History of Northeastern US Maple Syrup Price Trends

T. Eric McConnell
Gary W. Graham

Abstract

Average annual percentage rates of change (APR) in maple syrup prices (average gallon equivalent price in the United States) in seven northeastern United States and their aggregated region were determined for the years 1916 to 2012. The price trend lines were then compared on state-by-state and region-by-state bases. Maple syrup prices across all states and the region as a whole were increasing nominally at significant average annual rates. Nominal APRs ranged from 3.42 percent for Maine to 4.13 percent for New Hampshire, with the price in the combined region increasing at a rate of 3.96 percent annually. Real prices (discussed in 2012 constant dollars) were appreciating at significant annual rates in all areas except Maine. Real APRs ranged from 0.46 percent for Maine to 1.12 percent for New Hampshire, and the regional price was increasing at 0.95 percent annually. Whereas the region's all-time high price of $40.38 was obtained nominally in 2008, the real price actually reached its highest point in 1987 ($53.89). Two other real price peaks were observed regionally: 1947 ($41.17) and 1972 ($45.31). No differences in trend line intercepts and slopes were found across the region. Obtaining price information for any one location has historically provided producers and processors a reasonable expectation of market activities occurring in the greater region.

Production of maple-based products is one of the oldest and most vertically integrated industries in American agriculture. Price trends are one piece of information that can assist maple clientele with their decision making, be it the hobbyist, commercial operator, or someone contemplating entry into the market. Trend analysis provides information on past market activities and plays a key role in guiding forest management (Dennis and Remington 1985).

The collecting of maple syrup production data by the US Department of Agriculture (USDA) dates to 1840, yet little information is currently available regarding maple syrup price trends. The findings of Sendak and Bennik's (1985) maple production and cost analysis were valuable at the time because their 1972 to 1985 price series included a period of hyperinflation in the American economy. Unfortunately, their research covered a relatively short period and to our knowledge has not been updated. The past decade has also experienced several year-to-year increases of 5 percent or more in the inflation rate, and our interactions with maple producers have indicated an increased interest in price trend information.

Our goal was to determine the average annual percentage rates of change (APR) in maple syrup prices recorded in Graham's (2012) recent compilation of maple industry data for the northeastern United States. Our price series covered the years 1916 to 2012. Autoregressive functions were used to determine the APRs for seven states, with price movements between states compared to determine where differences existed. We then developed a weighted regional price and compared it with the states' price trends.

Historical Background

Maple syrup production

The first written accounts of maple sugaring date to the early 1500s, when French explorers were introduced to the practice by Native Americans (Moore et al. 1951). James Smith, a settler who had been taken prisoner by the Caughnawagas Indians of the Ohio Valley in 1756, described a very basic process of collecting maple sap from large gashes on the stems of maple trees and boiling down the sap in hollowed-out stumps. The market for maple sugar expanded rapidly during the 1700s and 1800s owing to the expense of importing cane sugar from the West Indies. Foreign reliance on cane sugar became looked on in an increasingly negative light, so much so that after visiting

The authors are, respectively, Assistant Professor and Extension Specialist, Dept. of Forest Biomaterials, North Carolina State Univ., Raleigh (eric_mcconnell@ncsu.edu [corresponding author]); and Associate Professor and Natural Resources Specialist, Ohio State Univ. Extension, Ohio State Univ., Millersburg (graham.124@osu.edu). This paper was received for publication in September 2014. Article no. 14-00088.

Forest Prod. J. 66(1/2):106–112.
doi:10.13073/FPJ-D-14-00088

Vermont in 1791, Thomas Jefferson suggested every citizen should have a maple orchard or sugar bush to reduce reliance on foreign cane sugar (Lawrence et al. 1993).

Increasing populations meant that greater quantities of wood were needed for fuel, shelter, and durable goods, while productive lands needed to be converted from forests to farms for homesteads and food production. By the mid-1800s, Vermont, for example, was only 20 percent forested (Vermont Agency of Natural Resources 2005). Westward expansion into the Ohio Valley and Great Lakes states resulted in a similar trend in land conversion, albeit approximately 50 to 75 years later. By the early 1910s, lands across the eastern United States began reverting back to forests either because they were ''farmed out,'' tax delinquent, or often both (Steer 1932). Maple production gradually fell in the 20th century with the decline in timber supply and science and technology making dairying a more profitable and year-round activity (Fig. 1). Cane sugar also became increasingly affordable for citizens owing to technological innovations (Whitney and Upmeyer 2004). Maple producers, historically more reluctant to adopt new technology (Kelley and Staats 1989), failed to keep pace. Maple sugaring increasingly became a supplemental rather than primary source of income.

