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Dynamic regional model of the US apple industry: Consequences of supply or demand shocks due to pest or disease outbreaks and control

Peter R. Tozer[a,*], Thomas L. Marsh[b]

[a] School of Agriculture and Environment, Massey University, Palmerston North, New Zealand
[b] School of Economic Sciences, Washington State University, Pullman, WA, USA

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ABSTRACT

The apple industry is the largest temperate tree fruit crop in the United States and like other plant crops it is subject to pest or disease outbreaks. In this study we examine the economic impacts of pest or disease outbreaks on producers (in different regions) and on consumers (domestic and or international) using a dynamic regional model of the apple industry. The model divides US apple production into four regions that are subject to idiosyncratic production methods, varietal choice, and consumption patterns. Using this type of model the outcomes and impacts on various stakeholders in the apple industry; producers, consumers, and market intermediaries, such as fruit packers or processors, can be measured. Shocks, representing pest or disease outbreaks on tree population dynamics or fruit yields or their consequences on consumer (international and or domestic) markets to pest or disease outbreaks or controls, enter the model exogenously. The outcomes show heterogeneous impacts by type of shock, due to industry structure and regional allocation of apples to fresh or processed markets, on consumer, intermediary, and producer welfare.

1. Introduction

Pest, disease, and food safety events, as well as control responses to these events, have significant economic impacts in agriculture (Pendell et al., 2015). Tree fruit is no exception (Jiang et al., 2017; Zhao et al., 2007). Major pest or disease outbreaks in fruit crops are sporadic but do occur with potentially large costs that burden producers and other economic agents along the supply chain. Although a variety of potential diseases can impact temperate fruit yield, some that cause significant damage to trees (impair fruit quality, or shorten tree life) include fireblight (*Erwinia amylovora*) and Plum pox virus (Jock et al., 2002; Van der Zwet et al., 2012). Both of these diseases are endemic to Europe and the Americas, and fireblight is present in other fruit growing countries, such as New Zealand. An outbreak of fireblight in Michigan state in the USA in 2000 resulted in the removal of between 350,000 to 450,000 apple trees and a direct cost of $42[1] million (Longstroth, 2001). An outbreak of Plum pox virus, discovered in 1999 in Pennsylvania state, lead to the destruction of 678 ha of orchards and a restriction on replanting of *Prunus* species; peaches, plums, apricots, and nectarines, until testing determined the disease had been eradicated, which occurred in 2013 (Bucher, 2013). Pests such as Codling Moth (*Cydia pomonella*) can have a significant impact on apple production, but due to successful integrated pest management (IPM) programs control of this pest has reduced the potential of crop damage (Damos et al., 2015). However, other recent novel pests such as the Brown Marmorated Stink Bug (**BMSB**) (*Halyomorpha halys*) for which IPM programs have not been developed could impose major costs on producers, either through control programs or crop losses due to damage (Leskey et al., 2012).

In addition to pest or disease impacts, the outcomes of control methods in agriculture are being more heavily scrutinized as consumers and policy makers become more conscious of food and pesticide safety issues related to control (Grunert, 2005; Simon et al., 2011; Food Standards, 2011). Food safety issues also occur in the tree fruit industry and these can also have significant effects on producers and or consumers depending on the source of the contaminant and the impact on supply and or demand. An example of this type issue was the industry impact of the Alar scare in 1989. Alar, (Chemical name daminozide) was a permitted chemical used by apple growers to aid in fruit retention on trees first registered in 1968 (Grunert, 2005; Herrmann et al., 1997). However, food safety issues with risks to individuals were identified with Alar mid-season in 1989, which led to the withdrawal of the chemical, and a substantial loss in revenue to producers in that growing season (O'Rourke, 1990).

* Corresponding author at: School of Agriculture and Environment, Massey University, Palmerston North, New Zealand.
E-mail address: p.tozer@massey.ac.nz (P.R. Tozer).

[1] All prices and costs unless otherwise indicated are in $US.

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Our interest is in better understanding the economic impacts of pest and disease shocks on outcomes and welfare for the heterogeneous agents along the vertical apple supply chain. Jiang et al. (2017) demonstrated the importance of wholesale intermediaries in the pear industry, providing an assessment at the national level. Our contribution is to model the tree fruit sector (apple production, packing and processing intermediaries, and demand) in a regional intertemporal model to improve assessment of economic outcomes and welfare impacts from disease shocks. The specific objective in this current research is to construct a dynamic model of the U.S. apple industry, extending Jiang et al. (2017) by using regional supply models to allow for heterogeneity in production responses, and to study the impacts on regional production, supply, as well as producer and consumer welfare of the effects of shocks, such as pest or disease outbreaks, that could occur within a region. Unlike pears and some other tree fruit, commercial production of apples is not as highly concentrated in a geographical area, but rather growers are more geographically diversified across the USA, motivating the importance of a regional model. Regional models also assist understanding local outbreaks and quarantines, as well as regionalization of international trade embargoes.

