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CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Diploma thesis

Econometric Analysis of Maple Syrup Market in Quebec

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Faculty of Economics and Management

DIPLOMA THESIS ASSIGNMENT

Bc. Zdislava Pechrová

Economics and Management
European Agrarian Diplomacy

Thesis title

Econometric Analysis of Maple Syrup Market in Qubec

Objectives of thesis

The aim of the diploma thesis is to determine and to evaluate the Maple Syrup Market in province of Quebec in the selected period.

The aim will be fulfilled based on the partial aims. Then, several hypotheses will be defined and verified. Based on the results of and empirical analysis the final conclusions will be introduced.

Methodology

The diploma thesis will cover both theoretical and empirical part. Theoretical part will contain theoretical background of the selected topic as well as the methodological framework. Scientific literature will be used to prepare the literature overview. The empirical analysis will be based mainly on the time series analysis and econometric approach. Other suitable methods will be employed as well. Based on the empirical analysis the results will be presented and some recommendations will be suggested.

The proposed extent of the thesis

60 – 80

Keywords

Maple syrup, Quebec, time series, econometric model.

Recommended information sources

DOUGHERTY, C. *Introduction to econometrics.* Oxford: Oxford University Press, 2011. ISBN 978-0-19-956708-9.

GUJARATI, D.N. Essentials of Econometrics. McGraw-Hill/Irwin, USA 1992. ISBN 0-07-025194-0.

KOČENDA, E. – UNIVERZITA KARLOVA, – ČERNÝ, A. *Elements of time series econometrics: an applied approach.* Prague: Karolinum, 2014. ISBN 978-80-246-2315-3.

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SEDDIGHI, H. *Introductory econometrics : a practical approach.* London: Routledge, 2012. ISBN 978-0-415-56688-9.

Expected date of thesis defence

2019/20 SS – FEM

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Declaration

I declare that I have worked on my diploma thesis titled "Econometric Analysis of Maple Syrup Market in Quebec" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the diploma thesis, I declare that the thesis does not break copyrights of any third person.

In Prague on 6.4.2020 ______________________________

Acknowledgement

I would like to thank Ing. Lenka Rumánková, Ph.D. for her help and advises during writing of this thesis and Ing. Marie Šimpachová Pechrová, Ph.D. for her corrections. And to my friends and family for their mental and financial support during my whole studies.

Econometric Analysis of Maple Syrup Market in Quebec

Abstract

In this thesis econometric analysis of the maple syrup market in Canadian province of Quebec was performed. For this simultaneous econometric model was employed, where production and consumption of maple syrup were endogenous variable and, after initial analysis, price of maple syrup, yield and number of taps were used as exogenous variables. Using Two-Stage Least Square method the parameters of the model were estimated. Structural form of the model was applied for economic characterization of parameters and creation of reduced from which was then used for forecast. In the thesis, it was found out that the biggest impact on consumption has price of maple syrup and biggest impact on production has yield. The three-year forecast predicts 7.9% increase in consumption and 8% increase in production.

Keywords: maple syrup, econometric analysis, Quebec, forecast

Econometrická analýza trhu s javorovým sirupem v Quebecu

Abstrakt

Tato práce se zabývá ekonometrickou analýzou sektoru javorového sirupu v Kanadské provincii Quebec. Pro tuto analýzu byl vytvořen simultánní model, kde produkce a spotřeba javorového sirupu byly endogenní proměnné a po úvodní analýze jako exogenní proměnné byly použity cena javorového sirupu, výtěžek a počet "tap". Parametry rovnice byly stanoveny pomocí Dvoustupňové metody nejmenších čtverců. Strukturální forma modelu se použila pro ekonomickou interpretací parametrů a vytvoření redukovaného tvaru modelu, který byl poté použit pro prognózu. V diplomové práci se vyzkoumalo, že největší vliv na spotřebu javorového sirupu má jeho cena a největší vliv na produkci má výtěžek. Tříletá prognóza předpovídá 7.9% nárůst u spotřeby a 8% nárůst produkce.

Klíčová slova: javorový sirup, ekonometrická analýza, Quebec, prognóza

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1 Introduction

For north-eastern U.S and parts of Canada maple syrup production is both culturally and economically important industry, where the commercial harvest of the sap has occurred for several centuries, long before the arrival of European settlers, the sap of the sugar maple (Acer saccharum) was valued by the Indigenous people. Quebec is the leader in production number (90.7%, 2018), number of maple farms (90.3%, 2018) and number of maple taps (90.5%, 2018) and therefore the maple syrup industry is a huge part of their agriculture sector and it is interesting for analysis.

Diploma thesis will look at the production and consumption of maple syrup in the province of Quebec, Canada in the last 20 years, from the year 1999 to 2018. From the literature review relevant parameters are going to be use for the construction of the two-equation econometric model.

2 Objectives and methodology

2.1 Objectives

Main objective of the diploma thesis is to create a quality model for agricultural market of maple syrup in the province of Quebec in period from 1999 to 2018 and then apply this model for short-term 3-year prognosis. To achieve the main goal of the thesis several sub-goals are specified. These sub-goals consist of establishing and quantifying links, influences and trends between production and consumption of maple syrup and other parameters based on economic theory and trends in agriculture.

Diploma thesis is divided into theoretical and practical part. In theoretical part thesis describes maple syrup industry, its production and what influences it, consumption in the province, and international trade. For theoretical part, literature from academic sources was used to elaborate literature review.

In the practical part, firstly simultaneous econometrical model will be formulated, where the variables and its relationships will be determined based on economic theory. Then, parameters of the model will be estimated using Two-stage least square method by the Gretl software. Suitability and applicability of the model will be assessed by the economic, statistical, and economical verification.

Finally, the created model will be used for application. To determine which factor has the biggest influence on the endogenous variable, elasticity will be calculated. For the prognosis, reduced form of the model will be created, and from that short-term forecast will be conducted.

As the final part, all the results will be summarized and disputed. Data sources are mainly STACAN (Statistical office of Canada), publication from Federation de producteur et productricex acéricole du Quebec (FPAQ), publication of Government of Quebec, Institut de la Statistique Quebec, and Nielsen publication on sales in shops.

2.2 Methodology

Econometrics may be defined as the quantitative analysis of actual economic phenomena based on the concurrent development of theory and observation, related by appropriate methods of inference. (Samuelson, Koopmans, and Stone, "Report of the Evaluative Committee for Econometrica") Methodology of the construction of the econometric model is divided into four main parts: specification, quantification, verification, and application.

2.2.1 Specification

First phase in econometric modelling is formulation of hypothesis, which comes from economic theory.

1. Determination and classification of all variables in the model based on economic theory. In econometric model we have four types of variables. Endogenous, denoted y_{it}, where i is number of endogenous variable and t is time, exogenous, denoted x_{jt}, where j is number of exogenous variables, predetermined, denoted either x_{jt}, $x_{j(t-1)}$, $y_{i(t-1)}$, and random variables, denoted u_t.

2. Estimation of the slope and expected values of model parameters.

3. Selection of mathematical and analytical shape of the model or its equations.

There are three main type of economic models, one-equation model, a multi-equation model of completely independent equations, and a simultaneous model consisting of a set of interdependent equations. Shape of a model is most often chosen so that the dependencies of the explained and explanatory variables are linear.

2.2.2 Quantification

This phase of the process is used to estimate the numerical values of the parameters and begins with the collection and modification of statistical data. Data are usually non-experimental, i.e. they are not generated specifically for model estimation. They can be of various kind, such as cross-sectional, panel data, or time series which is the most common.

The non-experimental nature of statistical data raises several problems for which the data must be adjusted or adjusted. One of them is insufficient number of observations, measurement errors or multicollinearity or high dependence between explanatory variables. (*Hušek*, "Aplikovaná ekonometrie") Before the estimation itself the correlation matrix is conducted to point out the high dependencies. Matrix contains paired correlation coefficients of each explanatory variables which are calculated according to the Equation 1, where $x_{it}^{'}$ is matrix of normalized vector, which can be calculated by Equation 2,

$$x^{'T}x^{'} \tag{1}$$

$$x_{it}^{'} = \frac{x_{it} - \overline{x_i}}{\sqrt{n}\sigma_{x_t}} \tag{2}$$

where x_{it} is a value of *i* explanatory variable in time *t*, $\bar{x}_i$ is its average, and $\sigma_{x_t}$is standard deviation and *n* is number of observations.

If the value of paired correlation coefficient is higher than 0.8 there is multicollinearity occurring and data must be transformed. This can be done by using dummy variable or expressing the variable as a gradual or relative difference.

Ordinary least squares (OLS) methods based on regression analysis, Variance minimization method, Two-step least squares method, Three-step least squares method, and others have been developed to estimate the econometric model. (*Tvrdoň*, "Econometrics Modelling") The ordinary least squares method is mostly used for its simplicity, providing the best, impartial and consistent estimates of model parameters when model assumptions are met. However, for the simultaneous model OLS cannot be used as it leads to inconsistencies. For this reason, two-stage least squares method was developed. As the name says, it involves two successive application of OLS.

In the 1st stage, to get rid of the likely correlation between Y_2 (matrix of real values of endogenous variable) and ε_2. It replaces matrix Y_2 by the matrix $\hat{Y}_2$ (matrix of theoretical values) where the values are estimated on all predetermined variables. Equation 3 is utilized for that, where *X* is a matrix of all predetermined variables.

$$\hat{Y}_2 = X(X^TX)^{-1}X^TY_2 \tag{3}$$

Estimated values are then used for estimation of structural parameters itself, and Equation 4 is used,

$$\begin{bmatrix} \beta_2 \\ \gamma_{1*} \end{bmatrix} = \begin{bmatrix} \hat{Y}_2^T \hat{Y}_2 & Y_2^T X_* \\ X_*^T Y_2 & X_*^T X_* \end{bmatrix}^{-1} \begin{bmatrix} \hat{Y}_2^T \\ X_*^T \end{bmatrix} y_1 \tag{4}$$

where y_1 is a vector of real values of endogenous variable, X_* matrix of values of predetermined variables in the selected equation and the $\begin{bmatrix} \hat{Y}_2^T \hat{Y}_2 & Y_2^T X_* \\ X_*^T Y_2 & X_*^T X_* \end{bmatrix}$ is a matrix *K* which is a complex matrix, comprising of four submatrices. (*Čechura*, "Cvičení z ekonometrie")

For the simultaneous model it is important for the model to be identify in the reduced form. A reduce-from of a model is one that expresses an endogenous variable in one equation only by predetermined variables and error therm. Model is identify whether coefficient of the parameters of a structural form can be obtained from the estimated reduced form. If this cannot be done, then the equation is underidentified. For determination of identification Equation 5 is utilized.

$$K - k \geq m - 1 \tag{5}$$

where *K* is number of predetermined variables in the model including the intercept, *k* is number of predetermined variables in each equation and *m* is number of endogenous variables in a given equation. (*Gujarati*, "Basic econometrics")

In this thesis, the parameters will be estimated using two stage least squares method using the Gretl software. It is a program that contains useful and easy-to-use econometric analysis tools. A positive feature of the program is its availability, thanks to which the program can be downloaded free of charge from the Internet. Gretl uses several estimation techniques, such as the Ordinary Least Squares (OLS) method, the Weighted Least Squares (WLS) method, the Two-Step Least Squares (TSLS) method, panel estimation methods, two-dimensional data, as well as methods for estimating time series and for estimating parameters based on some methods of maximum likelihood of models. ("Gretl: Gnu Regression, Econometrics and Time-series Library")

2.2.3 Verification

The estimated econometric model must be verified, that the estimated parameters are consistent with the underlying hypotheses and meet the model assumptions. Based on this, verification can be divided into economic, statistical and econometric.