Government-sponsored tree planting initiatives of the 1930s promoted conservation and erosion control while also providing needed employment. On-farm demonstrations and field-based research helped farmers better understand sugar bush and sugarhouse management. Ill-advised practices, including crude tapping procedures and in-woods grazing, still persisted well into the 20th century. A study of adjacent woodlands conducted from 1938 to 1942 in Geauga County, Ohio, found that in-woods grazing negatively impacted forest conditions for maple syrup production (Dambach 1944). Revenue losses then were estimated at \$10.67/acre, which in 1942 had the equivalent purchasing power of almost \$130 today.

Forests have rebounded in New England to make up a majority of the total land area in those states (US Forest Service Forest Inventory and Analysis 2015). Forest cover has returned primarily to only the more marginal sites in the upper Midwest, with more productive soils remaining in agricultural production. Farrell and Chabot (2012) found that states in the maple-producing region significantly differed regarding the utilization rates of their maple resource. Forest-based production on smaller farm woodlots, such as those of the upper Midwest, can be difficult to economically justify. Farrell's (2012) net present value calculator gives producers the ability to evaluate the cost-effectiveness of managing maple trees for either maple syrup or sawtimber production.

Production levels

Maple syrup production is a uniquely North American practice and produced nowhere else in the world. Today's more commercial operations, those greater than 1,000 taps, are often a small minority of all producers in a state, but they frequently represent the majority of total syrup production (Graham et al. 2007).

The USDA National Agricultural Statistics Service (NASS) reported maple syrup production contributed \$106.0 million to the US economy and \$364.5 million to the Canadian economy in 2011 (USDA NASS 2012). In the first agricultural census of 1840, Ohio was the top producer with 6.3 million pounds of sugar, and in 1870, Ohio was responsible for producing 38 percent of the maple crop. Vermont, Maine, and New York are now the US leaders in maple production and have been so for quite some time (Graham 2012 and references therein). Canadian production initially surpassed the United States in the early 20th century (Whitney and Upmeyer 2004). The largest maple-producing area in the world is the province of Quebec, Canada, which produced 78.6 percent of the North American maple crop in 2011 (USDA NASS 2012).

The significant rise and present dominance of the Canadian maple syrup industry has changed the way American producers compete for business. The Canadian industry's ability to offer large volumes at what for many years was a favorable exchange rate made it increasingly difficult at times for American operations. The exchange rate between the two countries began a general rise in 1976, peaking in 2002 at 1.5704 in terms of US dollar base currency (Board of Governors of the Federal Reserve System 2013). This pushed American syrup prices down in order for US producers to compete and consequently

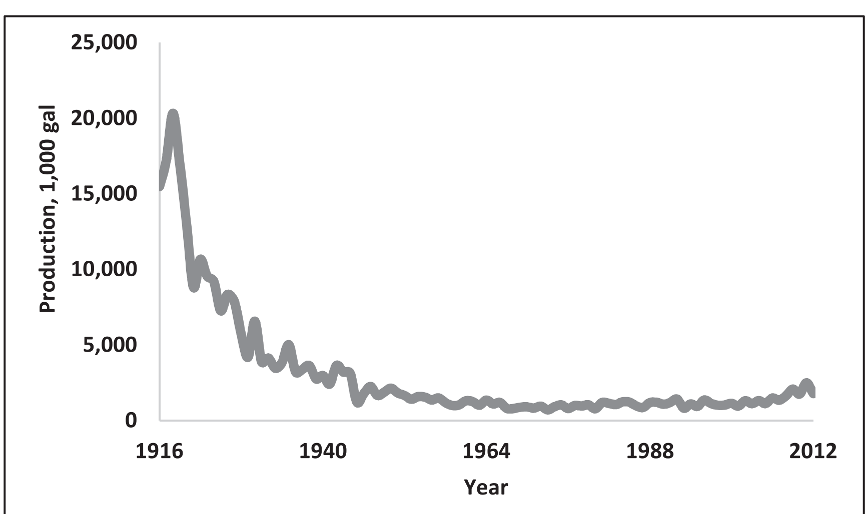

Figure 1.—Maple syrup production for the seven-state region, 1916 to 2012 (1,000 gal). Connecticut, Michigan, and Wisconsin production volumes were not included in the analysis.

drove many from the marketplace. Production remained low, fluctuating around 1.0 million gallons for approximately 30 years, until the exchange rate began trending down in 2002. By 2012, the exchange rate was parity at 0.9995 (Board of Governors of the Federal Reserve System 2013).

