mechanics of modeling a perennial crop market, the origin of concerns connecting imidacloprid to CCD must be examined. Some have questioned the connection because of the time gap between when the pesticides were approved for use in apple production and when the disorder was first observed (McGrath, 2014). Recent research suggests the connection may be longer and more complicated than initially believed, having only a distant association with apple production. Lu, Warchol and Callahan (2012) perform extensive studies on the connection between imidacloprid in high fructose corn syrup (HFCS) and CCD. These authors explain how, due to the availability and cost-effectiveness, bee keepers often substitute HFCS in place of honey and sucrose as a food source for their hives over the winter. They go on to explain that, while imidacloprid has been registered for use in apple production since the mid-1990s, the chemical's registration for use in corn seed treatments was not enacted until 2005, only a year prior to the first occurrences of CCD. Because bee keepers did not alter their feeding source after the chemical was approved for use in corn production, the researchers believe hives were exposed to harmful residue levels of the chemical the following winter. The results of the project also provide evidence that even sub-lethal exposure levels of imidacloprid can initiate effects of CCD in hives and disprove the hypothesis that CCD is linked to external environmental factors such as migration stress or mite infestations (Lu, Warchol, & Callahan, 2012). While the researchers are unable to specifically pinpoint an explanation for why CCD does not emerge until later in the year, they offer the suggestion that exposure to the sub-lethal imidacloprid levels in the larval stage could be exacerbated by the time the bees reach adulthood.

Unlike annual crops such as corn and soybeans, the modeling of perennial crops comes with new difficulties. Evaluating supply responses in perennial crops takes greater consideration of the time needed to make adjustments in production. While corn and soybean producers are able to decide the acreage to devote to each crop prior to planting during the current year, apple producers must plan a minimum of three to five years in advance when they want to increase bearing acreage. The idea of modeling these crops is not new, however the approaches to handling the acreage changes and production lags have varied over the years. Ben C. French and Jim L. Matthews (1971) present a theoretical approach to outlining the perennial modeling dilemma of supply response using asparagus. While there is additional research predating that of French and Matthews, theirs is the most used for its adaptability to other perennial crops. In their article, French and Matthews explain how the extended gestation period between input and first output delay the return on investment for producers. While the return is delayed, producers of perennial crops will experience returns for years to come as a result of that initial investment. However, the extended output eventually declines as the production lifespan of the crop draws to a close. Understanding the production lifecycle of perennial crops is essential to modeling supply responses. French and Matthews emphasize the importance of acknowledging the variables of new plantings and removals in equations for calculating bearing acreage. They go on to explain how producers adjust bearing acreage to achieve desired production levels, outlining producers' assumptions regarding the expected profitability of the commodity and the opportunity costs of the land. Because of the delayed turnaround time with perennial crops, producers are likely to be less responsive to short-term market fluctuations. French and Matthews design an equation for new plantings, factoring in adjustment and dampening of unaccomplished desired plantings. Access to capital and nursery stock allows producers to act on their decisions to expand production quickly, although the production is not realized until later, so that not meeting planting goals in one year might not affect future plantings. Assumptions such as these are useful when data for annual new plantings are unavailable, although it would be ideal to model plantings and removals separately. The other element French and Matthews focus on in their research is how acreage removals factor into bearing acreage and production capabilities. Removals can occur for a variety of reasons, including more profitable alternatives for the land, disease and weather, and declining productivity of older plants. There is not a set deadline for how many years a plant will produce before it is removed after production starts to decline, but the average production lifespan for an apple tree ranges from 20 to 30 years. French and Matthews determine short run profit expectations play a significant role in a producers' decision to remove plants. If profits are projected to be high for the coming year, producers will often delay the removal of plants that are still producing. At the same time, if the reverse is expected to occur and profits will be low, producers may shorten the removal schedule of plants with declining production. Taking extra care to emphasize the influence of producer expectations on new planting and removal decisions, the researchers also acknowledge the impacts of technological advances, growth and production stage of the bearing acreage, and external factors such as weather, pests and diseases that can impact yields. While it is ideal to have time series data for ages of all plants to determine production stages, the researchers concede this is not essential for perennial crops with prolonged life where different age groups do not have great variances in average yields. Apples are not an exception to this rule. The researchers go on to offer an example where expanded acreage is accompanied by an increased number of new plantings with lower yields than acreage with more established plants. In regards to estimating the model parameters, French and Matthews offer alternatives when specific data are unavailable particularly to address acreage adjustment. Without specific information on production costs, farm wage rates and labor costs are factored in and found to be highly correlated. In addition, nonbearing acreage and opportunity costs from alternative uses of the production acreage are eliminated due to data unavailability and immeasurability respectively. These variables are instead factored into the disturbance term. With the additions of their acreage change equation and an alternative expected profitability equation in lieu of continuous data, the researchers are able to provide a basic framework for understanding how and when producers of perennial crops will respond to market changes by increasing or dialing back their supply (French & Matthews, 1971).

Other researchers take the theoretical work introduced by French and Matthews and apply it to region specific models for perennial crops. By narrowing down the production area, Stephen Devadoss and Jeff Luckstead (2010) are able to acquire time series data for new plantings and removals of apple trees for orchards in Washington State. Washington accounts for almost 70% of the total U.S. apple production making it a reasonable proxy for the U.S. for the purposes of their research (Geisler, 2013). For their bearing acreage equation, Devadoss and Luckstead use lagged variables of bearing acreage, investment and removals. While the bearing acreage and removals are considered for the previous year, the new plantings data that serves as the investment variable are considered from four years prior to the year being considered because it takes an average of three to five years for most newly planted apple trees to begin producing. While French and Matthews found it difficult to adequately determine what alternative crops figure into the opportunity costs of growing asparagus, Devadoss and Luckstead use cherries and pears as the crops that most often compete with apples when producers are deciding on which crops to use their land and financial resources. However, the researchers acknowledge also running into the issue of not being able to determine age distribution of trees for the purpose of gauging productivity. Their profits are calculated by subtracting total revenues from the total variable costs. Great consideration and effort are taken in determining an adequate measurement of costs and acquiring the necessary data. Devadoss and Luckstead use fuel, labor, service and machinery, materials, and interest costs in their profit calculation for each of the three types of fruits. To factor in the impacts of weather, selective temperature data is obtained and a minimum temperature is designated. Exposure to freezing temperatures at critical times can severely reduce yields. The number of days below the set temperature is found to be negatively correlated with the yield per acre. For their empirical analysis, the researchers incorporate a two-step approach using rational expectations to estimate expected variables. In order to estimate the endogenous variables in the structural model, the expected variables are then substituted in. Relying heavily on the rational expectations of producers when deciding their future production choices, the researchers utilize an autoregressive procedure to create forecasts of expected variables. Devadoss and Luckstead also employee the use of dummy variables to represent known supply shocks not incorporated elsewhere, such as pest and disease outbreaks that occur in certain years. Confirming French and Matthews' theoretical notion that periods of high revenue decrease removals and vice versa, their results show a negative coefficient for expected apple revenues. The paper concludes by stressing the importance of adequate perennial crop models to adequately forecast the impacts of potential policy developments on the apple market.