- Economic verification consists of verifying the correctness of signs and the magnitude of the numerical results of the estimated parameters.
- Statistical verification is a tool for assessing the statistical feasibility of individual estimated parameters, but also of the whole econometric model. The conformity of the estimated model with the data in the case of the linear function is assessed based on the coefficient of determination R^2. (*Čechura*, "Cvičení z ekonometrie") The coefficient expresses "how many % of changes in a dependent variable are explained by changes in independent variables". Statistical significance of individual parameters is evaluated by p-values. The p-test consists of comparing the calculated p-value with the selected significance level, considering a given number of degrees of freedom. If the p-value is smaller than the selected significance level, we reject the null hypothesis of the statistical insignificance of the parameter, which means that the parameter is statistically significant and vice versa. (*Čechura*, "Cvičení z ekonometrie") Similarly, F-test verifies if the model as a whole is statistically significant. Null hypothesis assumes that all parameters re jointly equal to zero. When it is rejected, model is statistically significant.
- Econometric verification verifies that the model assumptions have been met.
  - the assumption of non-zero mean values and the impartiality of the estimation
  - assumption of finite and constant variance of random components is referred to as homoscedasticity. Unwanted heteroscedasticity is tested by White, Breusch Pagan or another test.

- assumption of zero covariance, i.e. zero non-diagonal elements of the covariance matrix of random components, if the random component of the model is correlated with the random component in the previous period in any period, there is an autocorrelation in model. This is tested by the commonly used Durbin-Watson statistic.
- assumption of linear independence of all columns of the matrix of observed values, i.e. that none of the variables can be expressed as a linear combination of another, this effect is called multicollinearity. It is determined by paired correlation coefficients of explanatory variables, which should not be higher than 0.8. (*Hušek*, "Ekonometrická analýza")

2.2.4 Application

For the application of the model several characteristics of the functions were found, namely: average production/consumption; marginal production/consumption, elasticities, and marginal rate of substitution.

Average production/consumption (AP, AC) is the amount of production/consumption per unit of factor (x_j). Maximum of AP/AC is at the point where first partial derivation of production/consumption function equals to zero and at the same time second partial derivation is negative. AP/AC is calculated according to the Equation 6, where AP_{x_j} (resp. AC_{xj}) is average production (resp. average consumption) per certain factor and *y* is the function of production/consumption.

$$AP_{x_j}(AC_{xj}) = \frac{y}{x_j} \tag{6}$$

Marginal production/consumption (MP, MC) is rate of change (increase x decrease) of production/consumption with increase of certain parameter. Maximum of this function is at the point where first partial derivation equals to zero. $MP_{x_j}(MC_{x_j})$ of a factor is calculated according to Equation 7.

$$MP_{x_j}\left(MC_{x_j}\right) = \frac{\partial y}{\partial x_j} \tag{7}$$

While the estimated parameter expresses how the respective explanatory variable affects the explained variable in units, elasticity allows to express this effect in relative expression (%). Relative expression then allows to compare influence of individual explanatory variable, i.e. comparison with different units. General equation for calculation is Equation 8.

$$e_{ij} = \frac{\partial y_{it}}{\partial x_{jt}} \cdot \frac{x_{jt}}{\hat{y}_{it}} \tag{8}$$

For quantification of relation between factors Marginal Rate of Substitution (MRS) can be used. MRS is a ratio of change in the quantity of factor x_1 and the change in the quantity of factor x_2. If we know the function of each factor, we can calculate MRS according to the Equation 9.

$$\text{for } x_1 = \text{fc}\ (x_2)\ \rightarrow MRS = \frac{\partial x_1}{\partial x_2} \tag{9}$$

Verification of the model results is a decision on its practical use or rejection. A good or acceptable econometric model can then be used for application. There are many ways of applying econometric models including structural analysis, simulation of effects and outcomes of various scenarios. The main field of econometric applications models are forecast. (*Čechura*, "Cvičení z ekonometrie") The econometric forecast is a quantitative estimate of the probability of the future value of an economic variable using both past and present information, represented by the estimated model. For practical and methodological reasons, ex post and ex ante forecasts are distinguished. Ex post forecasts are obtained when it is possible to determine the values of variables in the forecasting period with certainty. If future values are not known, these are ex-ante forecasts. (*Hušek*, "Základy ekonometrické analýzy") Depending on the quality of the model, short- and medium-term forecasts are usually prepared at the horizon of 1-3 or 5-7 years. Prognosis formulation is calculated by Equation 10 where $\hat{Y}_{n+j}$ is prognosed values each of the endogenous variables, M is matrix of multiplicators and $\hat{X}_{n+j}$ is prognosed values of predetermined variables in period $n+j$, where j is the prognostic horizon.

$$\hat{Y}_{n+j} = M \cdot \hat{X}_{n+i} \tag{10}$$

The forecast from econometric models takes place in two stages. In the first stage, the expected values of predetermined variables in the forecast period are determined by extrapolating individual trend functions. It is only in the second stage that the calculated values of endogenous variables are calculated according to the Equation 10. (*Tvrdoň*, "Econometrics Modelling")

3 Literature Review

For north-eastern U.S and parts of Canada maple syrup production is both culturally and economically important industry. The commercial harvest of the sap has occurred for several centuries. Long before the arrival of European settlers, the sap of the sugar maple (*Acer saccharum*) was valued by the Indigenous people. Maple syrup and maple products are strongly associated with Canadian identity as demonstrated by the saying "as Canadian as maple syrup", and by their flag where the leaf of the sugar maple is at the centre.

For Québécois, more broadly for the French Canadians in general, going to the *cabane à sucre* (e.g. sugar shack) is remaining popular cultural practice. In the spring people traditionally gather for *le temps des sucres* (maple time). They gather on maple farms to listen to traditional music, eat a meal, and eat taffy on snow (Tradition, when maple syrup is concentrated by boiling and spread out to chill on snow). The traditional feast includes pea soup, ham, omelette, potatoes, baked beans, sausages, pancakes and *oreilles de crissé* (crispy pork rinds), all dipped in maple syrup. *(Werner and Yarhi,* "Maple Syrup Industry"*)*

3.1 Maple Syrup

Syrup are defined as high viscous sweeteners in liquid form, and they have been used as a food flavouring by the early societies, e.g., honey.

Maple sweeteners, made by concentration of the sap of the sugar maple tree (*Acer saccharum*), are produced in eastern Canada and north-eastern USA. During harvesting, heating of the sap causes colour and flavour development, as well as concentration, and other characteristic of the maple product. As a result of higher prices of the pure commodity, than traditional sucrose or starch-based sweeteners, many blends of maple syrup with other syrups, or syrups with maple flavouring, are nowadays available and generally labelled as such. *(Doner,* "SUGAR | Palms and Maples"*)*

Canadian government grades syrup based on colour and quality. The highest quality, A grade, is than divided into four categories based on percentage of light transmitted (Table 1). Second grade of maple, Processing grade, is either "made only from concentrated maple sap or by diluting or dissolving a maple product other than maple sap in potable water", "is clean, healthy, and edible", "has a minimum of 66% and a maximum of 68.9% soluble solids", or "does not qualify for Grade A". *(*"Classification - Producteurs et Productrices Acéricoles Du Québec"*)*

Table 1 Differentiation by colour of Grade A maple syrup by Canadian Ministry. Source: *Government of Canada, Canadian Food Inspection Agency, Food Safety and Consumer Protection Directorate,* "Canadian Grade Compendium Volume 7 – Maple Syrup"

Colour class	**Percentage of light transmitted, no less than**	**Characteristics**
Golden, Delicate Taste (Doré, goût délicat)	>75	Is clean, healthy, and edible Does not ferment
Amber, Rich Taste (Ambré, goût riche)	75- 50	Has no objectionable odour or taste
Dark, Robust Taste (Foncé, goût robuste)	50- 25	Has the maple flavour characteristic of its colour class
Very Dark, Strong Taste (Très Foncé, goût prononcé)	<25	

3.2 Production

In Figure 1 there is a distribution of production of maple syrup in Canada. Quebec is the leader in production number (90.7%, 2018), number of maple farms (90.3%, 2018) and number of maple taps (90.5%, 2018) and therefore maple syrup industry is an important and huge agriculture sector for analysis in this area. (StatCan, 2018) From the other provinces the biggest production is in Ontario (4.7%, 2018), and after that New Brunswick (3.7%, 2018), and Nova Scotia (0.6%, 2018). ("Statistique Acéricole 2018") For this reason, this work will concentrate on production in Quebec as the biggest maple syrup producer.

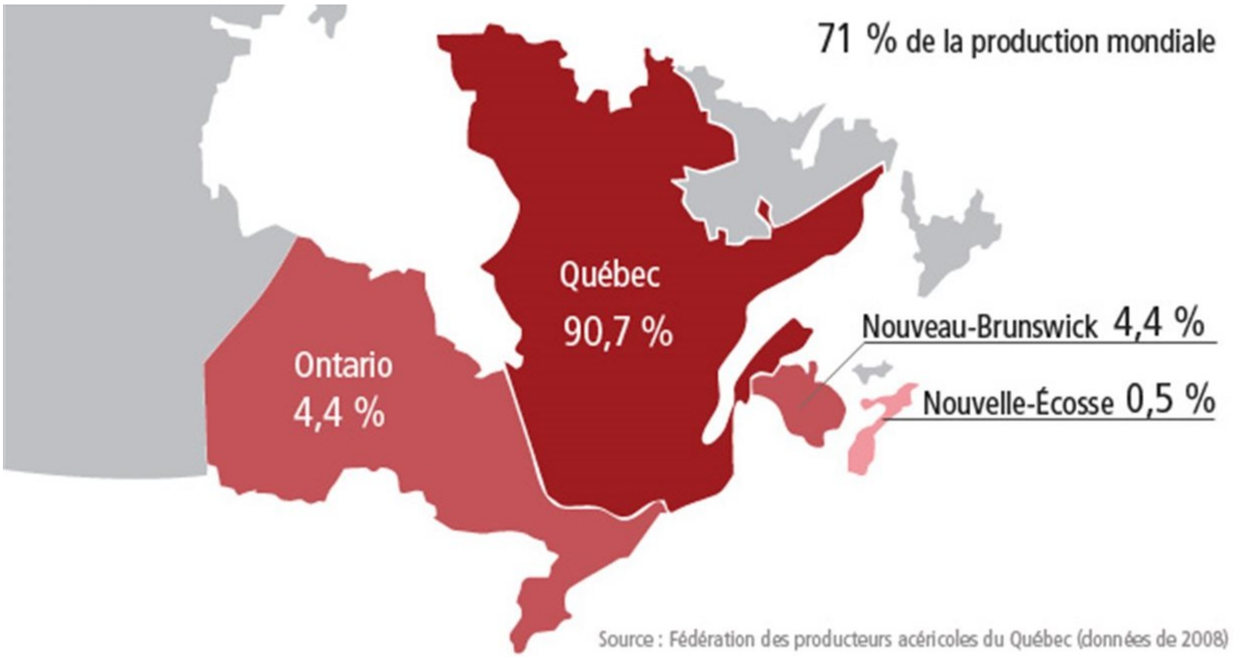

Figure 1 Distribution of production of maple syrup in Canada in 2008. Out of 71% of world production, the most of it is produced in Quebec (90.7%) and other smaller production is in Ontario (4.4%), New Brunswick (4.4%), and in Nova Scotia (0.5%), Source: "Classification - Producteurs et Productrices Acéricoles Du Québec"

The production of maple sugar and syrup is concentrated entirely in North American. Trees are usually owned and cared for by small farmers and in remain in the same family for a longer period, in some cases in over two centuries. It is an inseparable part of Quebecois identity culturally and gastronomically.