Development of the maple industry

Maple syrup production equipment has evolved as producers experimented with new tools and methods designed to improve sugar quality and quantity. The basic process of syrup production, though, is still quite similar today to that of 400 years ago (Koelling 2006). Settlers learned from the Native Americans to cut a gash in the maple tree and to use bark to direct sap into hollowed-out logs, birch bark bowls, or clay pots. Sap was boiled in iron or copper kettles to remove the water, leaving the granulated sugar. Wooden buckets would eventually replace other collection methods. A plentiful supply of tin became available, as it was a by-product of a new food storage system developed around the Civil War (Cook 1887, Lawrence et al. 1993). Tin buckets would eventually succeed wooden buckets, which were heavy and bulky and required frequent painting to keep them from drying and ultimately leaking. Spouts transitioned from hollowed-out sumac or elderberry stem sections to tin also (Koelling 2006).

Plastic spouts entered the market for use with plastic tubing collection systems most recently (Staats and Kelley 1996). Vacuum tubing systems, where a vacuum is used to induce sap flow, dramatically increased sap yield with no significant difference found in sap sugar content (Kelley and Staats 1989). This, like much of a maple sugaring operation, is generally scale dependent, with larger producers able to take advantage of vacuum tubing technology, while smaller operations have favored a ‘‘bucket’’ collection system (Demchik et al. 2000, Graham 2005).

Kettle boiling remained the primary method of evaporating maple sap to sugar until the mid-1800s. Tin was found to be a better heat conductor, and when formed into flat pans, it increased evaporation rates over the thick, heavy iron and copper kettles of the day. Today's modern designed evaporators are based on an 1872 patent from a Vermont sugar maker (Lawrence et al. 1993). Several evaporator patents were issued, and these companies together played an important role in the development of ‘‘continuous flow’’ evaporators, the current industry standard.

A number of accessories can be added to the evaporation process to increase sap reduction and efficiency. Reverse osmosis (RO) is a machine system of small, semipermeable membranes that separate water from the sap (Stowe et al. 2006). Up to 75 percent of the water can be separated from sap. Thermal heating is still required to concentrate the sap into syrup of an acceptable grade, but significant cost savings at the evaporator can be realized. Sendak and Morcelli (1984) calculated that RO cost savings were negligible for a 2,000-tap operation, but a 12,000-tap operation could reduce costs by one-third. Preheaters and steam hoods are also used by modern producers to improve evaporative efficiency via heat transfer and steam venting (Stowe et al. 2006).

Methodology

Maple production and price data

Maple syrup production and price data were obtained from the USDA NASS, its state field offices, as well as state departments of agriculture for seven states dating from 1916 to 2012: Maine, Massachusetts, New Hampshire, New York, Ohio, Pennsylvania, and Vermont (Graham 2012 and references therein). Statewide production was recorded on a 1,000-gallon basis. Price per gallon was the average gallon equivalent (AGE) price in the United States. The AGE is a weighted average across retail, wholesale, and bulk prices (USDA NASS 2012); thus, it varies based on the percentage sold to each outlet. While the AGE price is generally lower in states with greater quantities of bulk sales, we used this price for our analyses because it is the one reported by the USDA relating total value to production.

Three states, Ohio, New York, and Pennsylvania, had years for which government data were not collected. Ohio did not survey producers in 1982, 1983, and 1991. New York had an 8-year period from 1966 to 1973 for which data were not collected. Pennsylvania did not obtain production data from 1982 to 1991. Some state maple associations reported having production information for our missing data; however, this information was not government collected. With no knowledge of the percentage of the total producer base it represented, we determined it best not to utilize them. The other states for which maple data are currently collected by the USDA, Connecticut, Michigan, and Wisconsin, had either much shorter data ranges (in the case of Connecticut) or multiple gaps in the data of at least 10 or more years (Michigan and Wisconsin; Graham 2012). Therefore, we decided to exclude those three states from further analysis. Maine's price reporting underwent a significant change beginning in 1988, as responsibility for reporting data for northern Maine was assumed by the USDA from the Canadian government.

Statistical analysis

We first used the EXPAND procedure in SAS 9.3 to develop price estimates for the Ohio, New York, and Pennsylvania missing data. The EXPAND procedure fits cubic spline curves to a time-series variable's available data to form a continuous-time approximation of the series (SAS Institute 2008). Prices were next linearized by applying a natural logarithm (ln) transformation. Price trends were then analyzed at a significance level of $\alpha = 0.05$ using a simple linear regression model,

$$Y_t = \beta_0 + \beta_1 x_t + \varepsilon \tag{1}$$

where Y_t is the ln of the price in year t (1916, 1917, . . . , 2012), the intercept β_0 is the initial price in a series, β_1 is the continuous percentage rate of change in price, x_t is the year for the time series, and ε is the ln of the error in the model.