While Devadoss and Luckstead are able to adequately apply French and Matthews' theoretical approach to modeling perennial crops in a regional situation, there is still the dilemma of how to create a model that accurately reflects the entire U.S. apple industry. Lois Schertz Willett (1993) accomplishes this by simplifying the aspects of removals and new plantings on the bearing acreage equation and instead focusing on the three sectors of the apple market: supply, allocation, and demand. At the same time, Willett further divides the market into fresh and processed allocation and the various product destinations in the processed market such as canned, frozen, dried, juice, and other. Running into the common issue of inadequate data for removals and new plantings, her equation for bearing acreage consists of lagged bearing acreage and a three-year moving average for profitability measures such as average grower price and price index growers paid. The yield equation consists of a function using apple profitability and measures changes in technology. Production is an identity given by multiplying bearing acreage and yield. Willett also acknowledges that total production differs from utilized production, as not all apples produced are harvested and sold. By dividing the destination of production into fresh and processed market channels, total supply and expected relative prices in each market comprise a function for the allocation equation. Willett argues that a rational expectations approach is inappropriate because of the generality of the belief that producers base decisions on the entire economic structure of the industry. Instead, a modified version of the Nerlovian approach of adaptive expectations is utilized, substituting the previous year's price for the expected price. While other researchers utilize current prices when modeling the apple market, Willett argues growers' contractual obligations pre-determine allocation destinations of apple production. The production share to the fresh market segment is a function of total utilization, lagged fresh price and a variable comparing current utilized production with the three-year average, reflecting Willett's belief that producers will not make production choices based solely on market events of the previous year. Willett explains that more apples will be diverted to the processed market if the utilized production is large compared to that of last year's. The five markets comprising the processed market have similar equations using the total allocation to the processed market and the expected price of the specific processed product in relation to the expected prices of all processed products, substituting the previous price for the expected price. The author goes on to say how increases in total apple supply increase allocation to each market, while increases in expected prices for specific products increase the portion of total supply that goes to that market. On the demand side, Willett finds apples are normal goods and considers prices of fresh oranges, orange juice and processed pears in the demand equations for fresh apples, apple juice, and canned apples, respectively. She estimates each market sector model autonomously, with allocation being independent of demand. Fresh apples and juice are found to have inelastic demand, and cross-price elasticities between fresh and processed apples determine that the substitute or complement characteristics change depending on the products being considered. The projections from the model suggest a cyclical pattern with supply increases occurring every other year, and acreage changes being elastic with respect to lagged prices. Scenario analysis suggests that apple production is limited by almost constant acreage causing price to play a greater role in market allocation. While Willett's work is the most applicable of the studies researched for this project, the time period for the data set in this research ends in 1990, several years before neonicotinoid pesticides were introduced into apple production and CCD became a concern.

Whereas other studies focus on the aspects of modeling perennial crops and the difficulties that occur due to lack of data and lag responses, Susan G. Rozanski (1997) creates a supply response model of the tart cherry market and incorporates the cancellation of a pesticide's registration. While not addressing the apple market, the model considers the difficulties of data unavailability when dealing with perennial crop markets and still achieves a supply response to the loss of three pesticides used in tart cherry production. Like Willet's apple market model, Rozanski acknowledges the cyclical properties of cherry production, with expected long run profitability influencing the timing of new plantings and removals and the productive lifespan of trees. Unlike apples that are predominantly channeled into the fresh market, fruit appearance is not as significant in the pricing of tart cherries destined for processing (Rozankski, 1997). However, strict pest control on cherry shipments upholds the importance of reducing the occurrence of damaged fruit. Rozanski uses the Consumer Price Index to deflate all price terms and incorporates apple grower price as apples compete with cherries in the processed market. When national data is unavailable, regional data is substituted for national averages. Because the model runs into the same issue as others in not having data available for new plantings and removals, bearing acreage and yield equations compose the supply side of the model. An innovation in Rozanski's model is the incorporation of dummy variables for the three pesticides used in the model's scenarios, with the dummy variable equaling 1 for the years the pesticide is registered and available for use to cherry producers and 0 for the years it is unavailable. These dummy variables are introduced as an alternative to having adequate available data on specific pesticide applications, and all three are found to have a positive correlation with tart cherry yield when incorporated into the yield equation. The removal of the pesticides significantly reduces yield projections and total supply is predicted to decline, assuming no short-run changes in bearing acreage. As the supply decrease puts upward pressure on price, demand declines. Because Rozanski's model incorporates the use of stocks, the price stability is greater as increased stocks one year could offset high prices the following year when production declines. Rozanski's purpose of creating a model that accurately reflects the data and projects changes in pesticide use is accomplished even with the data limitations, though that it does reflect some imprecision is evident due to lacking sufficient data.

CONCEPTUAL FRAMEWORK

The basic economic principles of supply and demand are utilized for the purpose of creating the model. Perfect competition is assumed with no individual firm or person having the power to alter the market as a whole. While it is acknowledged that there is heterogeneity within the apple market and the different allocation sectors, demand and supply are calculated using aggregate measures as it is assumed apples grown for all market destinations are or can be subject to the use of the chemical being studied. It is also recognized that, while many fruits grown for the purpose of processing are grown under contract with price having little impact on product for the current year, the lag period in production is assumed to absorb any variances in growers' decisions to produce apples for the fresh or processing market. As many producers enter contracts on an annual basis, producers are able to take advantage of long-term differences between returns on fresh and processed apples following completion of their contracted obligations. There is no direct government price support to apple producers, though producers are eligible for crop insurance. While the U.S. does not have tariffs on fresh apple imports, imports are controlled by strict sanitary and phytosanitary (SPS) measures.

On the demand side, the law of demand is followed with the price of apples and the quantity of apples demanded being negatively related. In this regard, if the price of apples increases, the quantity demanded decreases as consumers shift to purchasing alternatives. At the same time, if the opposite is true and the price of apples declines, consumers will decrease purchases of other fruits and fruit products to buy more apples. How much consumers are willing to shift their purchasing preferences in regards to price depends on their utility, own-price elasticity, and cross-price elasticity. Supply is provided by apple growers that plant and manage the bearing acreage. For the purposes of the model, rent versus ownership of the land used to produce the apples is not considered. Instead, it is assumed that the producers will have the option to utilize the land for apple production for as long as price and circumstances deem it a viable option. Consistent with the law of supply, price and quantity are found to have a positive relationship, with quantity produced increasing with an increase in price.

The profit-maximizing application of pesticides would occur when the marginal benefits to production equal the marginal costs of application (Rozankski, 1997). However, regulation can limit the application levels below the optimum, restricting producers' ability to maximize profit margins. The economic theory utilized focuses on how the chemical's existence or absence affects fruit production, rather than the specifics of application levels. While both rational expectations and adaptive expectations are employed in previous studies with success, the adaptive expectation approach that focuses on expected prices based on historical prices is chosen due to the tractability of the method and evidence in the literature that it works well with the extended investment period for new plantings involved in perennial crop production. While there are other crops and land uses that may compete for apple production resources, they are not explicitly represented in this model. The model is intended to suit the purpose of analyzing apple market responses to certain shocks.

MODEL

Equations for bearing acreage, yield, production, trade, consumption, and receipts are introduced. Macro variables for population, consumer expenditures, and gross domestic product (GDP) deflator are incorporated. The unavailability and inconsistency of reported stocks data warrants its exclusion from the model. Equations' variables are appropriately lagged to reflect the delay for producers' production decisions to be reflected in the market, particularly the interval before new plantings begin producing fruit.