Quebec is also the leading producer of Maple syrup in the world, about three quarters of world production is made there. In 2018, the value of maple products on the farm was estimated at nearly 345 million CAD and it was harvested approximately 53.5 million kg of sap.

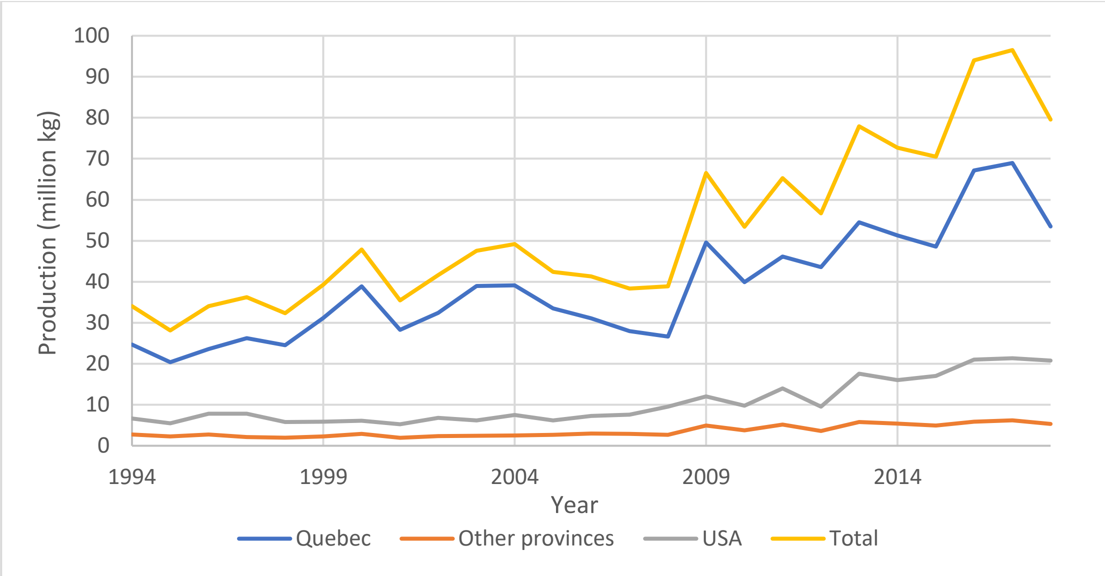

Figure 2 Evolution of production of maple syrup between the years 1994 and 2018 in Quebec, other Canadian provinces, USA and total world production. Own elaboration based on data from "Statistique Acéricole 2018".

Evolution of total production and then production in Canada and USA since 1994 is in Figure 2. During the 2011-2015 period maple syrup production reached record volumes. In fact, 54.5 million kg of syrup were produced in 2013, a peak not previously unmatched. The five-year average for this period is also significantly higher than the previous period, at 48.9 million kg compared to 35.0 million kg. This growth is partly explained by an improvement in the tap yield, which averaged 1.14 kg/tap for the 2011-2015 period compared to 0.99 kg/tap for 2006-2010.

Average production between the last period, 2015-2018, was even higher 59.56 million kg (which is about 44.9 million litres) with value exceeding 445 million dollars. The year 2017 was a record year for production, more than 98 million kg of sap was collected.

Total production in the world basically copies the trends in Quebec because three quarters of maple syrup is made there. Even though there can be observed an increase of fraction produced in the United states (Figure 3). In the year 1994 only 19% of production was done in the USA but in 2018 it was 26%, which is a 7% increase. This was partially influenced by low production in Canada (but that was lower in US too) but also by an absolute increase from production of 6.4 million kg in 1994 to 20.4 million kg in the USA, increase by 300%.

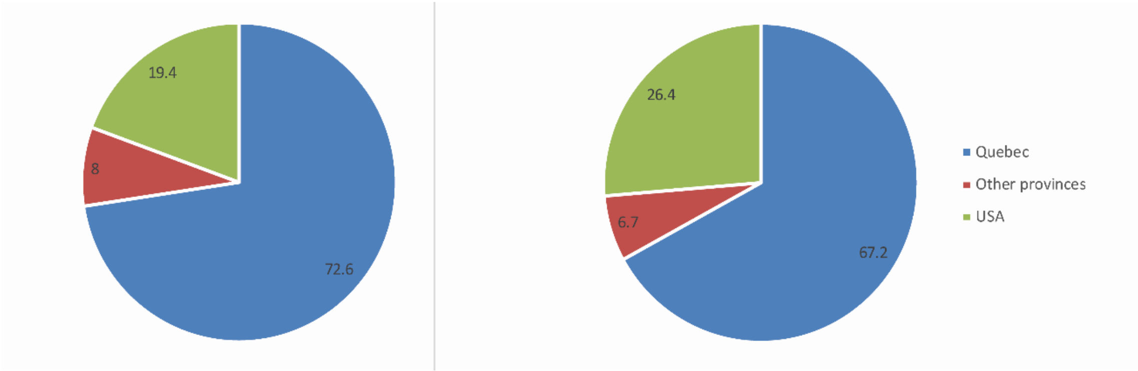

Figure 3 Change in production share in Quebec (blue), other Canadian provinces (orange) and USA (grey) from the year 1994 (left) to the year 2018 (right). Own elaboration based on data from "Statistique Acéricole 2018".

Production in other provinces is negligible in comparison to Quebecois production. Its share in total production is steadily around 6-8%.

After a significant increase in the producer price of maple syrup in 2009, the maple syrup industry experienced a period of relative stability. The Quebec maple syrup sector generated cash amounting to 305.3 million CAD in 2015. In 2017, a peak value of 444.6 million CAD, attributable to record production, was reached. Over the 2015-2018 period, value of production averaged at 382.95 million CAD, compared to 292.94 million CAD in the period 2010 -2014, an increase of almost 25%.

Looking closely at Quebecois production, from the regional division (Figure 4) most of the production is done in region Chaudière-Appalaches (region 2412 in the district map in the Figure 4). In 2016 farms in Chaudière-Appalaches region produced 42 million pounds of maple syrup counting almost 40% of total Quebecois production. In 2018, the production in the district increased by 38%, 58 million pounds was produced there, counting for 38% of total Quebecois production.

Figure 4 Regional division of Quebec. Source: StatCan, 2018.

In Table 2 there is shown increase in production in main districts of Quebec. All of them, except for Montérégie, undergo increase in production, from only 10% increase in Centre-du-Québec to massive 70% increase in Bas Saint-Laurent region. On the other hand, in Montérégie production decreased by 25%.

Table 2 Comparison of production in 2016 and in 2018 in different districts of Quebec. Source: "Statistique Acéricole 2018" and "Statistique Acéricoles 2016"

District	*Production in 2016 / kg*	*Production in 2018 / kg*
Bas Saint-Laurent/Gaspésie	6 346 853.9	10 810 596.8
Capitale nationale, Saguenay/Lac-Saint-Jean	1 675 346.2	2 041 028.2
Centre-du-Québec	6 318 385.1	6 967 672.3

Chaudière-Appalaches	18 964 460.4	26 496 768.6
Estrie	11 055 915.7	12 330 757.4
Lanaudière. Laval, Montréal	1 034 744.9	1 202 903.9
Laurentide, Outaouais, Abitibi-Témiscamingue	1 870 582.9	2 212 242.7
Mauricie	520 393.3	780 418.9
Montérégie	5 709 807.7	4 281 788.2
Total Quebec	53 496 490.0	67 124 176.9
Total Canada	72 981 335.1	58 787 169.0

3.3 Number of enterprises

As seen in Figure 5, in 2018, Quebec had more than 11 300 maple syrup producers grouped into 6 548 companies eligible for subsidiary payments. In comparison in 2016 there were almost 13 500 producers in 6 358 companies which is 3% decrease, however, as seen in the previous chapter the production was not affected by this decrease.

The regional distribution of Quebec maple syrup businesses has been stable for several years. Although this type of business is found in most regions of Quebec, half of them are concentrated in the Chaudière-Appalaches region and the number in in increases each year. The other major regions are Estrie (13%), Center-du-Québec (13%) and Bas-Saint-Laurent (9% with Gaspésie). In these regions it was observed an increase in number of farms at the expense of smaller producing region.

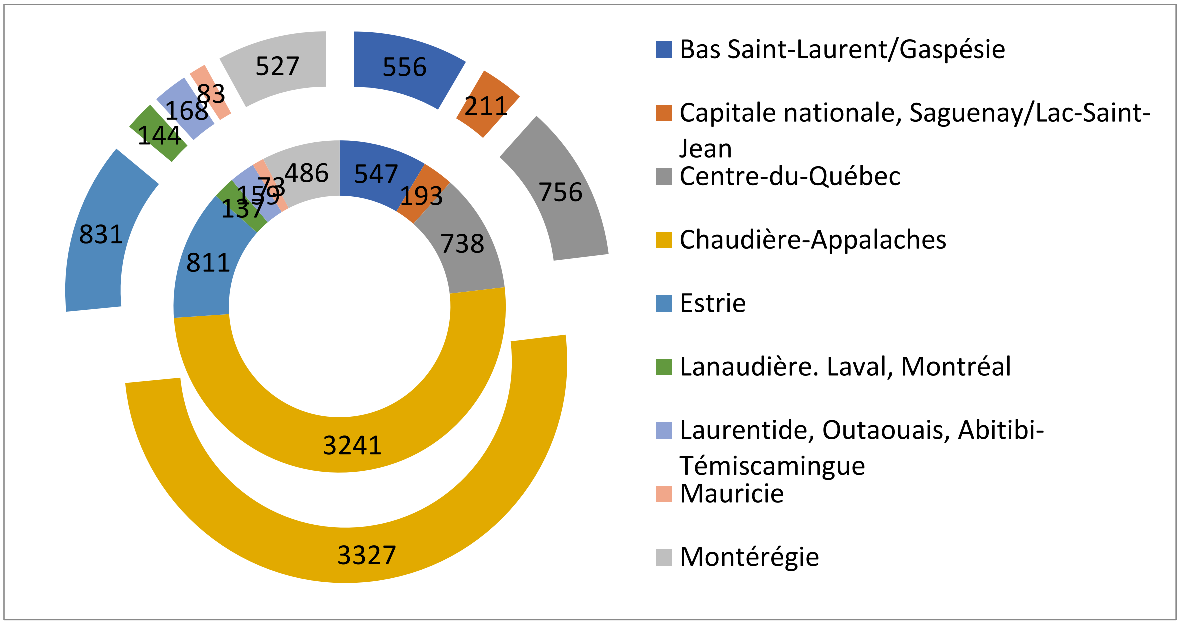

Figure 5 Number of producers in Quebec districts in 2016 (inner circle) and in 2018 (outer circle). Own elaboration based on data from "Statistique Acéricoles 2016" and "Statistique Acéricoles 2018".