A weighted regional price for each year, Y_{wt}, was developed by first calculating the ratio of each state's annual production, $Y_{p(\text{State})}$, to the total annual production for the seven states, $Y_{p\ \text{Region}}$. This was multiplied by the price for each state within year t, $Y_{t(\text{State})}$, and summed to determine the composite regional price for year t:

$$Y_{wt} = Y_{t\ \text{Maine}} \times \left(\frac{Y_{p\ \text{Maine}}}{Y_{p\ \text{Region}}}\right) + \ldots + Y_{t\ \text{Vermont}} \times \left(\frac{Y_{p\ \text{Vermont}}}{Y_{p\ \text{Region}}}\right) \tag{2}$$

The presence of autocorrelation was examined by applying the Durbin-Watson statistic, which found the residuals for the price data for each state and the region to be serially correlated. An autoregressive function using PROC AUTOREG was then run by initiating five lag variables into each model and eliminating them in a backward stepwise fashion. First-order autoregressive models were found to significantly describe the changes in price for all areas. The continuous rate of change, β_1, determined for each location was converted to an annualized rate APR using Equation 2 (Wagner and Sendak 2005):

$$\mathrm{APR} = (e^{\beta_1} - 1) \times 100 \qquad (3)$$

Price trends were developed for both nominal and real prices for each state and the region. Real prices were adjusted for inflation to 2012 constant dollars using the Producer Price Index for all commodities (US Department of Labor, Bureau of Labor Statistics 2013). Errors for each model were reported as percent root mean square error (%RMSE). The %RMSE was obtained by using Equation 3, replacing APR with %RMSE and replacing β_1 with the determined RMSE for each location's regression (Linehan et al. 2003).

Additional regressions were run to test for price trend differences between locations. This was done by adding an indicator variable to a regression function to differentiate between two areas,

$$Y_t = \beta_0 + \beta_1 x_{1t} + \beta_2 x_{2t} + \beta_3 x_{1t} x_{2t} + \varepsilon \qquad (4)$$

where Y_t is the ln of the price in year t, x_{1t} is the year in the price series, x_{2t} is the indicator variable (1 for the area of interest, 0 for the default area), $x_{1t}x_{2t}$ is the interaction term, and β_0, β_1, β_2, and β_3 are model coefficients. The indicator variable coefficient, β_2, was tested for an intercept difference between locales, i.e., whether the initial prices between the two areas were different. The interaction coefficient, β_3, was tested for an APR difference between two locations. These regressions were run on real prices only, as real prices are better indicators of price performance over long periods. Autocorrelation was tested and accounted for as described previously.

Results

State and regional price trends

Nominal and real APRs are reported in Figure 2. Nominal price APRs were significantly different from zero for all states. Maine's nominal APR was the lowest at 3.42 percent, while New Hampshire's was the highest at 4.13 percent. The inflation rate was approximately 3.00 percent over the time series. Removing inflationary effects showed that the real prices in 2012 constant dollars were also significantly increasing for six states, ranging from 0.84 percent for Pennsylvania to 1.12 percent for New Hampshire. Maine's real price APR, 0.46 percent, was not significantly different from zero.

The regional price of maple syrup was increasing at a nominal APR of 3.96 percent and a real APR of 0.95 percent, respectively. Both significantly differed from zero. Figure 3 illustrates the regional price trends, where three primary peaks in real price were observed over the reporting period. The first was shortly after World War II in 1947 ($41.17), a second peak occurred in 1972 ($45.31), and the final was in 1987 ($53.89). Smaller price peaks also occurred in 1932, 1953, 1998, and most recently in 2009. While the nominal price reached its all-time high of $40.38 in 2008, the real price actually reached its highest point much earlier, in 1987. The 2012 price ($38.30) was within the range of real prices bounded by the years from 1973 ($41.42) to 1985 ($39.67).

Price trend comparisons

Comparisons of the states' trend lines found that neither initial prices nor APRs significantly differed between any two states (both parameters were $P > 0.05$ in all two-state comparisons). Moderate degrees of slope (APR) differences were noted between Pennsylvania and New Hampshire ($P = 0.06$) and Pennsylvania and Massachusetts ($P = 0.10$). Differences were lacking between the regional trend line and any state as well. Neither initial prices nor APRs differed across all comparisons ($P > 0.05$ in all cases). While the intercepts and slopes between Maine and the region did somewhat contrast ($P = 0.06$ in each case), these differences could perhaps be best described as moderate. Given the lack of trend line differences, the maple-producing region studied here has not historically exhibited any significant price-level spreads between market areas. Neither have the individual price trends within the region been diverging or converging.

Discussion

Nominal maple syrup prices increased 40-fold from 1916 to 2012, reaching a record level in 2008. Prices dipped slightly afterward, but they were still higher than any other year except 2008. The nominal price for the region had been appreciating at a 3.96 percent average annual rate.