Data are collected from 1980-2014 from NASS, ERS, and FAPRI data files, and equations are estimated using annual data from 1990-2014 with the exception of the equation for bearing acreage that uses 1988-2014 annual data for improved fit. A cost index provided by NASS in 2011 terms is back-cast using the percentage changes from the 1990-1992 terms and estimated in the projection period as a percentage change from the projected GDP deflator. Projected values of macro data for consumer expenditures, population, and GDP deflator are gathered from FAPRI data files, which in turn are based on projections from IHS Global Insight. Projections for endogenous variables of bearing acres, yield, imports, exports, domestic use, residual use, cash receipts, production, and market price are calculated in the model. All prices are converted from nominal to real price terms in model equations using the GDP deflator with a base year of 1982.

With several previous studies incorporating equations for bearing acreage, an equation is developed that considers the inelasticity of bearing acreage from year-to-year as well as the lag time between when producers decide to alter bearing acreage and when that decision is reflected in the data. The equation for bearing acreage (BA) incorporates lagged bearing acreage, a moving three-year lagged average returns variable of nominal price (NP) multiplied by yield (YLD) divided by a general cost index of prices producers paid for commodities and services, interest, taxes, and farm wage rates (PPITW), and a trend (T). While three years is on the lower end of the timeline for when a newly planted tree begins producing fruit, it was chosen based on Willett's utilization of the same lag. It also provided the best fit of the lag structures attempted for the model.

(1) $BA_t=f(BA_{t-1}, (NP_{t-1}*YLD_{t-1},/PPITW_{t-1}+ NP_{t-2}*YLD_{t-2},/PPITW_{t-2}+ NP_{t-3}*YLD_{t-3},/PPITW_{t-3})/3,T_t)$

The price index used here is a general one relating to agriculture. Consequently, the weights might not be well aligned to apple producer costs. While there are a variety of costs associated with apple production, Lynch (2010) explains that labor costs are the predominant direct contributor to production expenses, responsible for over 60%. He goes on to note that chemicals are the second-largest expense for producers, contributing to around 25% of total costs, particularly those chemicals utilized as insecticides and fungicides.

Table 2. Regression Results for Bearing Acreage

Bearing Acreage				
R Square: 0.982				
Adjusted R Square: 0.980				
	Coefficient	P-Value	Short-run Elasticity	Long-run Elasticity
Intercept	63325.826	0.2145		
Bearing Acreage$_{t-1}$	0.829	6.31E-10	0.84	
(Nominal Price*Yield/PPITW)$_{t3avg}$	841.426	0.0036	0.14	0.88
Trend	-2440.778	0.0003		

For the historical period, yield is defined as total production divided by bearing acreage. In the projection period, yield is forecasted by incorporating a moving three-year average of nominal price divided by the cost index as well as a trend. During times of higher apple prices and lower costs, producers are encouraged to invest more inputs to ensure maximum harvest of every acre. Estimation experiments did not demonstrate strong effects associated with the introduction of imidacloprid, but adoption was distributed over a number of years during which other technologies were introduced and, as well, some of its impacts might have been on costs rather than strictly on yields. The trend implies a yield increase of about 1% per year.

(2) $YLD_t=f(NP_t/PPITW_t+NP_{t-1}/PPITW_{t-1}+NP_{t-2}/PPITW_{t-2})/3,T_t)$

Table 3. Regression Results for Yield

Yield			
R Square: 0.809			
Adjusted R Square: 0.792			
	Coefficient	P-Value	Short-run Elasticity
Intercept	3433.920	0.3476	
(Nominal Price/PPITW)$_{t3avg}$	5053039.281	0.0011	0.49
Trend	340.734	2.58E-07	

Total trade data combining fresh and processed apples are used in the regressions. Data for processed apple products are converted to fresh weight equivalents. Canned apples are multiplied by 1.25 and dried apple products by 8 following the NASS guidelines (ERS, 2015). Apple juice is converted from gallons to pounds on a single-strength equivalent measure of 12 pounds of apples per gallon of juice (ERS, 1992). In the model, imports (IM) are a function of lagged imports and real price (RP) that equals nominal price divided by the GDP deflator:

(3) $IM_t=f(IM_{t-1}, RP_t)$

Table 4. Regression Results for Imports

Imports				
R Square: 0.822				
Adjusted R Square: 0.806				
	Coefficient	P-Value	Short-run Elasticity	Long-run Elasticity
Intercept	534.598	0.431		
$Imports_{t-1}$	0.839	3.19E-08	0.87	
Real Price	360714.702	0.607	0.08	0.62

While similar to the imports equation, the exports equation (EX) incorporates the use of a trend. During periods of high domestic prices, foreign demand for U.S. apples decreases and exports decline.

(4) $EX_t=f(EX_{t-1}, RP_t, T_t)$

Table 5. Regression Results for Exports

Exports				
R Square: 0.608				
Adjusted R Square: 0.552				
	Coefficient	P-Value	Short-run Elasticity	Long-run Elasticity
Intercept	757.769	0.019		
$Exports_{t-1}$	0.458	0.041	0.44	
Real Price	-121516.08	0.598	-0.08	-0.14
Trend	20.574	0.039		

Oftentimes in apple production the total volume of apples grown in orchards differs from the production utilized. Lynch (2010) explains a variety of factors can be connected to the discrepancy, from limited labor supply during harvest to damage during transport and commercial waste. He goes on to explain how labor availability in particular has played a significant role in the amount of total production that is harvested in time to make it to market. While apples are more durable than many fruits, the risk of damage from mechanical harvesting methods is still an issue. As a result, a majority of the apple orchard maintenance practices and harvesting require an extensive supply of manual labor to ensure a successful harvest with minimal damage. Labor shortages can lead to higher labor costs for apple growers as producers attempt to raise wages to ensure adequate labor during harvest. Even then, Lynch explains it is not uncommon for a portion of total apple production to be left on the trees or harvested late and unfit for market. In an effort to correct for the difference, an equation for residual supply is incorporated. Historically, residual use (RE) is calculated as the difference between total production, net exports and utilized demand. Because of discrepancies that can occur when converting processed apple products into fresh weight, it is acknowledged that the residual contains some level of error not contributed to behavioral decisions. For the projection period, residual use is calculated by incorporating the net returns variable of nominal price divided by the cost index and total production. When prices are high relative to costs, producers will increase efforts to ensure maximum utilization.

(5) $RE_t = f(NP_t/PPITW_t, QP_t)$

Table 6. Regression Results for Residual

Residual			
R Square: 0.241			
Adjusted R Square: 0.128			
	Coefficient	P-Value	Short-run Elasticity
Intercept	-3242.092	0.641	
Nominal Price/PPITW	-31564.433	0.732	-0.13
Total Production	0.103	0.045	1.45

Domestic demand for apples is based on basic economics of demand, taking own-price and income into account. This equation should in principle also incorporate all intermediate stages of processing, distributing, and marketing apples and apple products. Domestic use (DU) is calculated per capita utilizing per capita consumer expenditures (CE), real price and trend. While the coefficients have the expected signs, they are not statistically significant. A potential explanation for the poor fit of the equation and statistical insignificance of the variables is the use of aggregated demand in this equation instead of separating the demand for fresh and processed apples.