3.4 Number of taps

During the cold spring days trees are tapped for the sugar maple to start flowing out of it. Number per one tree can differs, usually there are 1-4 taps per tree depending on the tree diameter. For trees with smaller diameters only 1 tap is required and with the increasing diameter the number of taps increases, trees with diameter 64 and up can require 2-4 taps. However, some research indicates that using fewer taps-per-tree can substantially increase yield of sap per tap. (*Tyminski*, "The Utility of Using Sugar Maple Tree-Ring Data to Reconstruct Maple Syrup Production in New York")

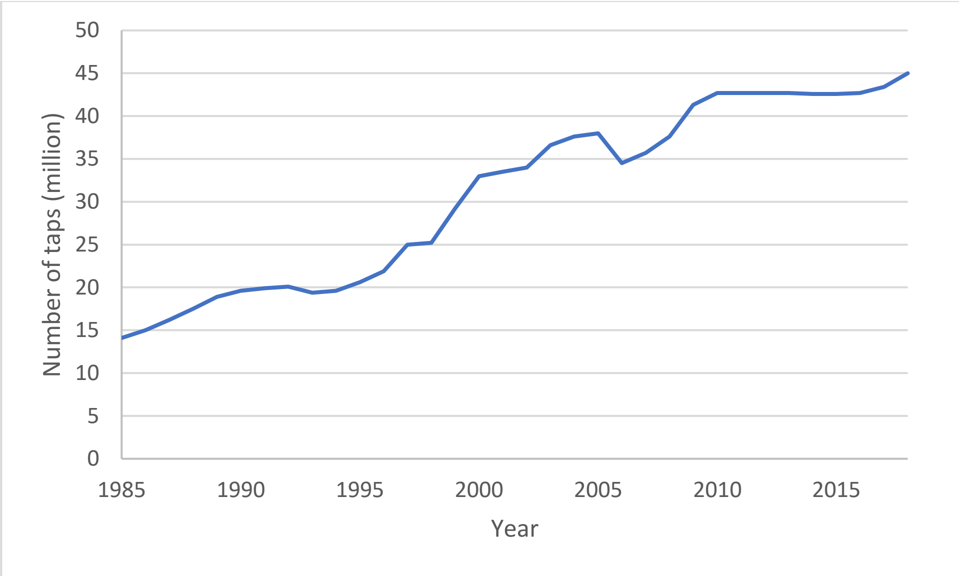

Figure 6 Total number of taps in Quebec since 1985 till 2018. Own elaboration based on data from "Statistique Acéricole 2018".

As seen in Figure 6 number of taps is steadily increasing since 1985. Difference between the year 1985 and 2018 is 319%. Overall number of taps in 2018 was whopping 45 million which is 3% increase from last year, and overall, from the period 2010-2017 where the number of taps was stagnating. Drop in year 2007 is in accordance with the overall small harvest and production in 2007 and 2008, however, since then business recovered as seen in the numbers.

Table 3 District division of taps and their average number per business in the year 2016 and 2018. Source: "Statistique Acéricoles 2018"

District	Number of Taps in 2016	Average number of taps in 2016	Number of Taps in 2018	Average number of taps in 2018
Bas Saint-Laurent/Gaspésie	8 057 687	14 731	9 153 926	16 464
Capitale nationale, Saguenay/Lac-Saint-Jean	1 273 076	6 596	1 439 535	6 822
Centre-du-Québec	4 024 447	5 453	4 103 541	5 428
Chaudière-Appalaches	16 817 660	5 189	17 777 589	5 433

Estrie	7 186 198	8 861	8 472 131	10 195
Lanaudière. Laval, Montréal	742 368	5 419	693 908	4 819
Laurentide, Outaouais, Abitibi-Témiscamingue	1 521 830	9 571	1 542 281	9 180
Mauricie	516 675	7 078	542 706	6 539
Montérégie	2 569 080	5 286	3 078 294	5 841
Total	42 790 021	6 702	46 803 911	7 148

The Bas-Saint-Laurent region has differentiated larger size businesses. In fact, the average number of taps in production per business in Bas-Saint-Laurent – Gaspésie was 14 731 in 2016 and 16 464 in 2018, twice as more than the provincial average, which is 6 702 taps per business (respectively 7 148 in 2018). In comparison, the average number of taps per business is 5 189 in the biggest production Chaudière-Appalaches region. (Economic Report 2015, p. 7, FPAQ)

Most of the taps are situated on private lands, 38 216 138 (84.4%) and the rest of trees are located on public property. In some districts the distribution is more equal, for example the Bas-Saint-Laurent region have the distribution almost 50/50 between private and public property (Figure 7). Out of 6 538 business in 2018, 6 031 were operating only on private lands. 266 businesses were harvesting on public lands, and the rest, 241, were producing on both public and private lands.

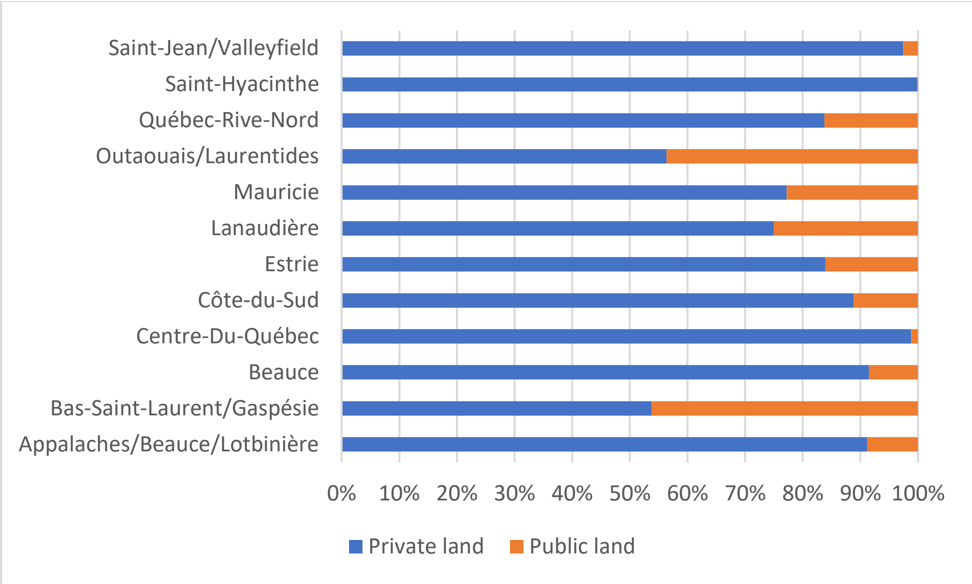

Figure 7 Percentage of taps growing on private (blue) and public land (orange) in different administrative regions of Quebec. Source: "Statistique Acéricoles 2018"

3.5 Biological production

Maple syrup industry follows the same trends in biological production as other agricultural businesses. Percentage share of enterprises (Figure 8) who produce biological maple increase from 6% to 13%, it doubled in the ten-year period from 2010-2018.

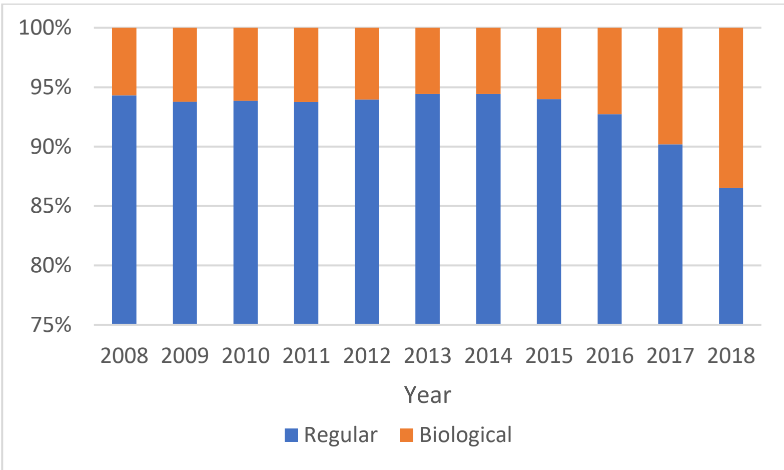

Figure 8 Percentage share of enterprises labelled as biological (orange) and regular (blue). Own elaboration based on data from "Statistique Acéricoles 2018".

And while it is only 13% of enterprises doing biological production it counts for 35% of all taps (Figure 9). Share of biological taps also increased since 2008 from 14% to 35%. In 2018, 16.6 million taps were labelled as biological.

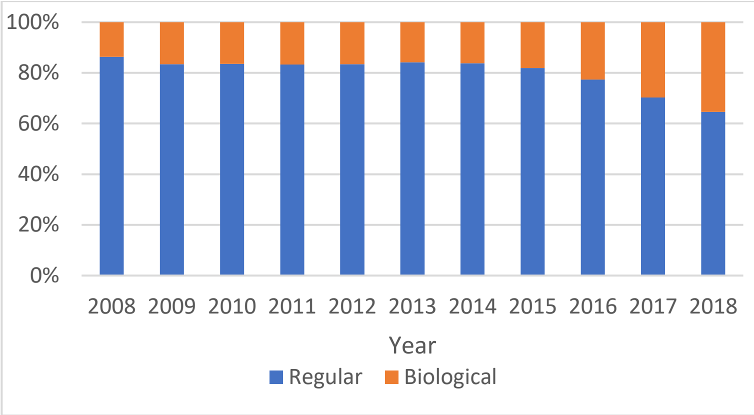

Figure 9 Percentage share of taps labelled as biological (orange) and regular (blue). Own elaboration based on data from "Statistique Acéricoles 2018".

3.6 Yield

Yield is greatly affected by temperature especially during the season (form February to April) and the biggest influence has the microclimate of the region. Looking at the number average yield in the years 2015-2018 was 1.36 kg per tap which is 23% more than in period 2010-2014 where it was only 1.1 kg per tap. And the overall change since the start of the data set is increase by 80% from only 0.8, not counting very low yield in 2018 (Figure 10).

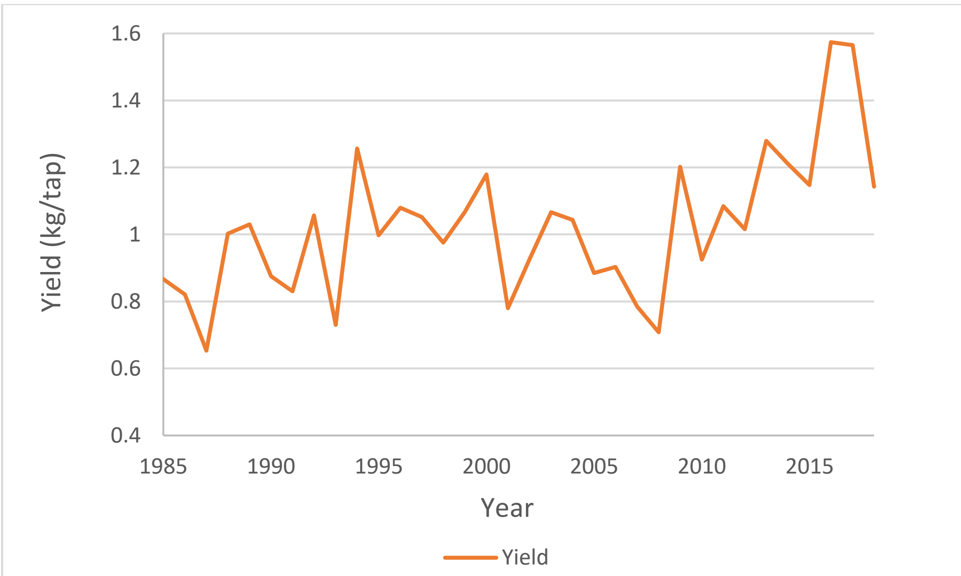

Figure 10 Evolution of yield (kg/tap) during the period 1985 to 2018. Own elaboration based on "Statistique Acéricoles 2018".