Real rates of price change were more tempered. Removing inflationary effects found that prices in constant dollars actually increased about threefold, reaching their all-time peak much earlier, in 1987. Still, all states, with the exception of Maine, had positive real APRs that significantly differed from zero over their entire price ranges. While the regional real price has appeared to trend downward since 1987, the rate of change over the entire price series was still nearly 1.00 percent better than the average inflation rate.

We found prices at the state level tended to follow one another quite closely. When the USDA began reporting maple data for northern Maine, though, we noticed a sizable increase in both syrup production and total value for that state. The AGE price, though, did not exhibit a comparable change, as it is the quotient of value and production. No statistical differences were observed between trend line intercepts and slopes for any two states. Also, in no case did the initial prices or APRs significantly differ between the regional trend line and a state. The results suggested that obtaining maple syrup prices for any one state has historically provided producers a reasonable expectation of the price across the greater region.

Three specific regional price peaks were noted over the series, 1947, 1972, and 1987. During the war years, the federal government capped the price of maple syrup at $3.39/gallon, nominal (Koelling 2006). Our weighted regional nominal price fluctuated between $2.26 and $3.27 from 1942 to 1946. Maple syrup production in 1945, at 1.21 million gallons, was the lowest on record up to that time in our data series, dropping 61.3 percent from 3.14 million gallons in 1944. Production rebounded somewhat over the next 2 years but has never since approached prewar levels, as one significant maple consumer—tobacco processors—

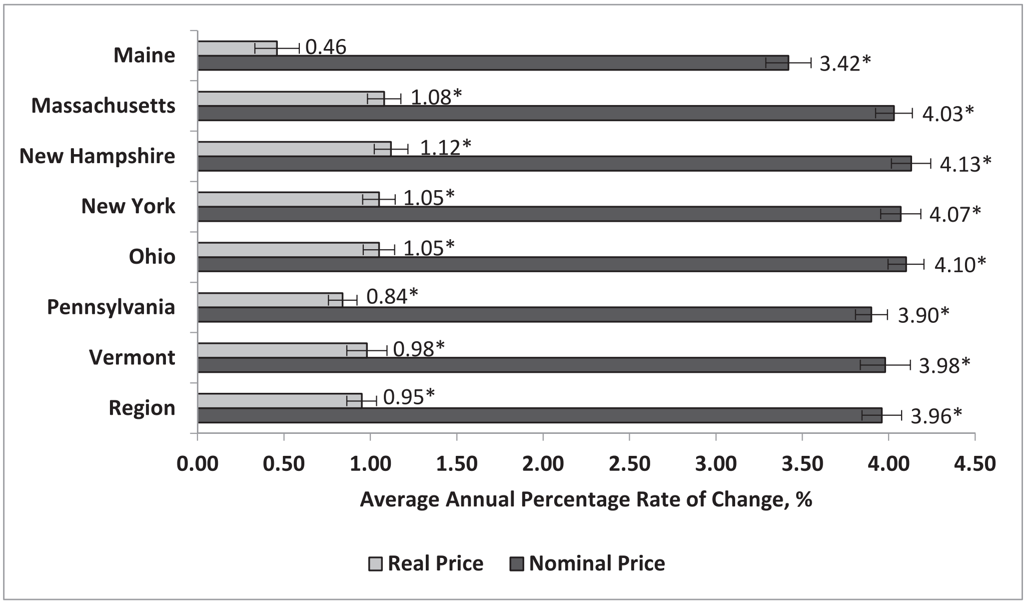

Figure 2.—Nominal and real average annual percentage rates of change in maple syrup prices for seven states and their combined region, 1916 to 2012. Values followed by an asterisk (*) were significantly different from zero at $\alpha = 0.05$. Error bars are percent root mean square error.

was forever lost (Koelling 2006). When the sugar ration was lifted and the syrup price cap rescinded, prices reacted accordingly. The price peak of 1972 was attributed to a world shortage created by below-average North American production in 1971 (Sendak and Bennik 1985). Production levels in 1986 and 1987 were below average compared with 1981 to 1985. Warm temperatures, acid rain, and a thrips outbreak hit the maple region simultaneously hard in the mid- to late 1980s (Kolb et al. 1992, Bergeron and Sedjo 1999, Rock and Spencer 2001).

The large capital investment required for both sugar bush and sugarhouse equipment (Graham et al. 2006); tree density, proximity to an access road, and topography (Farrell 2009); and the size of the operation (Huyler and Garrett 1979, Sendak and Bennik 1985, Farrell and Stedman 2013) are but a few of the individual and/or spatially dependent factors that can affect local maple prices for any given year. Weather events (e.g., ice storms; Kidon and Fox 2000) and climatic influences (MacIver et al. 2006) have, and will continue to have, short- and long-term implications for producers both locally and on larger geographic scales. These and other variables work together to determine the volume produced and the price at which a producer is able to sell his or her product.