(6) $DU_t/Pop_t=f(CE_t/Pop_t, RP_t, T_t)$

Table 7. Regression Results for Domestic Use

Domestic Use per capita			
R Square: 0.258			
Adjusted R Square: 0.152			
	Coefficient	P-Value	Short-run Elasticity
Intercept	-26.631	0.036	
Consumer Expenditures per capita	1.358	0.067	0.73
Real Price	-2713.790	0.255	-0.09
Trend	-0.479	0.089	

Production is calculated as an identity of bearing acreage and yield:

(7) $QP_t=BA_t*YLD_t$

Finally, the market balance of supply and demand is incorporated as an identity to determine price:

(8) $QP_t+IM_t=EX_t+DU_t+RE_t$

Table 8 provides a summary of the symbols used in the model, a description of the variable, and the equation or equations in which the variable is used.

Table 8. Explanation of Equation Symbols

Symbol	Definition	Equation
BA_t	Bearing Acreage in Year t	1, 7
BA_{t-1}	Bearing Acreage in Year t-1	1
CE_t/Pop_t	Consumer Expenditures per capita in Year t	6
DU_t	Domestic Use in Year t	6, 8
DU_t/Pop_t	Domestic Use per capita in Year t	6
EX_t	Exports in Year t	4, 8
EX_{t-1}	Exports in Year t-1	4
IM_t	Imports in Year t	3, 8
IM_{t-1}	Imports in Year t-1	3
NP_t	Nominal Price in Year t	2,5
NP_{t-1}	Nominal Price in Year t-1	1,2
NP_{t-2}	Nominal Price in Year t-2	1,2
NP_{t-3}	Nominal Price in Year t-3	1
$PPITW_t$	Producers' Cost Index in Year t	2,5
$PPITW_{t-1}$	Producers' Cost Index in Year t-1	1,2
$PPITW_{t-2}$	Producers' Cost Index in Year t-2	1,2
$PPITW_{t-3}$	Producers' Cost Index in Year t-3	1
QP	Total Production	5, 7, 8
RP_t	Real Price: Nominal Price/GDP deflator in Year t	3,4,6
RE_t	Residual Use in Year t	5, 8
T_t	Trend in Year t	1,2,4,6
YLD_t	Yield in Year t	2, 7
YLD_{t-1}	Yield in Year t-1	1
YLD_{t-2}	Yield in Year t-2	1
YLD_{t-3}	Yield in Year t-3	1

Complications of Estimations

While the three-year-moving average was determined to be acceptable for the purposes of this model, alternative approaches could have been used to address the lag in production response. Looking at the historical apple prices, there appears to be a cyclical trend with price climbing every three years to fall sharply the following year. This pattern could be taken into account using a three-year-average instead of annual data. More generally, underlying patterns in this or other variables could be removed before estimation to ensure that all data are stationary. Another option for estimating bearing area, rather than incorporating returns data for all three years prior to the year being estimated, would be to only utilize the furthest lagged year and the most recent year to incorporate new planting and removal decisions, respectively. This method might be appropriate because prices during the intermittent years do not influence producers' production decisions.

Econometric issues can occur when using OLS regressions, such as omitted variable bias and endogeneity bias. When factors are excluded from the equation, either from data unavailability or immeasurability, the effects of other parameters estimated in the equation can be over- or under-stated. Wooldridge (2002) explains that, to correct for endogeneity bias from omitted variables, a proxy variable for the unobserved data can be introduced. He goes on to explain that the proxy variable must be exogenous with respect to other variables. If there is little or no correlation between the omitted variable and those used in the equation, then the impact of the omitted variable on estimated parameters might not be very large, although there would still be negative effects on measures of statistical fit. Other potential problems that might affect the results of OLS regressions, such as autocorrelation or multicollinearity, were not tested or explored. For the purposes of this project, the endogeneity risk from simultaneity was checked by comparing OLS and 2SLS regression results.

Because the unknown variables the model solves for are calculated using variables estimated by the model, there is the potential risk of endogeneity bias from simultaneity occurring. To test for endogeneity bias in the estimation results from the OLS regression, the variables are also analyzed using the Two-Stage Least Squares (2SLS) regression. Data from 1988-2014 are used for both the OLS and the 2SLS regressions in SAS to test for endogeneity bias. The OLS parameter results calculated in SAS vary slightly from those calculated using OLS regressions in Excel. This is because the 2SLS estimation requires that all variables are estimated over the same time period. The model calculated in Excel estimates the yield equation using 1988-2014 data while the other equations use data from 1990-2014.

The OLS and 2SLS parameter estimates are compared. Table 9 offers a summary of the parameter estimates and standard errors found for each variable. Overall, the results are mostly similar. The coefficients on lagged exports in the exports equation and price in the residual equation are found to have the largest changes between the two regression methods. A z-test is used to assess the differences between all of the coefficients. For all equations, it is determined that the differences are not statistically significant at the 10% confidence level.

Table 9. OLS and 2SLS Parameter Estimates

Eq.	Variable	OLS		2SLS	
		Parameter	Standard Error	Parameter	Standard Error
BA	BA_{t-1}	0.83	0.08	0.90	0.10
	$(NP*YLD/PPITW)_{t3avg}$	840	260	745	289
	T	-2442	573	-1860	695
YLD	$(NP/PPITW)_{t3avg}$	893861	1642610	1228924	2442407
	T	383	51	380	54
IM	IM_{t-1}	0.83	0.10	0.91	0.10
	RP	574553	680896	266852	709239
EX	EX_{t-1}	0.51	0.2	0.93	0.28
	RP	-177002	222566	-252834	247826
	T	23.08	9.10	9.45	11.46
RE	NP/PPITW	11283	82789	-3637	87602
	QP	0.13	0.05	0.12	0.05
DU	CE	1.29	0.65	1.35	0.65
	RP	-2667	2184	-2550	2203
	T	-0.44	0.24	-0.47	0.24

SCENARIOS

In order to estimate how removing imidacloprid's pesticide registration would affect the U.S. apple market, it is important to understand producers' reasons for using the chemical. When deciding which, if any, chemicals to use, apple producers must consider the effectiveness, expense, time and safety of applying chemicals. While chlorpyrifos is an alternative organophosphate chemical that protects against the same insects as imidacloprid, many producers have shifted away from using chlorpyrifos due to its broad spectrum toxicity that includes mammals (Knutson & Smith, 1999). Since the introduction of neonicotinoids in the late 1990s, apple growers have been moving away from treating apple acreage with organophosphates (NASS, 2016). When looking at per-unit cost, neonicotinoids are much more expensive than organophosphates at $11 an ounce for imidacloprid compared to $2.5 for the same quantity of chlorpyrifos (P&M Solutions, 2016). The advantage of using imidacloprid over its organophosphate counterpart comes when looking at the amount of pesticide required for treating an acre of trees. When using imidacloprid, the application rate is much smaller than for chlorpyrifos with no change in the number of applications needed. Apple growers spend $56.60 on average to treat an acre of trees with chlorpyrifos compared to spending $13.86 to treat the same acre with imidacloprid (NASS, 2016).