Some regions of Quebec have higher yield. Regional difference was not that apparent in the beginning. In 2008 yield was almost everywhere 0.75 kg per tap (Figure 11). However, in the next years some regions are getting better yield. But the overall trend is the same, when one region has lower yield most of them have it too. Only in the last couple years the difference appears to be bigger. The best yield in 2017 was in Gaspésie almost 12% higher than the provincial average. And only in Montréal and Montérégie, there were able to increase the yield from 2017 to 2018, where all the others flopped. Gaspésie region experienced the biggest decrease after the record year 2017. From the yield almost 1.8 kg per tap to only 0.69, almost 50% decrease.

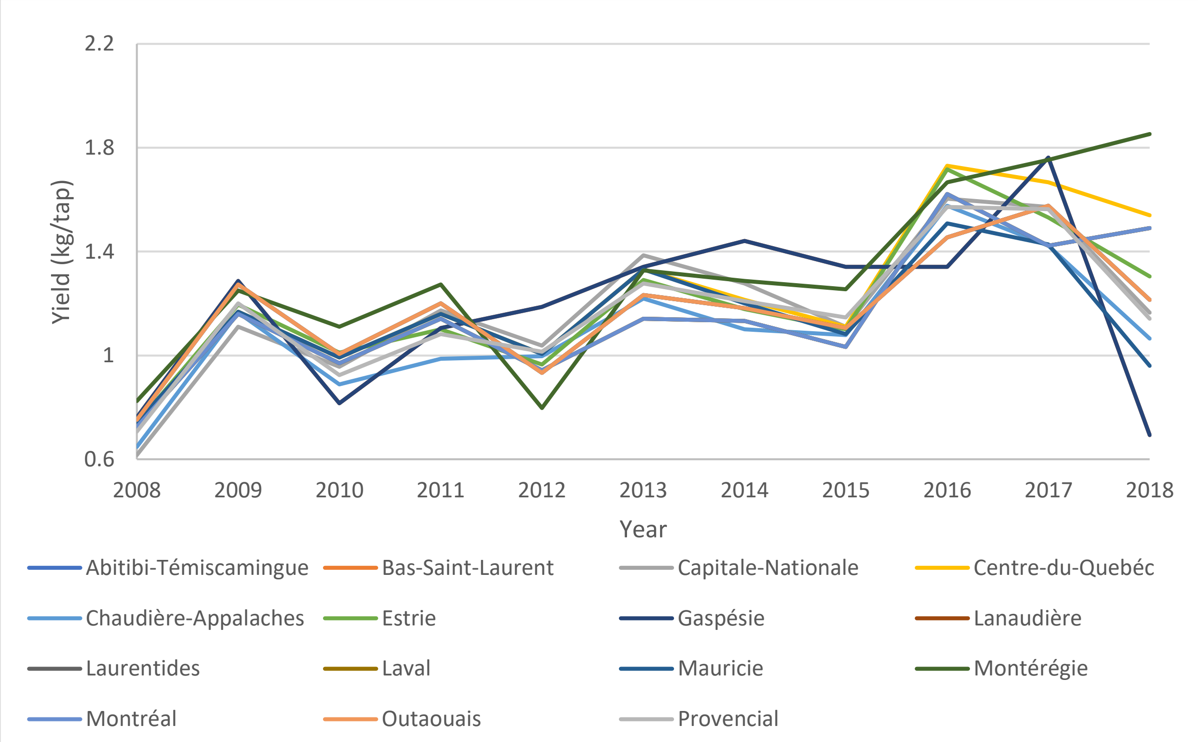

Figure 11 Yield in different administrative regions of Quebec and the provincial average from 2008 to 2018. Own elaboration based on data from "Statistique Acéricoles 2018".

3.6.1.1 Temperature

The influence of recent climate variability on crop productivity and quality has been the subject of considerable investigation. Despite the importance of the maple industry in North America, uncertainty exists about its future. Despite the large research on maple syrup production since the late-1800s focusing on the impact of climatic conditions, few studies have addressed this problem from a holistic approach integrating not only environmental factors but also biological factors to investigate and quantify the variables associated with the decline of maple sap production. Based on research done by Tyminski (*Tyminski*, "The Utility of Using Sugar Maple Tree-Ring Data to Reconstruct Maple Syrup Production in New York") it appears that production primary responds to microclimatic and local site variables and the macroclimatic influence parameters being secondary influence.

Temperature trends in the springtime are very volatile as seen in the Figure 12. The average max a minimum temperature fluctuates around the same value. However, any overall increase in temperature cannot be observed but this is due to short reference period. It also seems that cold year is followed by milder temperature next year.

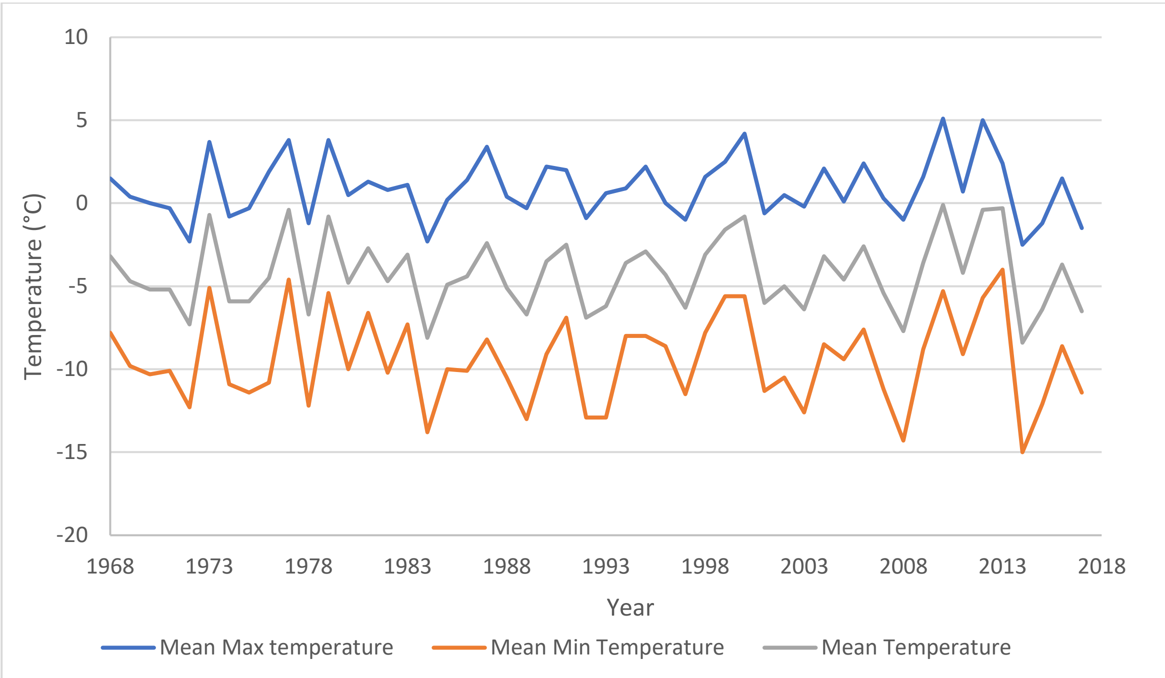

Figure 12 Evolution of mean maximum, mean minimum and mean temperature in springtime in Quebec. Own elaboration based on data from "Government of Canada".

3.7 Consumption

World consumption of maple syrup was estimated at 74.3 million kilograms in 2015, up 30% from 2011 and 43% over the past 10 years. Trends in consumption are seen in the Figure 13. Apart from the 2006-2010 period, which was stable due to the global economic performance and a supply constrained by the poor harvests of 2007 and 2008, consumption of maple syrup worldwide from 2011 to 2015 followed a constant increase of 7% on average annually. In Canada, maple syrup consumption per person reached 0.45 kg in 2015, an increase of 42% since 2011 and 80% since 2006.

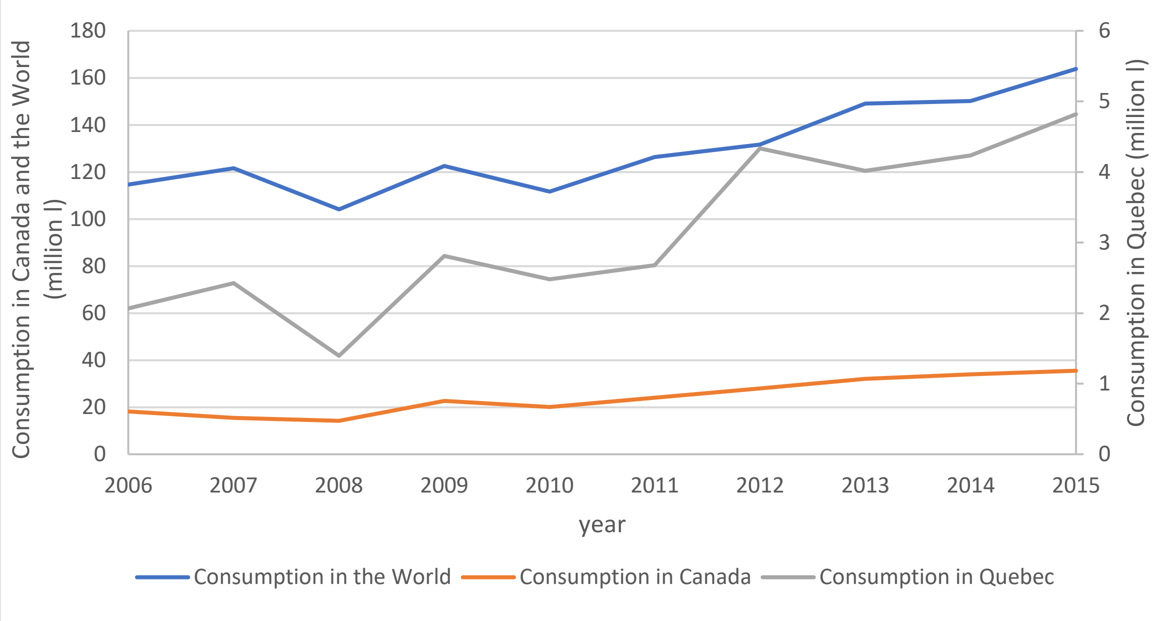

Figure 13 World, Canadian, and Quebecois consumption of maple syrup from 2006 to 2015. Own elaboration based on data from CANSTAT table 32-10-0054-01, and "Monographie de l'industrie acéricole du Québec 2011-2015".

In Quebec, maple syrup in a good position compared to other sweeteners as seen in the Figure 14. Retail sales data made in department stores (*Nielsen*, "Ventes au détail de produits alimentaires dans les grands magasins au Québec 2018") in Quebec observed that in 2018, the quantity of maple syrup sold in department stores amounted to 5.9 million pounds valued at 34.6 million CAD. And from 2012 to 2018, the market share of maple syrup among all sweet products sold in stores increased slightly, from 5% to 8%, to the detriment of refined sugar (from 82% to 77%) and table syrup (from 2.4% to 1.7%).