Figure 1 and our historical synopsis highlight the overall change in the US maple industry since the Civil War, and this has been attributed to many factors (Whitney and Upmeyer 2004, Graham et al. 2006). Land use changes led to historical industry shifts, with the US maple industry currently centered in the New England states of Vermont and Maine. Cane sugar displaced maple sugar as a staple sweetener in the latter 19th century. Technological changes

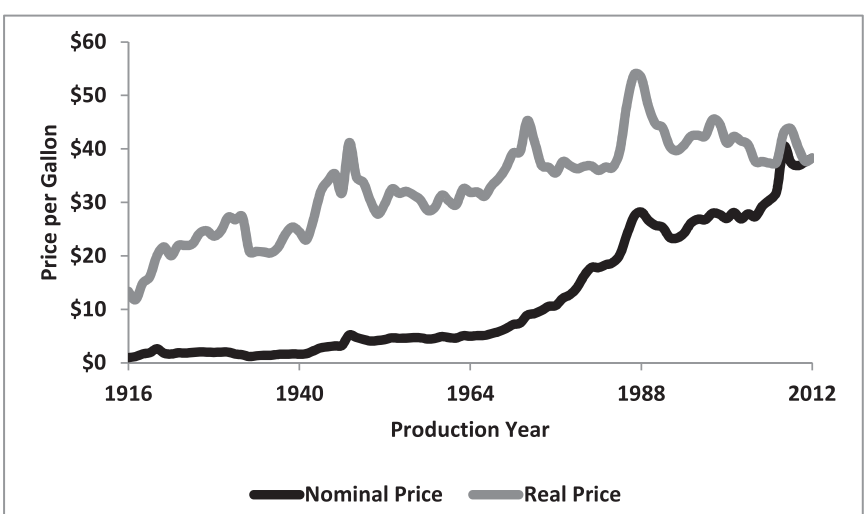

Figure 3.—Nominal and real regional maple syrup prices, 1916 to 2012. Real prices are illustrated in 2012 constant dollars.

placed greater financial incentives on agricultural production at the expense of maple sugaring. As maple syrup became more of a luxury item and supplemental source of income, the tendency of industry participants to be early adopters lessened.

The presence or absence of federal and state government regulatory, promotion, cost share, and incentive programs resulted in market share shifting away from areas lacking strong government–industry partnerships. Vermont, for example, is very active in promoting its industry and has its own syrup-grading standard. This governmental support, in conjunction with independent producer organizations, has resulted in increased market share for that state's producers across the United States, particularly in many upscale markets of the Northeast (Graham 2005).

Contrast Vermont with Ohio, whose industry is much smaller. Nearly 90 percent of the operations in Ohio are less than 1,000 taps in size, less than one-fourth of their sales are bulk, and 99 percent of all their sales remain in state (Graham 2005, Graham et al. 2007). Although a voluntary grading standard is in place, the Ohio Department of Agriculture has not been actively involved overall in regulating Ohio's maple syrup industry. Collaboration with the state's producer association to promote the industry has also been limited. Likewise, Ohio State University Extension has historically focused on educational programming to improve production practices and efficiencies and less so on marketing strategies (Graham et al. 2006).

Another significant factor is Canadian maple syrup production, particularly Quebec, where over three-fourths of the world's production is currently concentrated (Farrell 2012). Canada's maple industry has grown exponentially over the past 80 or more years and now dominates North American production (MacIver et al. 2006). Canadian production began a noticeable rise in the early 1980s (Farrell and Chabot 2012). One focus of the Canadian government's efforts to increase production beginning in the 1990s centered on offering low lease rates on sugar bushes to producers. A world surplus developed due to a lack of marketing and promotion, driving global prices down and resulting in the implementation of a quota system by the Canadian government in 2003 (Farrell 2009). The Canadian quota system works to keep production, and prices, in check. Thus, any changes in Canada's quota system directly impact world prices. Also, the exchange rate between the two countries affects American production because US producers find it more difficult to compete with their Canadian counterparts in times of a strong US dollar.

Recent years have seen one growing consumer base in the United States where producers are well positioned for an advantage, namely, the local foods movement. Strategic marketing, such as capitalizing on the direct-to-consumer approach long used by the industry (Snow 1964), offers these customers a unique ''forest-to-fork'' opportunity. International maple trade associations have been working with producers to emphasize the need for effective marketing (Whitney and Upmeyer 2004). The scale dependency of the industry underscores the challenge of who can justify the costs of marketing their products. Many producers directly retailed at least a portion of their production (Graham 2005). Larger producers tended to market through retail outlets, while smaller operations were more inclined to retain greater a portion of their syrup for personal consumption (Demchik et al. 2000).