Using this information, a scenario is introduced that incorporates the price difference apple producers will face if imidacloprid's registration is not renewed and the share of area on which imidacloprid is applied. Based on NASS surveys for pesticide application area, a decrease in returns per acre of $42.74 on 35% of the total bearing acreage is applied beginning in the year 2017. Assuming the ban is put in place too late to affect 2017 production, market effects of a chemical loss in 2017 are not going to begin until 2018. By 2020, given the estimated lag structure, expected producer returns will reflect fully the decline in profitability caused by the removal of this chemical. While it is possible the decision not to renew the chemical's registration could be repealed in the future, the approach for this study assumes the decision remains in place for the duration of the projected period. As demand increases for chlorpyrifos, it is likely that the cost of the chemical will increase, widening the gap in producers' returns. It is also feasible that chlorpyrifos's registration will also be removed in the future leading to potentially much larger effects on the U.S. apple market. However, the scenario is solely focused on the actual cost information that is available.

The second scenario is more speculative and applies understanding of the additional challenges apple producers will face if imidacloprid's registration is not renewed. Oftentimes, growers alternate applications of neonicotinoids with their organophosphate counterparts in an effort to reduce the development of resistance in pests to one particular chemical. If imidacloprid is taken out of the rotation, producers might be forced to solely rely on chlorpyrifos to combat these insects. As the effectiveness of chlorpyrifos declines and producers are left with no alternative, the risk of damage to fruit increases and yields decline as a result. While no direct references could be drawn from existing research, it is assumed that producers could face a 10% decrease in yields-at a given price-following the removal of imidacloprid from chemical pest management practices in apple production starting in 2017. The 10% is not based on agronomics, but it is used to demonstrate the sensitivity of the model. If actual yield losses as a result of the chemical loss are larger or smaller, the estimated impacts would increase or decrease as a result. Because the cost effect on returns is still present, the cost effect is included along with the impact on yields.

Another scenario considers the combined effects of cost and an impact on trade if apple imports are restricted as a result of the removal of imidacloprid in U.S. apple production. Similar to what occurred in the EU when the neonicotinoid ban in production also banned imports grown using the chemicals, U.S. apple imports could be affected. Canada, the second leading supplier of apples to the U.S., is one of the countries where imidacloprid is registered for use in apple production. While it is not practical to say U.S. imports would decline by the full amount of Canada's import share, which was 12% of total imports in 2014, a 5% decrease in U.S. apple imports-at a given price- starting in 2017 is feasible as SPS restrictions limit which countries are granted access to the U.S. apple market (Lynch, 2010).

The final scenario combines the assumed effects on imports with the proposed yield loss, while still incorporating the change in returns due to increased spending on alternative chemicals. Considering all three of the potential impacts is intended as a reminder that policy changes are often associated with direct impacts to more than one area of the market.

RESULTS

The model is forecasted up to 2025. Table 10 offers a comparison of 2014, the last year historical data are available, with the projected years. The decline in bearing acreage continues in the projection period through 2016, before increasing through 2020 as growers respond to higher prices and production expands. Imports increase slightly at the start of the projection period compared with the historical data, and exports decrease almost proportionally. Overall, price increases and stays high for the first several years of the projection, resulting in an increase of cash receipts.

Table 10. Baseline Projections for U.S. Apple Market

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Bearing Acres (1,000 acres)	322	319	316	318	326	334	337	335	329	325	325	327
Yield (1,000 Lbs./Acre)	35.51	33.85	33.69	33.85	32.19	32.58	32.95	33.20	33.68	34.22	34.70	35.09
Production (Bil. Lbs.)	11.43	10.78	10.66	10.77	10.49	10.87	11.09	11.13	11.08	11.12	11.28	11.47
Imports (Bil. Lbs.)	5.77	5.95	6.12	6.25	6.45	6.54	6.58	6.65	6.74	6.83	6.89	6.93
Exports (Bil. Lbs.)	2.41	2.20	2.12	2.11	2.10	2.14	2.19	2.22	2.25	2.27	2.31	2.35
Domestic Use (Bil. Lbs.)	13.89	13.84	13.98	14.23	14.20	14.57	14.77	14.84	14.86	14.97	15.13	15.30
Residual (Bil. Lbs.)	0.90	0.69	0.67	0.69	0.64	0.69	0.72	0.72	0.71	0.71	0.73	0.75
Farm Price ($/Lb.)	0.26	0.36	0.37	0.37	0.44	0.39	0.38	0.41	0.45	0.46	0.46	0.47
Cash Receipts (Mil. 2014 $)	2915	3798	3875	3853	4300	3910	3831	4005	4248	4338	4330	4336

Scenario 1 provides estimates of how the U.S. apple market would respond to the loss of imidacloprid as an insecticide if the only effect were an increase in chemical costs. The cost difference of -$42.74 per acre is an average of only 0.5% of the revenues per acre. There are still slight changes observed in the projection period when scenario results are compared with the baseline. While the differences are not substantial enough to provide a visual difference when using a graph, the percentage changes are summarized in Table 11 to indicate market responses. The change for yield is not shown because it is very small given the modest price change and absence of any direct yield impact in this scenario. Results for domestic use are also excluded for the same reason. Table 11 offers an idea of how each variable is affected by the small adjustment in returns, and how that effect changes over time even though the loss in returns does not change. Because there is essentially no effect on yield and a decrease in bearing acreage as a result of the decrease in returns per acre, production declines and price rises. Inelastic domestic use is hardly affected. Imports increase and exports decrease as the U.S. price increases. Overall, real cash receipts increase.

Table 11. Scenario 1 Percentage Changes from Baseline

	2018	2019	2020	2021	2022	2023	2024	2025
Bearing Acres	-0.011	-0.028	-0.043	-0.044	-0.039	-0.036	-0.038	-0.041
Production	-0.010	-0.023	-0.035	-0.034	-0.030	-0.029	-0.032	-0.035
Imports	0.004	0.011	0.020	0.024	0.026	0.026	0.027	0.029
Exports	-0.004	-0.010	-0.015	-0.015	-0.012	-0.010	-0.010	-0.011
Residual	-0.024	-0.051	-0.073	-0.069	-0.059	-0.056	-0.061	-0.067
Cash Receipts	0.025	0.063	0.088	0.059	0.029	0.022	0.031	0.039
Farm Price	0.035	0.087	0.123	0.093	0.059	0.051	0.063	0.074

Table 12 outlines how the baseline projections change when the increase in costs is combined with the assumed 10% decline in yields at any particular price in Scenario 2. The reduction in supply as a result of the decrease in yields puts upward pressure on the price. Bearing acreage increases because the net effect of lower yield and higher price is higher returns, despite the slight increase in chemical costs. The remaining market elements move in the same directions as in Scenario 1 but with greater percentage changes from the baseline. Even the unresponsiveness of domestic use is continued as, other than in the first year of the yield decrease, it does not decrease by more than 2% relative to the baseline projection despite price increases of 5-14%. The inability of producers to quickly expand acreage contributes to a large initial increase in farm price and cash receipts in 2017.