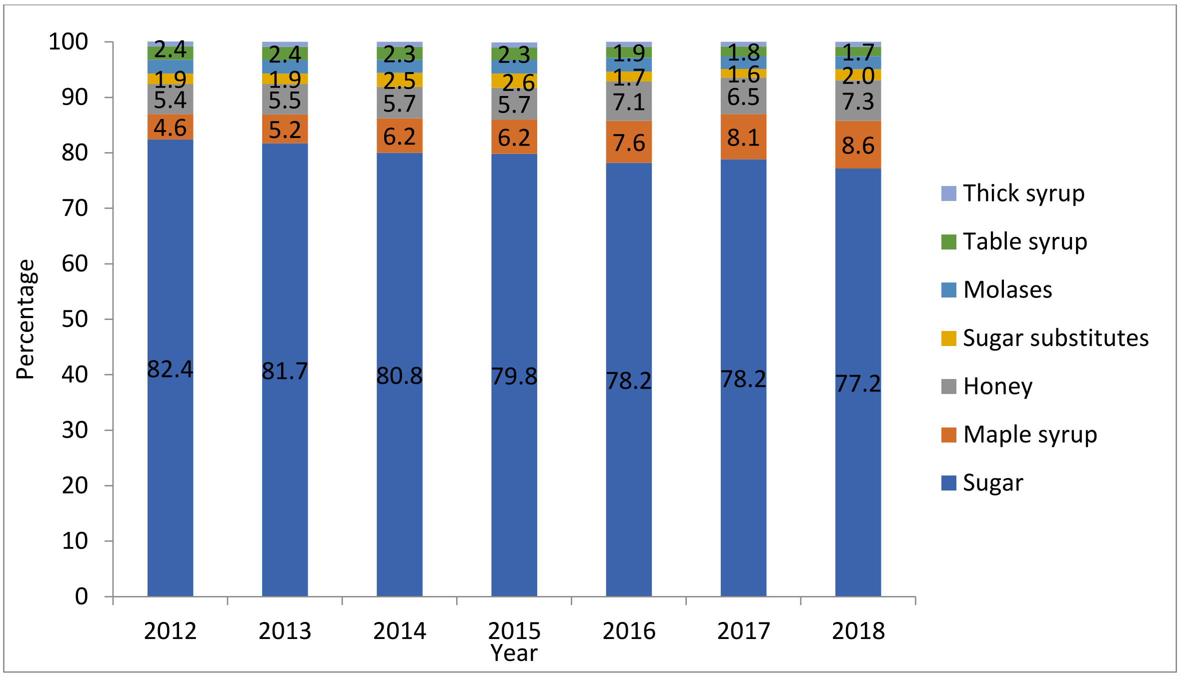

Figure 14 Share of sugar and sugar like compounds bought in Quebecois department store from 2012 to 2018. Own elaboration based on data from *Nielsen*, "Ventes au détail de produits alimentaires dans les grands magasins au Québec 2018".

These findings clearly show that maple syrup in Quebec is positioned advantageously compared to other sweetening products, despite a higher selling price. ("Monographie de l'industrie acéricole du Québec 2011-2015")

3.8 Price

Investigating at the consumer price of maple syrup in Quebec (Figure 15), we can see that over the period 2008-2010 price went up by 20%, which is higher than any other sugary condiment. Reason for that was poor harvest in previous years (2007 and 2008) and relatively small supply to high demand. The increase had a lasting effect as the price level for maple syrup remained higher, however since then, the price is relatively stable. Since 2008 there was only 6% increase in price where in the case of honey the price went up by 37.4%. Price of sugar on the other hand decreased in the period.

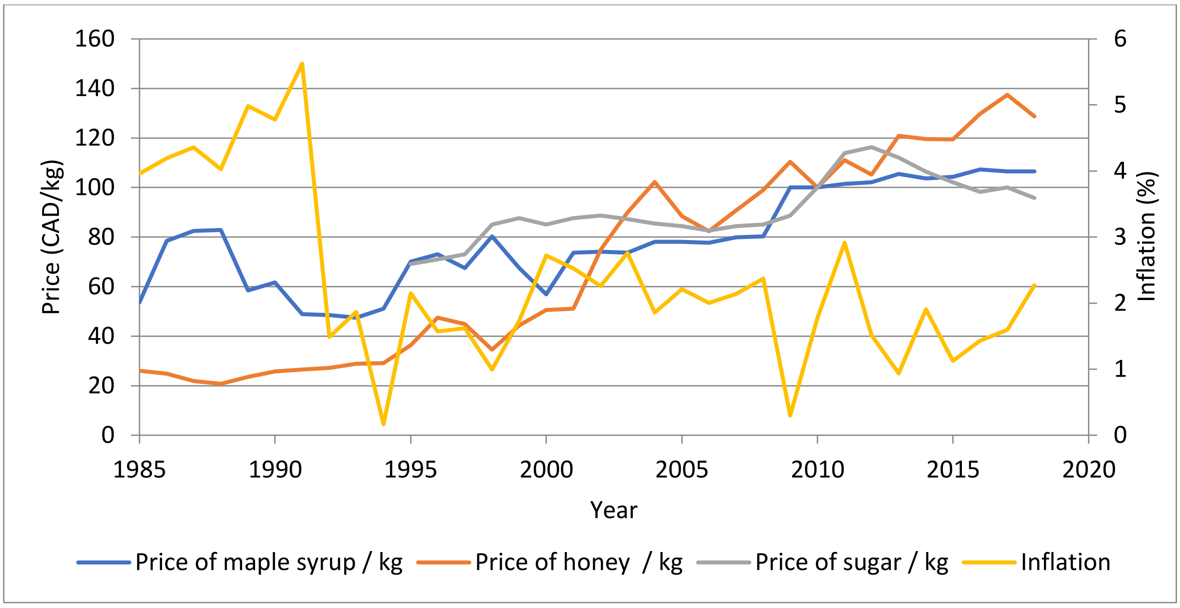

Figure 15 Evolution of prices and inflation of selected sugar like products (price in 2010=100% and inflation 2010=100). Own elaboration based on data from "Statistique Canada" table 32-10-0353-01, "Statistique Canada" table 18-10-0004-01, "Monographie de l'industrie acéricole du Québec 2011-2015", "The World Bank", and Nielsen, "Ventes au détail de produits alimentaires dans les grands magasins au Québec 2018".

There are differences between the price and the colour grading of the syrup. The highest quality and in the result the most expensive are the Golden syrup. However, the differences in prices are similar in recent years, 2.9 CAD per kg. Only slightly cheaper is the colour variant very dark. The last category, transformation category is industrial grade, it is not sold in stores and it is sold at lower price.

Table 4 Prices of different colour grades of maple syrup in Quebec from 2005 to 2018 in CAD per kg. Source: "Statistique Acéricole 2018"

	Golden	**Amber**	**Dark**	**Very Dark**	**Transformation category**
2005	2.35	2.30	2.20	1.75	1.00
2006	2.25	2.25	2.20	1.80	1.65
2007	2.25	2.25	2.22	2.00	1.70
2008	2.29	2.29	2.26	2.03	1.73
2009	2.75	2.75	2.73	2.65	2.20

2010	2.77	2.70	2.75	2.67	2.21
2011	2.81	2.81	2.79	2.71	2.22
2012	2.89	2.89	2.87	2.79	2.22
2013	2.92	2.92	2.92	2.82	1.80
2014	2.92	2.92	2.92	2.82	1.80
2015	2.92	2.92	2.92	2.82	1.80
2016	2.92	2.95	2.93	2.82	1.80
2017	2.95	2.94	2.85	2.55	1.80
2018	2.92	2.94	2.85	2.55	1.80

3.9 Distribution

In 2018. maple syrup production in Quebec was estimated at more than 110 million pounds for a value exceeding 344 million CAD. There are three marketing channels for maple products. The most important channel (90.2%) is that of the sales agency. which includes the bulk sales (93.6 million pounds) and sales from agency inventories (20.1 million pounds).

Other channels are not going through the agency. in 2018 this way 12.4 million pounds (9.8%) was sold. There are two possible ways of retail marketing without agency. Retail marketing in small containers through intermediaries constitutes, a less important sales channel with 5.04 million pounds (4%). Sales done this way must be registered with the Federation of Quebec Maple Syrup Producers (FPAQ) under the Joint Plan. Finally. maple syrup producers can sell their products in small containers directly to the consumer. Estimated volumes for this sales channel are 6.3 million pounds (5%) with a value of around 15.8 million CAD. (*Nielsen*, "Ventes au détail de produits alimentaires dans les grands magasins au Québec 2018")

About sixty buyers are authorized by the FPAQ to source Quebec syrup in bulk (barrels and other large containers). Many are producers who buy quantities of maple syrup to package bottled small containers for the retail market or for processing into by-products. Among these sixty authorized buyers. there are also industrial buyers who generally have significant storage capacity. They serve a large share of the Canadian and export markets.

In the 1990s. the Quebec maple industry experienced significant market growth which raised it to the rank of world leader. far ahead of its main competitors. This growth occurred in parallel with the structuring of the sector around a collective marketing system and mechanisms aimed at balancing supply and demand.

3.10 Governmental aid

Principle program for maple producers by Financière agricole du Quebec (FADQ) is based on crop insurance (both federal and provincial). individual type program (collective for some productions). These programs substantially limit the financial losses due to yield reductions due to climatic conditions and uncontrollable natural phenomena.

La Financière agricole du Québec makes available the funds necessary to finance the advance to the tap and the interest is being covered by the APP (Advance Payment Program). To date, the advance to the tap is 1.25 CAD per tap up to a maximum of 100 000 CAD per business. Maple syrup producers can also benefit from various government support programs. namely AgriStability, AgriInvestment, Agri-Quebec and, since 2013, Agri-Quebec Plus. ("Résumé de protection. Assurance récolte individuelle (ASREC)"). In 2017 9.3% from the AgriInvestment program went to the maple production (Figure 9). For the financial year 2018/2019 15.8% of claims out of the insurance program were for the maple industry.

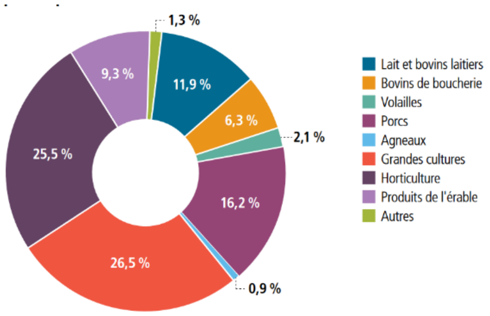

Figure 16 Distribution of government contributions from the AgriInvest program for the 2017 participation year. Blue is milk and dairy cattle, orange is meat cattle green is poultry, dark purple is pigs. light blue is lamb, red is field crops, deep purple is horticulture, and light purple are maple products. Source: "Rapport Annuel 2018-2019 – La Financière Agricole Du Québec"

In 2018-2019. a new protection covering the winter frost of fall cereals was developed by FADQ and will be available from 2019. These crops are especially important because they help to reduce the use of herbicides and they prevent wind erosion of the soil. In addition to that, maple syrup producers can count on increased protection covering up to 85% of their losses. The 2018 harvest season was particularly trying for maple syrup producers, particularly those in the Bas-Saint-Laurent and Chaudière-Appalaches regions. Producers in these two regions were able to count on crop insurance benefits of 12.5 million CAD and 2.3 million CAD, respectively. In addition, almost 70% of these benefits were paid as of June. ("Rapport Annuel 2018-2019 – La Financière Agricole Du Québec")

3.11 Future research priorities in the maple syrup sector

The development of medically functional product is a long-term priority in maple syrup production. Research is continuing in this area and the first scientific results are already available. In 2016, preliminary results suggested that extracts of pure maple syrup had been found to be promising for preventing neurodegenerative diseases, including Alzheimer's disease. According to another study, maple has a significantly favourable effect on blood sugar control and insulin resistance compared to white sugar. Concentrated maple sap also has great potential to produce probiotic beverages, as it can maintain a high level of viable probiotics. These results are promising, but more research is still needed for commercial exploitation of these properties. ("Monographie de l'industrie acéricole du Québec 2011-2015")

3.12 Trade

There was an enormous increase in Quebec exports of maple products. During the 2011-2015 period, the value of international exports of Quebec maple products increased from 231 to 339 million CAD, which corresponds to an average annual growth of 8.0%. This increase is due to both price and volume growth. In fact, the quantities exported increased from 70.0 to 87.7 million pounds for an average annual growth rate of 4.6%. In 2015, as in previous years, the main destination for maple products was the United States with 63% of the value of Quebec exports. The rest of the exports went to the European Union (22%), Japan (7%). Australia (4%) or other countries (4%). During the 2011-2015 period, only exports from Quebec to Japan decreased. In contrast, the European Union’s share of Quebec’s exports has particularly increased. In terms of products, maple syrup represents 99% of total quantities exported from 2011 to 2015.