The industry's outlook is optimistic as worldwide demand continues to grow for maple products. North American production over the past decade has intensified in response to rising consumer demand (Farrell and Chabot 2012), with 2012 production in our study region up 50 percent from that of 10 years prior. The relative contributions of maple species to hardwood sawtimber inventories (trees with average diameters at breast height of at least 11 in. capable of producing lumber) has grown in the eastern United States (Luppold and Miller 2014). This is due more to the overall limited degree of forest management practiced in the Northeast (Wagner and Sendak 2005) than to strategies targeted toward maple species. The maple resource overall remains underutilized, and Farrell and Chabot (2012) estimated the United States alone had the potential for a $500 million maple syrup industry.

Conclusions and Implications

Nominal prices for maple syrup in all seven Northeast states have been trending upward at significant annual rates since 1916. Real maple syrup prices have been increasing at significant average annual rates since 1916 for six states. The real APR for Maine did not differ from zero over the reported period. The regional price for maple syrup increased at a nominal APR of 3.96 percent and a real APR of 0.95 percent since 1916; both rates were significantly different from zero. No trend line differences were found between states, nor was the regional price regression determined to differ from any individual state. Based on the historical prices analyzed, price information obtained for any one area has been able to provide maple syrup producers with an indication of the prevailing market price across the greater region.

Maple producers of all sizes benefited at least moderately from Extension programming on the economics of syrup production, where sugar bush management and sap processing efficiencies were areas of greatest need (Graham 2005, Graham et al. 2006). Results from this trend analysis may be used in comparisons with other market rates of change, e.g., sawtimber, to assess potential investments. Extension specialists can assist those desiring further study on price trends, which can help producers maximize their operation's returns. Encouraging market participation could also entice forest landowners who in the past have not looked at their land as a source for generating forest-based income, particularly in areas of the Northeast where maple sugaring may not be as widely practiced.

Literature Cited

Bergeron, N. and R. Sedjo. 1999. The impact of El Niño on northeastern forests: A case study on maple syrup production. Discussion Paper 99-43. Resources for the Future, Washington, D.C.

Board of Governors of the Federal Reserve System. 2013. Foreign exchange rates—H.10. http://www.federalreserve.gov/releases/h10/hist. Accessed September 17, 2013.

Cook, A. J. 1887. Maple Sugar and the Sugar-Bush. A. I. Root, Medina, Ohio. 41 pp.

Dambach, C. A. 1944. Comparative productiveness of adjacent grazed and ungrazed sugar-maple woods. *J. Forestry* 42(3):164–168.

Demchik, M. C., J. C. Finley, A. L. Davenport, and R. D. Adams. 2000. Assessing the characteristics of the maple syrup industry in Pennsylvania to aid in the development of Extension programs. *North. J. Appl. Forestry* 17(1):20–24.

Dennis, D. F. and S. B. Remington. 1985. The influence of price expectations on forestry decisions. *North. J. Appl. Forestry* 2(3):81–83

Farrell, M. 2009. Assessing the growth potential and future outlook for the U.S. maple syrup industry. *In:* Proceedings of the 11th North American Agroforestry Conference, Agroforestry Comes of Age: Putting Science into Practice, M. A. Gold and M. M. Hall (Eds.), May 31–June 3, 2009, Columbia, Missouri. 8 pp.

Farrell, M. L. 2012. The economics of managing maple trees for syrup or sawtimber production. *North. J. Appl. Forestry* 29(4):165–172.

Farrell, M. L. and B. F. Chabot. 2012. Assessing the growth potential and economic impact of the U.S. maple syrup industry. *J. Agric. Food Syst. Community Dev*. 2(2):11–27.

Farrell, M. L. and R. C. Stedman. 2013. Landowner attitudes toward maple syrup production in the northern forest: A survey of forest owners with $\geq$ 100 acres in Maine, New Hampshire, New York, and Vermont. *North. J. Appl. Forestry* 30(4):184–187.

Graham, G. W. 2005. Analysis of production practices and demography characteristics of the Ohio maple syrup industry. PhD dissertation. Ohio State University, Columbus. 121 pp.

Graham, G. W. 2012. Maple syrup production statistics. Technical report issued to the North American Maple Syrup Council. 29 pp.

Graham, G. W., P. C. Goebel, R. B. Heiligmann, and M. S. Bumgardner. 2006. Maple syrup production and the impact of Ohio State University Extension programming. *J. Forestry* 104(2):94–100.

Graham, G. W., P. C. Goebel, R. B. Heiligmann, and M. S. Bumgardner. 2007. Influence of demographic characteristics on production practices within the Ohio maple syrup industry. *North. J. Appl. Forestry* 24(4):290–295.

Huyler, N. K. and L. D. Garrett. 1979. A cost analysis: Processing maple syrup products. Research Paper NE-430. USDA Forest Service, Broomall, Pennsylvania. 6 pp.