Table 12. Scenario 2 Percentage Changes from Baseline

	2017	2018	2019	2020	2021	2022	2023	2024	2025
Bearing Acres	-	2.41	4.73	6.31	4.92	3.46	2.87	3.11	3.37
Yield	-8.95	-8.42	-8.28	-9.24	-9.37	-9.11	-8.85	-8.84	-8.93
Production	-8.95	-6.22	-3.95	-3.51	-4.92	-5.96	-6.24	-6.00	-5.86
Imports	3.47	4.26	4.00	3.75	4.12	4.67	5.08	5.26	5.35
Exports	-3.47	-3.08	-1.87	-1.27	-1.58	-1.99	-2.12	-2.00	-1.86
Residual	-20.24	-13.13	-7.20	-6.30	-9.56	-11.89	-12.28	-11.48	-10.98
Domestic Use	-3.76	-1.61	-0.53	-0.47	-1.14	-1.46	-1.41	-1.22	-1.14
Cash Receipts	25.03	6.75	1.13	1.23	5.91	6.83	5.90	4.73	4.38
Farm Price	37.32	13.82	5.28	4.91	11.38	13.61	12.95	11.42	10.88

In Scenario 3, the yield decline is replaced with a 5% shift in the supply curve for imports, keeping increase in production costs. Effects of these changes on the baseline projections are explained in Table 13. The combined effect of higher costs to producers and fewer sources of imports is a reduction in apply supply to the U.S., driving up price. Consequently, as in Scenario 2, the change in imports causes higher prices the first two years. This effect works against the returns loss with the net effect that bearing acreage increases. In other words, unlike in the previous two scenarios, there is an increase in production as the increase in price caused by lower imports more than offsets the effects of the modest increase in production expenses. As regards yield, the higher apple price leads to more apples harvester per acre for the first several years. The higher price puts upward pressure on imports, and the -5% shock is moderated as new import sources are found. While producers receive higher prices compared to the baseline at first, the initial increase is not as great as in Scenario 2 and by 2019 price falls below the baseline projection. While the percentage increase in cash receipts is largest in the first year, 2017, as in Scenario 2, cash receipts in Scenario 3 follow a similar pattern as price.

Table 13. Scenario 3 Percentage Changes from Baseline

	2017	2018	2019	2020	2021	2022	2023	2024	2025
Bearing Acres	-	1.18	2.52	3.33	2.42	1.19	0.68	0.97	1.26
Yield	0.37	0.53	0.41	-0.14	-0.28	-0.08	0.15	0.15	0.01
Production	0.37	1.71	2.94	3.19	2.13	1.11	0.83	1.12	1.27
Imports	-3.89	-3.74	-3.61	-3.51	-3.02	-2.34	-1.82	-1.60	-1.50
Exports	-1.11	-0.88	-0.09	0.40	0.22	-0.14	-0.26	-0.09	0.08
Residual	-1.21	2.25	5.27	5.80	3.47	1.38	1.00	1.84	2.24
Domestic Use	-1.20	-0.40	0.33	0.49	0.05	-0.28	-0.22	0.03	0.15
Cash Receipts	12.37	5.23	-0.49	-2.05	1.67	3.72	2.90	0.83	-0.17
Farm Price	11.95	3.46	-3.32	-5.08	-0.45	2.58	2.06	-0.29	-1.42

Table 14 shows differences from the baseline projections when all three of the shocks associated with disallowing this chemical occur simultaneously. Initially, domestic supply declines sharply because there is less incentive to plant, lower yields, and loss of some foreign apple suppliers. All of these factors put upward pressure on price, with a 50% price increase in the first year. Other countries are prompted to increase apple shipments to the U.S. because of the higher price, and the loss of other foreign suppliers is offset. The higher price also encourages changes in practices to deliver more apples per acre, and the negative impact on yield is moderated as well. The incentive to expand bearing area is increased as a result of the net effect of lower yield, slightly higher cost, and much higher price. Despite the lower yields, the production impact is smaller as older orchards are maintained longer and new orchards are planted. The price impact moderates over time as domestic supply recovers, though real cash receipts remain above the baseline with the exception of the year 2020. In 2020, the high increase in bearing acreage and minimal decline in production despite the yield loss brought prices to within 0.5% of the baseline, resulting in a loss of real cash receipts for producers.

Table 14. Scenario 4 Percentage Changes from Baseline

	2017	2018	2019	2020	2021	2022	2023	2024	2025
Bearing Acres	-	3.52	7.16	9.66	7.61	5.06	3.84	4.10	4.54
Yield	-8.60	-7.92	-7.86	-9.31	-9.60	-9.22	-8.78	-8.73	-8.89
Production	-8.60	-4.68	-1.27	-0.55	-2.72	-4.62	-5.28	-4.99	-4.75
Imports	-0.40	0.59	0.53	0.41	1.18	2.30	3.19	3.66	3.91
Exports	-4.59	-4.03	-2.07	-0.97	-1.35	-2.03	-2.29	-2.10	-1.84
Residual	-21.53	-11.30	-2.48	-0.93	-5.89	-9.96	-11.01	-9.90	-9.11
Domestic Use	-4.97	-2.08	-0.28	-0.04	-1.03	-1.62	-1.60	-1.26	-1.06
Cash Receipts	36.55	12.37	1.52	-0.14	7.25	9.80	8.58	6.14	4.89
Farm Price	49.40	17.89	2.82	0.41	10.25	15.12	14.63	11.71	10.12

While Scenario 1 utilizes available cost sources that provide an idea of the direct results of the loss of imidacloprid, the changes are not large enough to observe in a graph. The projection results of Scenario 2, Scenario 3, and Scenario 4 are combined with the baseline estimates of the model into graphs to show how the market reacts to different combinations of adjustments on cost and yield, on cost and imports, and on cost, yield and imports. The model projections begin in 2015 because data are only available through 2014, but the cancellation of imidacloprid's registration is assumed not to occur until 2017. Figure 2 shows the changes that occur for bearing acreage between the baseline and each scenario, with the combined effects in Scenario 4 having the greatest impact. Scenario 3, with no yield shock, produces the smallest change from the baseline but still results in an increase in bearing acreage. This is because the increase in price immediately following the loss in imports encourages producers to expand orchard area.