Export to other countries is constantly increasing (Figure 18). Since 2006, when 75% of exports were to USA, share of the total export decreased to 60%, even though absolute value of the export increased. This indicates higher demand for the maple syrup in other countries.

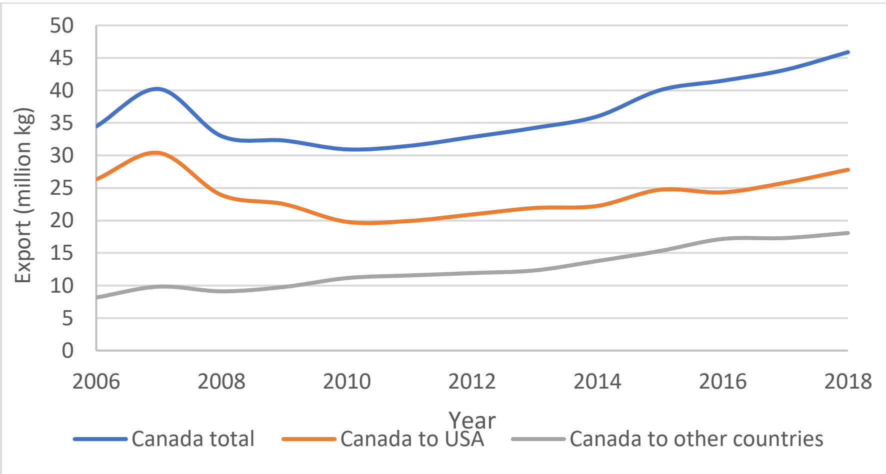

Figure 17 Volume of total Canadian export. export to USA and other countries between the years 2006-2018. Own elaboration based on the data from "Statistique Acéricole 2018".

4 Practical part

In the first stage the hypothesis was stated, and data were collected. Econometric agricultural model was determined based on two equations, where parameters were estimated for each of them by Two Stage Least Square method (TSLS). And calculation was done using software Gretl.

The declaration of all variables is shown in the Table 5 and the data is available in the tables in the annexes (Table 15) and statistical analysis of the data is also in Table 5

Table 5 Declaration of variables and its notation and unit.

Variable	Notation	Unit	Average	Median	Stand. dev	Min	Max
Consumption	y_{1t}	million l	1.31	1.09	0.52	0.62	2.12
Unit vector	x_{1t}	million l (1st equation); million kg (2nd equation)	1	1	1	1	1
Consumer price of Maple syrup	x_{2t}	CAD / kg	5.37	5.45	0.97	3.44	6.48
Consumer price of Honey	x_{3t}	CAD / kg	5.75	5.95	1.58	2.61	8.08

Income	x_{4t}	CAD/ year	39037.00	39000.00	1728.46	35600.00	42200.00
Consumption lagged	$y_{1(t-1)}$	million l	1.25	1.03	0.50	0.62	2.13
Production	y_{2t}	million kg	42.62	39.58	12.38	26.67	69.06
Yield	x_{5t}	kg / tap	1.07	1.07	0.23	0.71	1.57
Number of Farms	x_{6t}	No.	6883.50	6632.50	535.16	6385.00	7966.00
Number of Taps	x_{7t}	million taps	38.91	39.65	4.50	29.20	45.00
Max. temperature in March	x_{8t}	°C	1.03	0.60	2.15	-2.50	5.10
Min. temperature in March	x_{9t}	°C	-9.43	-9.25	3.12	-15.00	-4.00

First model was based on the simultaneous model. We will research consumption of maples syrup in Quebec and the production of maple syrup in Quebec (Equations 22 and 23 in the appendix). Consumption of maple syrup is influenced, apart from consumer price according to the law of demand also by consumer price of honey. Honey is a type of sweetener used as a healthier version of traditional refined sugar, in this thesis we set to determine the relation between them if they are complimentary or substitutional goods. Income as an influence of consumption is used because with more money people are more likely to buy more products and have more money for not necessary products. Also, consumption form last year influences consumption of next year, people are more likely to buy the same product multiple times.

For production function, consumption was used as an influence, because the more people consume the more must be produced, environmental factors are also an influence in production, because it is very sensitive to temperature, especially cold nights and hot days, so we chose max and min temperature in March. Also, with more enterprises concerning itself with production the more can be produced. Those enterprises also need the trees and taps for production, so we chose a number of taps as an exogenous variable, with more taps, more sap is produced and consequently more maple syrup is produced. Lastly yield per tap influences the production by making the process more effective and in effect produce more.

Table 6 Variables and predicted development according to the economic theory.

Variable		**Sign**	**Economic interpretation**
Endogenous variable	y_{1t}	+	Consumption must be positive according to the econ. theory.
	y_{2t}	+	Production must be positive according to the econ. theory.
Exogenous variable	x_{2t}	-	If the price of maple syrup increases the consumption according to the economic theory decreases. Because people buy less with higher prices based on the law of demand.
	x_{5t}	+	If the yield increases, the production increases. Increasing amount of yield is more effective and more environmentally friendly than increasing area of production.
	x_{7t}	+	If the number of taps increases, the production increases. There is more space for production.

However, this model proved not to be ideal (Table 18 in appendix). Model itself was significant but many parameters were not statistically significant and not in accordance with economic theory. For that we omitted certain variables. Form the first equation we omitted price of honey (x_{3t}), income (x_{4t}) and consumption from last year ($y_{1(t-1)}$). And from the second equation we omitted minimal temperature in March (x_{8t}) and maximal temperature in March (x_{9t}). All of them were omitted because either of their statistical insignificance in the first model or their disagreement with economic theory.

Further, in the final model we assume that the consumption of maple syrup (y_{1t}) is influenced by production of maple syrup (y_{2t}), and consumer price of maple syrup (x_{2t}). In the second equation we assume that production of maple syrup (y_{2t}) is influenced by consumption of maple syrup (y_{1t}), yield per tap (x_{5t}), and number of taps (x_{7t}).

Predicted development of the economic model is in the Table 6. If the sign is positive, we expect positive relationship between endogenous and selected exogenous variable and when the sign is negative, we expect negative relationship.

4.1 Econometric model

For the construction of the econometric model we used the economic theory. The model is in the Equation 11 and 12. It includes the structural parameters γ of exogenous variables, β are parameters of endogenous variables, and error term ε_t. We used the linear model for this assumption, and we employed Two-Stage Least Square Method in the software Gretl for the estimation of the parameters. Data based for the analysis are in the appendix. In the software we used data in the tables and as a time series. They have non-experimental character.

$$y_{1t} = \gamma_{11}x_{1t} + \beta_{12}y_{2t} + \gamma_{12}x_{2t} + \varepsilon_{1t} \tag{11}$$

$$y_{2t} = \gamma_{21}x_{1t} + \beta_{21}y_{1t} + \gamma_{25}x_{5t} + \gamma_{27}x_{7t} + \varepsilon_{2t} \tag{12}$$

In the first part of the analysis correlation matrix was studied so there are no two exogenous variables strongly correlated. Correlation matrix is in the Table 7. There is a multicollinearity occurring between variable x_{2t} and x_{7t}, however, the variable x_{7t} is not appearing in the 1st equation and the multicollinearity is occurring with variable x_{2t}, which is only appearing in the 1st equation so we do not have to modify this variable. Because there is no problem with the data, we can use them as it is for the estimation of the parameters.

Table 7 Correlation matrix after adjustment of selected exogenous variable.

x_{2t}	x_{5t}	x_{7t}	
1	0.544	0.941	x_{2t}
	1	0.498	x_{5t}
		1	x_{7t}

Before the model estimation itself, identification test must be done, so coefficient of the parameters of a structural form can be obtained from the estimated reduced form. For both equation number of exogenous variables *p* is 4, including the intercept. And number of endogenous variables *m* is 2. From the test (Table 8) we found out that the 1st equation is overidentified and 2nd equation is exactly identified, so we can use this model for the estimation and there is exactly one reduced form of the model for this structural form.

Table 8 Identification of the model.

	K	k	m-1	$k \geq m$-1	Decision
1st equation	2	2	1	2>1	Overidentify
2nd equation	3	1	1	1=1	Identify

The model itself was estimated based on 20 observations and Two-step least square method was employed by the Gretl software. Estimated parameters are in the Table 9.

According to the **economic verification** we interpret that if all the other parameters are zero (no price and no production) that the consumption would be -0.86 million l. Which means that it is a negative consumption when there is no production and only after certain level of production there is some consumption. This shows us that the maple syrup is a luxury item and will be consume after other needs are satisfied. Also, not all of the maple production is used and sold in stores which is part of the original data.

Table 9 Model of consumption and production of maple syrup in Quebec. Asterixis in the last column show the statistical verification of the model where: parameter is statistically significant on *α = 0.1; ** α = 0.05; * α = 0.01.**

Model 1: TSLS, using observations 1999-2018 (T = 20)				
Endogenous variable: y_{1t}				
	Coefficient	**Standard deviation**	**p-value**	
x_{1t}	-0.86	0.33	0.018	**
y_{2t}	0.02	0.007	0.011	**
x_{2t}	0.24	0.094	0.021	**
Mean dependent var.	1.311	S.D. dependent var.	0.521	
Sum squared resid.	1.070	S.E. of regression	0.251	
R-squared	0.793	Adjusted R-squared	0.768	
F (2, 17)	32.53	P-value	$1.56*10^{-6}$	

Model 2: TSLS, using observations 1999-2018 (T = 20)				
Endogenous variable y_{2t}				
	Coefficient	**Standard deviation**	**p-value**	
x_{1t}	-40.88	3.79	$9.30*10^{-9}$	***
y_{1t}	0.47	1.18	0.044	**
x_{5t}	39.47	1.86	$3.96*10^{-13}$	***
x_{7t}	1.04	0.11	$5.92*10^{-8}$	***
Mean dependent var.	42.62	S.D. dependent var.	12.38	
Sum squared resid.	26.57	S.E. of regression	1.29	
R-squared	0.991	Adjusted R-squared	0.989	
F (3,16)	579.55	P-value	$1.59*10^{-16}$	

Interpretation of parameter y_{2t} is that if production increases by 1 million kg the consumption increases 0.02 million l. Which is a logical conclusion; the more is produced the more can be consumed. But the influence on this parameter is quite low (explained in economic characterization 4.2.1) the units of both production and consumption are million, so change in 20 000 l against 1 million kg is smaller. Lastly parameter x_{2t} tells us that if price increases by 1 CAD/kg, the consumption increases by 0.24 million l. This goes against our assumption when we expected a decrease. However, this type of goods exists. It is called Veblen goods, which violate the law of demand. This theory states that people viewed higher utility in higher priced goods which is according to our results maple syrup in Quebec.

In the second equation the economic interpretation of the variables would be: if all the other parameters are zero, the production would be - 46.76 million kg. Which makes sense that if there are no taps there cannot be no yield and that means no production. Only after certain number of taps or yield there is a product, because as stated above it takes a lot of sap to create a litre of maple syrup and not all of the taps and all of the sap yield is used for maple syrup production.