Kelley, J. W. and L. J. Staats. 1989. High-vacuum pumping effects on maple sap sugar yield. *North. J. Appl. Forestry* 6(3):126–129.

Kidon, J. and G. Fox. 2000. Impact of the 1998 ice storm on the eastern Ontario maple syrup industry: A case study of natural disaster policy in Canada. *In:* Canadian Agricultural Economics Society Annual Meeting, June 1–3, 2000, Vancouver, British Columbia; Canadian Agricultural Economics Society, Department of Economics, University of Victoria, Victoria, British Columbia. 29 pp.

Koelling, M. R. 2006. History of maple syrup and sugar production. *In:* North American Maple Syrup Producers Manual. Bulletin 856. R. B. Heiligmann, M. R. Koelling, and T. D. Perkins (Eds.). Ohio State University Extension, Columbus. pp. 5–13.

Kolb, T. E., L. H. McCormick, E. E. Simons, and D. J. Jeffrey. 1992. Impacts of pear thrips on root carbohydrate, sap, and crown characteristics of sugar maples in a Pennsylvania sugarbush. *Forest Sci*. 38(2):381–392.

Lawrence, J., R. Martin, and P. Boisvert. 1993. Sweet Maple: Life, Lore, and Recipes from the Sugarbush. Vermont Life, Montpelier, Vermont. 223 pp.

Linehan, P. E., M. G. Jacobson, and M. E. McDill. 2003. Hardwood stumpage price trends and regional market differences in Pennsylvania. *North. J. Appl. Forestry* 20(3):124–130.

Luppold, W. G. and G. W. Miller. 2014. Changes in eastern hardwood sawtimber growth and harvest. *Forest Prod. J*. 64(1/2):26–32.

MacIver, D. C., M. Karsh, N. Comer, J. Klaassen, H. Auld, and A. Fenech. 2006. Atmospheric influences on the sugar maple industry in North America. Adaptations and Impacts Research Division, Environment Canada, Toronto. 21 pp.

Moore, H. R., W. R. Anderson, and R. H. Baker. 1951. Ohio maple syrup: Some factors influencing production. Research Bulletin 718. Ohio Agricultural Experiment Station, Wooster. 53 pp.

Rock, B. and S. Spencer. 2001. Case study 2: The maple sugar industry. *In:* Preparing for a Changing Climate, the Potential Consequences of Climate Variability and Change, New England Regional Overview. US Global Change Research Program, University of New Hampshire, Durham. pp. 39–42.

SAS Institute. 2008. SAS, version 9.3. Cary, North Carolina.

Sendak, P. E. and J. P. Bennik. 1985. The cost of maple sugaring in Vermont. Research Paper NE-565. USDA Forest Service, Broomall, Pennsylvania. 14 pp.

Sendak, P. E. and M. F. Morcelli. 1984. Reverse osmosis in the production of maple syrup. *Forest Prod. J*. 34(7/8):57–61.

Snow, A. G. 1964. Maple sugaring and research. *J. Forestry* 62(2):83–88.

Staats, L. J. and J. W. Kelley. 1996. Field evaluation of the IPL VacuSpout for maple sap collection. *North. J. Appl. Forestry* 13(4):171–174.

Steer, H. B. 1932. Forest economics: With special reference to stumpage, log, and lumber prices. *J. Forestry* 30(7):860–866.

Stowe, B., T. Wilmot, G. L. Cook, T. Perkins, and R. B. Heiligmann. 2006. Maple syrup production. *In:* North American Maple Syrup Producers Manual. Bulletin 856. R. B. Heiligmann, M. R. Koelling, and T. D. Perkins (Eds.). Ohio State University Extension, Columbus. pp. 119–156.

US Department of Agriculture National Agricultural Statistics Service (USDA NASS). 2012. Maple syrup 2012. USDA NASS New England Field Office, Concord, New Hampshire. 8 pp.

US Department of Labor, Bureau of Labor Statistics. 2013. Producer price index. http://www.bls.gov/ppi. Accessed September 17, 2013.

US Forest Service Forest Inventory and Analysis. 2015. Forest inventory data online (FIDO). http://apps.fs.fed.us/fido/standardrpt.html. Accessed May 30, 2015.

Vermont Agency of Natural Resources. 2005. Vermont's forests: Growing and changing. Vermont Agency of Natural Resources, Waterbury. 4 pp.

Wagner, J. E. and P. E. Sendak. 2005. The annual increase of northeastern regional timber stumpage prices: 1961 to 2002. *Forest Prod. J*. 55(2):36–45.

Whitney, G. G. and M. M. Upmeyer. 2004. Sweet trees, sour circumstances: The long search for sustainability in the North American maple products industry. *Forest Ecol. Manag*. 200:313–333.