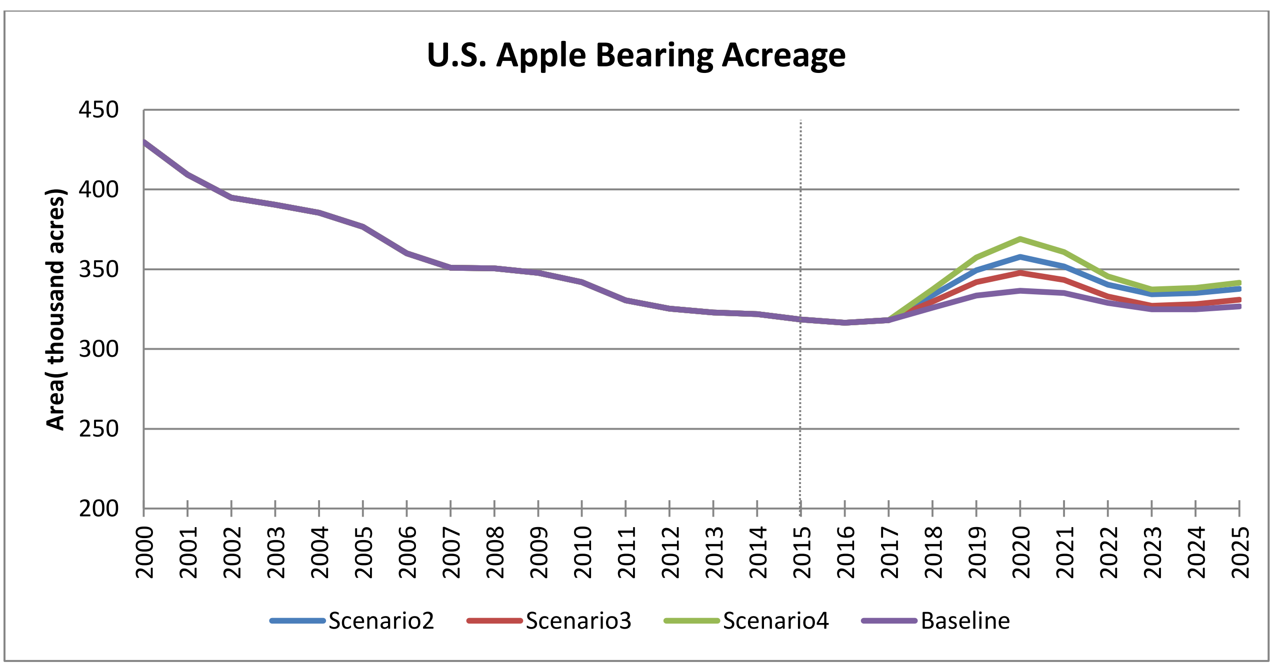

Figure 2. Scenario Effects on Bearing Acreage

Unlike bearing acreage where all of the scenarios had varying degrees of positive effects, Figure 3 shows how apple production moved in different directions initially depending on the scenario. While the initial decrease in Scenario 2 and Scenario 4 is expected due to the loss in yield, the inclusion of the decrease in imports in Scenario 4 increases production closer to the baseline estimate by 2020. This is because the higher price incentivizes producers to alter practices to obtain more apples per acre. As a result, yield does not decline by the full 10% that is introduced, and the percentage decrease from the baseline is smaller in Scenario 4 than in Scenario 2 even though the yield shock is the same in both instances.

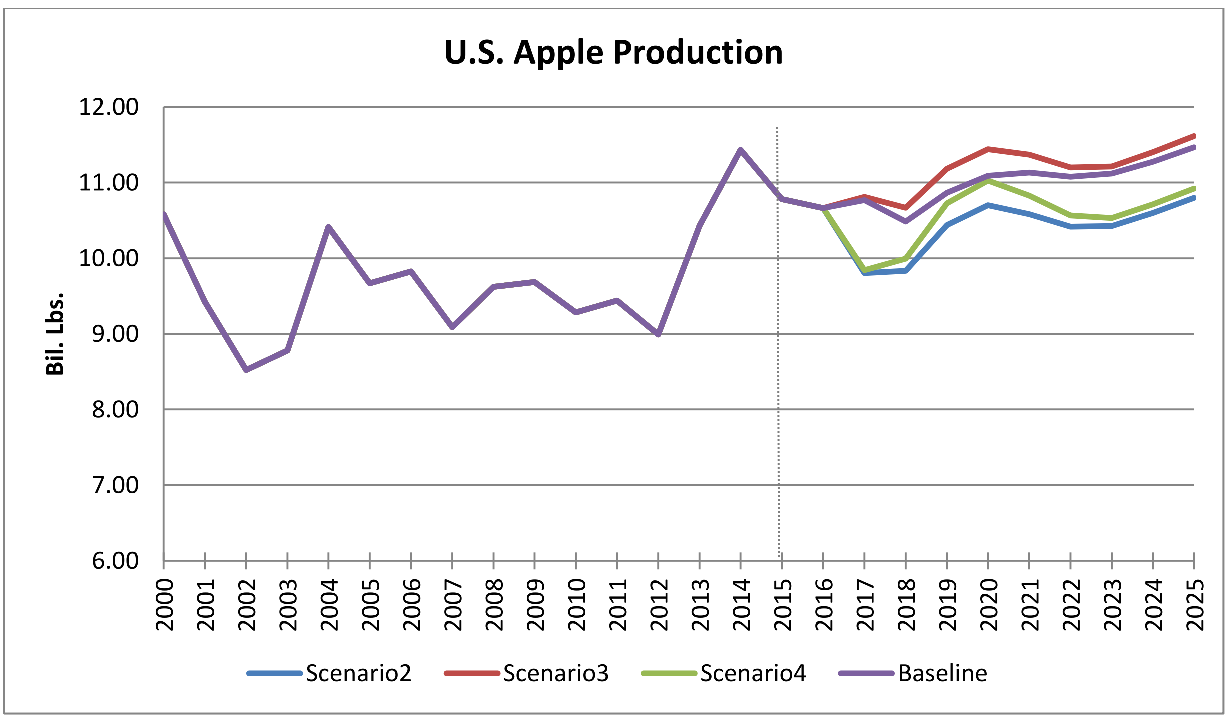

Figure 3. Scenario Effects on Production

Domestic apple demand is inelastic, so the proportional changes in domestic consumption are small relative to the changes in prices as seen in Figure 4. Scenario 3 has the smallest impact on domestic use because it has the smallest effect on price compared to the other scenarios shown in the graph. However, when import losses are combined with yield losses in Scenario 4 there is no alternative to compensate lost supply to meet demand. Price is driven higher until the market balances with lower quantities of supply and demand. However, as growers are able to increase production and the price spike levels out, the scenario projections for domestic use move closer to the baseline.