The apple industry is the largest non-citrus perennial tree fruit crop in the USA. The number of studies of this industry is relatively limited, and most recent studies have been econometric models of the industry. The models in these studies have been developed to provide estimates of expected industry responses to changes in exports and domestic conditions (Willett, 1993) or pesticide cancellations (Roosen, 1999). Willett (1993) constructed a series of econometric models of the apple industry, at an aggregated national level, and included sub-models of bearing area and yield for the supply side and functions of various demands for apples, such as fresh or processed into juice, frozen, or canned, and net imports; from these models supply and demand elasticities were estimated. The Willett (1993) study was an aggregated national model and did not consider regional changes in the industry or the potential for differences in regional supply and demand characteristics. Roosen's (1999) model disaggregated the USA apple industry into four supply and demand regions; the Northwest, Southwest, Central and East, and estimated regional supply elasticities for fresh and processed products and demand elasticities for fresh, processed and imported apples and apple products. Devadoss and Luckstead (2010) developed a rational expectations model of apple supply response for Washington State based on plantings and removal data, and revenues of apple, cherry and pear crops. An exception is Zhao et al. (2007), who studied the effect of apple maggot on the Washington state apple industry using a dynamic optimization model of the industry to analyze the aggregate and temporal economic welfare changes to producers in the state due to the spread of the pest.

1.1. The USA apple industry

Production of apples in the USA is spread across a majority of the 48 contiguous states. In 2012 United States Department of Agriculture-National Agricultural Statistics Service (USDA-NASS) collected data on apples grown in 27 states, and indicated that commercial-scale growers in another 19 states produced apples, but the size of the industry in each of these other states was too small to warrant inclusion in the complete data set (USDA-NASS, 1974–2015).

In the context of this study the West region includes the states of California, Colorado, Idaho, Oregon, Utah, and Washington; Central states are Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio and Wisconsin; the East region consists of Connecticut, Maine, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont; and the South states are Maryland, North Carolina, Tennessee, Virginia, and West Virginia. Summary statistics for the USA apple industry are provided in Table 1. Further analysis of trends in the industry are presented below.

The regional spread of apple production has changed dramatically since 1947. In 1947 the bearing area of apples (in hectares) in each region was 44,600, 48,000, 113,500, and 63,250 for the West, Central, East and South regions, respectively (Johnson, 1987); and total apple bearing area in the USA in 1947 was 312,000 ha. By 2012 these areas were 70,000, 6400, 32,000 and 10,000 ha for the same regions in the same order and total USA apple bearing area had fallen to 133,000 ha, the changes in bearing area over that period can be seen in Fig. 1 (Johnson, 1987, NASS various).

Table 1
Summary statistics for the period 1971–2012 for apple yield, real apple price, apple bearing area and change in apple bearing area in each region – West, Central, East, and South (Source USDA-NASS, 1974–2015, Johnson, 1987).

	Mean	Median	Std. dev.	Minimum	Maximum
Yield West (t/ha)	31.16	31.87	7.06	16.91	45.64
Yield Central (t/ha)	16.99	17.26	3.81	5.71	27.04
Yield East (t/ha)	20.28	19.34	3.91	14.26	29.57
Yield South (t/ha)	20.09	20.40	2.75	14.38	27.10
Real Price West ($/kg)	$0.35	$0.32	$0.12	$0.15	$0.65
Real Price Central ($/kg)	$0.32	$0.30	$0.12	$0.19	$0.81
Real Price East ($/kg)	$0.31	$0.30	$0.09	$0.19	$0.66
Real Price South ($/kg)	$0.25	$0.25	$0.07	$0.16	$0.56
Bearing Area West (ha)	69,228	73,430	15,279	42,411	92,997
Bearing Area Central (ha)	32,123	33,660	4955	20,234	39,416
Bearing Area East (ha)	42,263	42,148	6874	32,011	50,869
Bearing Area South (ha)	18,373	19,567	5379	10,117	25,698
Change in Bearing Area West (ha)[a]	1690	2250	5446	−13,000	14,300
Change in Bearing Area Central (ha)[a]	−1162	−1050	1946	−7550	2200
Change in Bearing Area East (ha)[a]	−1140	−480	1664	−5500	1020
Change in Bearing Area South (ha)[a]	−883	−900	1628	−5600	5500
n	42				

[a] Calculated from bearing area data.

Real apple prices across regions have also been subject to change over time as shown in Fig. 2. For the period 1971 to 1988 prices across regions, although variable were similar. However, after 1988 marked price differences across regions are observed, and there is also additional price volatility particularly in the West (NASS various).

Industry structural change is partially responsible for both factors noted above. The fresh apple industry is now, in most part, located in Washington State; however apples for the fresh market are still grown in other states, but in smaller quantities. Another factor to explain changes in industry location and prices is the varieties of apples grown in each region, the end market for the apples produced, and how much of production in each region is sold into the fresh or processed market. On average 98% of the apple crop produced is utilized in some form, either fresh, or processed into juice, apple sauce, or other preserved products. Of the four regions the percentage of crop utilized in the fresh market, since 1980 through 2012, on average was 70%, 43%, 45%, and 32%, for the West, Central, East and South regions, respectively, with the remainder being processed (NASS various).

Changes in varieties grown have also changed over time. For example, in 1986 the Red Delicious variety in Washington State accounted for 49,000 ha of the 65,000 ha of apples in the state, and there were no Fuji apples and 81 ha of Gala apples grown, by 2011 the area of Red Delicious had fallen to 17,400 ha of 67,600 total apple ha, and Fuji and Gala accounted for 11,300 and 13,400 ha, respectively (NASS-WA, 2011). Similar varietal changes were also observed in Michigan (NASS-MI, 2012).

In contrast to falling bearing area, total apple production over the period 1971–2012 has had periods of rapid increase from 1971 to 1987, then a period of relatively flat total production, and since the turn of the century a slight downturn in total production has been observed (see Fig. 3). Increasing total production, falling bearing area, and changes in varietal mix indicate that the apple industry as a whole has undergone