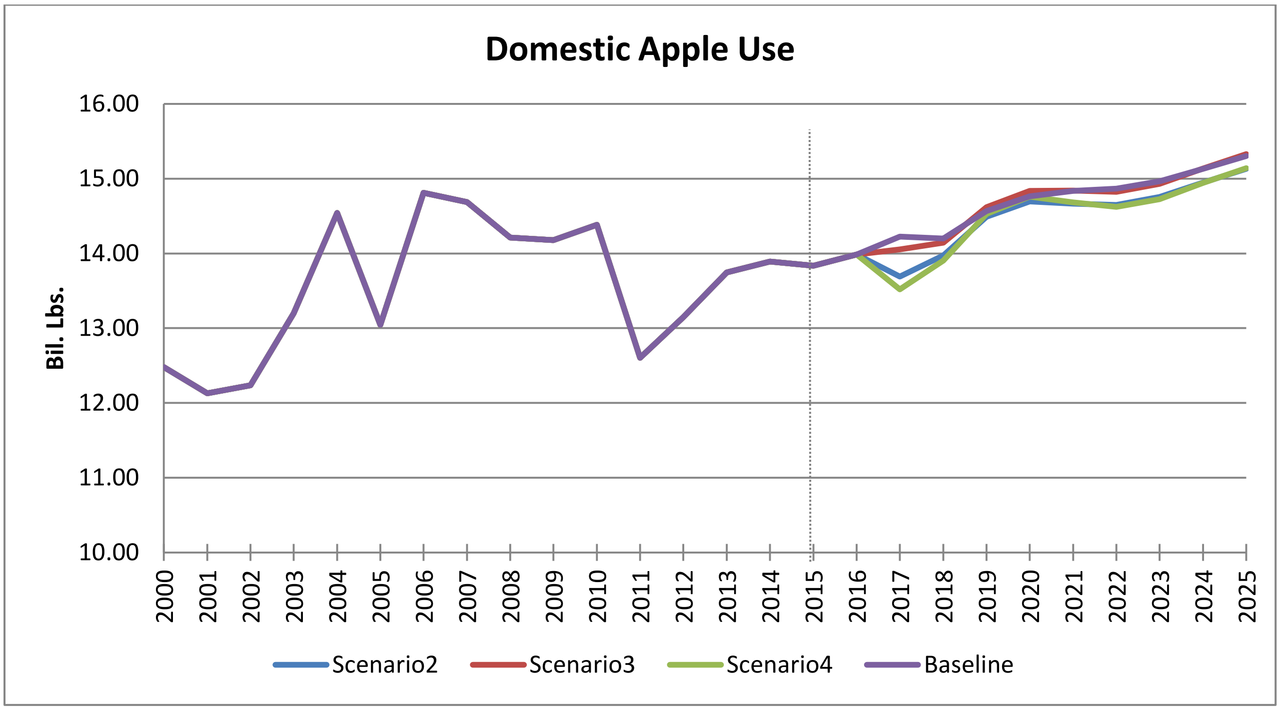

Figure 4. Scenario Effects on Domestic Use

Figure 5 shows the projected path of price in the baseline estimate compared with those obtained by three of the scenarios. The combination of inelastic demand and lag in production response mean the price growers receive is very responsive to market changes. This is especially true in the first year of Scenario 2 and Scenario 4 with a large initial shock. All of the proposed scenarios put upward pressure on price initially, which then declines as bearing acreage is expanded to increase production. The degree of the difference compared to the baseline depends on the scenario, with Scenario 4 where all the shocks are combined having the greatest impact. With the exception of Scenario 1 which is not shown on the graph, Scenario 3 varies the least from the baseline projection of the cases that are shown here.

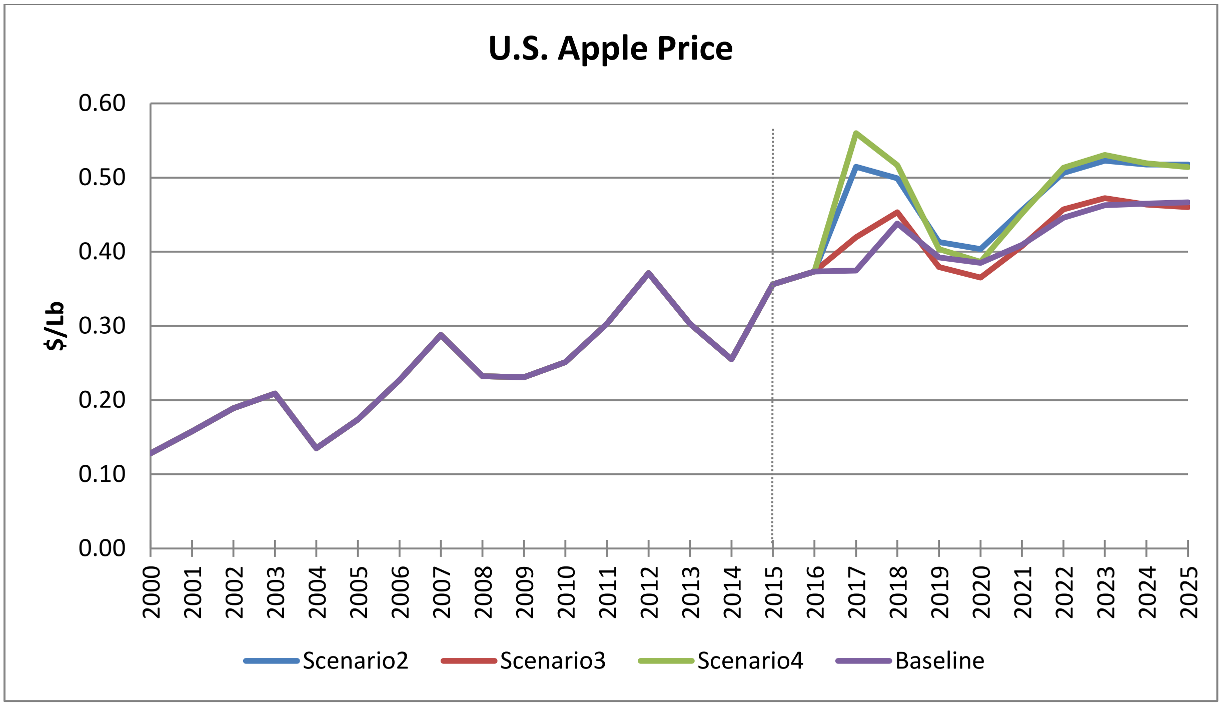

Figure 5. Scenario Effects on Price (Nominal)

CONCLUSION

In the twenty years since it was first registered for pesticide use, imidacloprid has offered apple producers an alternative to using large volumes of organophosphate chemicals that are proven to be harmful to both humans and insects. The selectiveness of imidacloprid, combined with the potential to save money on pesticide applications without sacrificing quality or yield, is what initially encouraged producers to incorporate the chemical in their production systems. Ten years after imidacloprid's introduction into the production agriculture system, CCD first appeared. Environmentalists are concerned about causation because of the relationship between agricultural production and pollinators. Now, due to concerns of the risks neonicotinoids pose to current and future populations of pollinators, the EPA could decide not to renew the registration of imidacloprid.

Previous research is considered to determine how best to estimate the effects such a decision would have on the U.S. apple market. A structural economic model of the U.S. apple market is created. Projected values for consumer expenditures, population, and GDP deflator are gathered from FAPRI. These are combined with the unknown variables of bearing acres, yield, imports, exports, domestic use, residual, cash receipts, production and market price to create eight equations that solve for the market balance. Limitations of data for representing new plantings and removals, as well as a lack of studies about the immediate impacts of the loss of imidacloprid's registration are acknowledged. Despite these limitations, four scenarios of different combinations of loss on returns, yield, and imports are introduced into the model. The scenarios are compared with the baseline estimates and the differences are discussed.

While there is a lack of evidence providing specific impacts of the EPA not renewing the registration of imidacloprid, the purpose of the model is to introduce potential effects based on the available information. One scenario assumes the only change in assumptions is an increase in production costs as producers shift to other insecticides, reducing producer net returns. It seems possible that failure to renew the registration could lead to reduced yields or imports, but the literature does not indicate the likely magnitude of any such effect. The other scenarios examined here assume specific reductions in yields or imports at a given level of apple prices. The results of these scenarios should be considered illustrative rather than definitive, as it is unlikely that the actual magnitudes of yield or import shifts would precisely match the assumptions here. All of the proposed scenarios increase producers' cash receipts for most of the projected years as decreased supply with little change in demand combined with low demand response put upward pressure on price. This increase in price more than offsets the slightly higher costs and reduced yields of banning imidacloprid, although this is an average or industry-wide effect whereas the impact on any individual producer in any given year can be different. While producers receive higher prices on a per-unit basis, more resources are required to maintain production levels due to decreased yields. Consumers have to pay more, imports rise and exports decline. Foreign markets that rely on U.S. apple exports will have to find alternative suppliers, and countries that export to the U.S. will require new markets for their apples.

As noted previously, this project is not without its limitations. Unavailability of data for new plantings and removals and lack of specific information on production costs require a proxy to determine when and how producers respond to changes in the market. At the same time, the lack of reported evidence on imidacloprid's effect on apple production means the scenarios introduced are speculative based on the information available. With access to additional orchard information, including some way to compare yields on orchards with and without imidacloprid applied, additional scenarios could be introduced that are more closely related with exact evidence. As understanding of the effect of CCD on the costs of pollination expands, producers may determine the risk of exposing pollinators to the chemical does not outweigh the benefits from using it. In addition to effects from chemical registrations , the apple market could also face new developments in coming years with changes in immigration registration or trade agreements. Models able to incorporate these impacts on perennial crops are important for understanding challenges producers and consumers could face in the future.

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