Other parameters are interpreted as that if the yield increased by 1 kg/tap, the production would increase by 39.46 million kg. Which means with technological advances the production has a huge potential to increase. And with change to more intensive use of the farmland the production is going to significantly increase. Lastly, if the number of taps increased by 1 million, the production would increase by 1.04 million kg. That means the bigger the number of trees and taps the production has a potential to grow, which make sense. However, this analysis does not show how much tap per tree are there and how much it affects it, because the data is not available. Further studies must be done it this matter. The percentual influence and which factor has the biggest effect on each of the endogenous parameters will be assessed in further chapters.

Statistical verification tells us about the quality of the model. In the 1st equation the model explains 76.8% of the endogenous variable and in the 2nd equation 98.9% of variability in endogenous variable is explained by the model. Both numbers show quite good fit of the data, even though the 2nd equation has way better fit. This points out on relatively high explanatory power of the model.

P-value of the F-test for both equations ($1.54*10^{-6}$; $1.59*10^{-16}$) is smaller than significance level α = 0.05, so we reject the null hypothesis (H_0: model is not statistically significant; all parameters are jointly equal to 0) and the model is statistically significant (H_A: model is statistically significant; at least one parameter statistically significantly differs from 0). In the last column of the Table 9 there can be seen which parameters are statistically significant on different levels: * is statistically significant on α = 0.1; ** α = 0.05; *** α = 0.01. H_0: is that parameter $\gamma = 0$; H_A assumes that the parameter $\gamma \neq 0$. And because all the p-values are smaller than $\alpha = 0.05$ we reject the null hypothesis in all the cases and all the parameters estimated are statistically significant.

We also performed a statistical test for redundant identification, where H_0 is that all instrumental variables are valid. P-values were 0.892 for the 1st equation and 0.201 for the 2nd equation. That means that we cannot reject the null hypothesis on significance level α = 0.05 and all the instrumental variables are valid in the model.

Results of **econometric verification** are in the table 10. All the tests were done in the software Gretl on significance level $\alpha = 0.05$. First the normality of the residuals was tested with following hypothesis: H_0: Residuals have normal distribution; H_A: Residuals do not have normal distribution. To sum it up, in the model in both equations the residuals have normal distribution (p-value = 0.79; 0.19, respectively) and inferences are valid.

For the test of heteroscedasticity, we employed Pesaran-Taylor test with H_0: There is no heteroscedasticity and H_A: Model is heteroscedastic. We cannot reject in both cases the null hypothesis (p-value = 0.2; 0.84, respectively), so the residuals are homoscedastic. It means that are equally distributed or put it differently: variance of residual is constant and finite.

Last test was Godfrey test for autocorrelation of the 4th order where H_0: There is no autocorrelation and H_A: there is autocorrelation occurring. P-values (0.27; 0.51, respectively) were higher than significance level, we cannot reject the null hypothesis and there is no autocorrelation of the 4th order occurring in the model. That means that the residuals are not correlated.

Based on all those tests, we can assess the quality of the model and goodness for application. And our results show that model is complete, we did not have extra variables, or we did not omit important variables in the model. Also based on the statistical and economic verification done previously, model is of good quality and can be used for application.

Table 10 Econometric verification of the model.

1st equation			2nd equation		
Test	**Test statistics**		**Test**	**Test statistics**	
Residual distribution	$\chi^2 = 0.79$	p-value = 0.79	Residual distribution	$\chi^2 = 8.09$	p-value = 0.017
H_0: Residuals have normal distribution					
We cannot reject H_0, residuals are normally distributed			We cannot reject H_0, residuals are normally distributed		
Pesaran-Taylor test	HET 1 = 1.29	p-value = 0.20	Pesaran-Taylor test	HET 1 = 0.20	p-value = 0.84
H_0: There is no heteroscedasticity					
We cannot reject H_0, there is no heteroscedasticity			We cannot reject H_0, there is no heteroscedasticity		
Godfrey test for autocorrelation	LMF = 1.45	p-value = 0.27	Godfrey test for autocorrelation	LMF = 0.86	p-value = 0.51
H_0: There is no autocorrelation					
We cannot reject H_0, there is no autocorrelation of 4^{th} order			We cannot reject H_0, there is no autocorrelation of 4^{th} order		

4.2 Model application

Equations 13 and 14 sums up the results from the model construction and show us the final structural form of the model, where the coefficients of all the predetermined variables can be seen on both endogenous variables. Evolution of the selected parameters were assessed in each individual chapter in literature review. In the 20 years, the price of maple syrup increases by 58% and even thought the increase of price, the consumption of maple syrup in the same period increased by 130%. And production of maple syrup in the same time increased by 72%. Effectivity of the production can be asses by yield, but only small change was observed in yield (7% change) but the number of taps doubled in the same time. Further, the production is not more effective, however, this is effect of biological capability of the maple tree not the farmers infectivity.

Economic, statistical and econometric verifications assess how well the model is suitable for forecasting, structural analysis, and other applications. As stated, before there were some inconsistencies with the model especially in economic verification, however they can be explained. The most important, the model and estimated parameters are statistically significant, there is no autocorrelation, heteroscedasticity and residuals are normally distributed. Quality of the model is also assessed by the R^2, which in both cases is very high, models have good explanatory power. This model will be used for elaboration of the forecast for 3-year period. For the forecast the reduced form of the model will be calculated.

$$y_{1t} = -0.86 + 0.02y_{2t} + 0.24x_{2t} + \varepsilon_{1t} \tag{13}$$

$$y_{2t} = -40.88 + 0.47y_{1t} + 39.47x_{5t} + 1.04x_{7t} + \varepsilon_{2t} \tag{14}$$

4.2.1 Economical characteristic of production and consumption functions

For characterisation of consumption and production function we use different tools that describe how the function changes with each of the factors. The main one that we are going to use are explained in the methodology. It is average production/consumption, marginal production/consumption, elasticity of production, marginal rate of substitution. For this calculation Equations 6, 7, 8 and 9 were used. MRS for the 2nd equation were calculated for each pair of parameters in the Table 11. The parameter substituted is in the bracket.

Average production/consumption is the amount of factor which is used for 1 unit of production/consumption. For consumption of 1 million litres of maple syrup 0.27 CAD/kg is used and 0.03 million kg of production. It is interesting to compare it because of the different units. But it does not mean that million litres of maple syrup costs 0.27 CAD, it means that to increase the production by 1 million litres the price would have to increase on average by 0.27 CAD/kg.

For production of 1 million kg of maple syrup 45.5 kg/tap is used and 1.15 million taps. We need big yield and huge number of taps for production of 1 million kg on average to increase the production.

Marginal production/consumption tells us the ratio between change of function and change of a factor. Value of MP/MC is little bit lower for all parameters than AP/AC. And it tells us that ratio of change in variables is higher with price of maple syrup in the 1st equation, so to increase the consumption it is better to increase price rather than production. And in the 2nd equation marginal production change the most with the yield, it has higher slope. It is better to increase yield by one unit rather than consumption or number of taps. So, it is better to intensify the production rather than increase the area. However, these results must be taken with the grain of salt because the units are different. For better interpretation elasticity indexes are used.

To assess which variable has the biggest impact on the variable Elasticity was used. For the 1st equation it was determined that price has higher impact on consumption than production. Which makes sense, that partially availability of the product influences the purchase but the main driving force for a purchase is the price. On the other hand, the biggest influence on production has number of taps rather than yield. However, the numbers are very similar. That means intensification or increasing area of production have the same effect on production percentage wise.

It would be more interesting to calculate MRS for some substitute or complimentary product; however, it was removed from the model for its insignificance. Further, it is interesting to see how in the same rate of consumption the price is substituted for production. For the same consumption, production must be 12 times higher than price (technically 12 million times higher because of the difference in the units). From this the producers can partially asses the future price.

The most interesting in the production function is how is yield substituted by number of taps. If we substitute 1 kg/tap of yield by 0.26 million taps we get the same production.

We get the result that it is more convenient the other way substitute 1 million taps by yield 41.04 kg/tap. So, again the result that it is better to intensify the production rather than increase the number of taps and consequentially area of production.

Table 11 Characterization of the equation of the model.

1st equation parameters	**value**	**2nd equation parameters**	**value**
ACx_2	0.27	APx_5	45.5
ACy_2	0.03	APx_7	1.15
MCx_2	0.24	APy_1	24.8
MCy_2	0.02	MPx_5	39.47
Ex_2	0.88%	MPx_7	1.04
Ey_2	0.61%	MPy_1	0.47
$MRSx_2$	0.0048	Ex_5	0.86%
$MRSy_2$	12	Ex_7	0.89%
		Ey_1	0.02%
		$MRSy_1$ (x_5)	83.98
		$MRSy_1$ (x_7)	2.21
		$MRSx_5$ (x_7)	0.26
		$MRSx_5$ (y_1)	0.012
		$MRSx_7$ (x_5)	41.04
		$MRSx_7$ (y_1)	0.49

4.2.2 Reduced form of the model

For the application of the model it is necessary to create a reduced form of the model where the endogenous variables are only explained by the exogenous variables. For that matrixes B and Γ (Equation 15 and 16) are constructed from the structural form of the model (Equation 13 and 14), where all the variables are put equal to the error therm. B matrix contains coefficients of the endogenous variables 1st row is the 1st equation, 2nd row is 2nd equation. First column is the variable y_{1t}, second column is variable y_{2t}. In the Γ matrix 1st row is the 1st equation, 2nd row is 2nd equation and the parameters in the columns are in the order x_{1t}, x_{2t}, x_{5t}, x_{7t}.

$$\mathrm{B} = \begin{vmatrix} 1 & -0.02 \\ -0.47 & 1 \end{vmatrix} \tag{15}$$

$$\Gamma = \begin{vmatrix} 0.86 & -0.24 & 0 & 0 \\ 40.88 & 0 & -39{,}47 & -1{,}04 \end{vmatrix} \tag{16}$$

Matrixes B and Γ are then used for the calculation of matrix M and from that we get the final reduced form of the model and it shows the complex relation – direct and indirect - between endogenous and predetermined variables. Equation 17 shows how to calculate matrix M and matrix M itself is in the Equation 18. Order of the parameters are the same as in the matrix Γ; e.g. x_{1t}, x_{2t}, x_{5t}, x_{7t} and y_{1t} first row, y_{2t} second row.

$$M = -\mathrm{B}^{-1} \times \Gamma \tag{17}$$

$$M = \begin{vmatrix} -1.69 & 0.24 & 0.79 & 0.02 \\ -41.68 & 0.11 & 39.85 & 1.05 \end{vmatrix} \tag{18}$$

And because we know the order and the coefficients of the parameters, we get the reduced form of the model which is in following Equations 19 and 20. Error term v_{1t}, v_{2t} are in a relation to the original error terms ε_{1t}, ε_{2t} of the structural form.

$$y_{1t} = -1.69 + 0.27x_{2t} + 0.79x_{5t} + 0.02x_{7t} + v_{1t} \tag{19}$$

$$y_{2t} = -41.8 + 0.11x_{2t} + 39.85x_{5t} + 1.04x_{7t} + v_{2t} \tag{20}$$

Interpreting the reduced form: in the first equation, variable y_{1t} is directly influenced by x_{2t} because it is both in structural and reduced form, and indirectly by x_{5t}, x_{7t}. And endogenous variable y_{2t} is directly influenced by x_{5t}, x_{7t}, and indirectly by x_{2t}.

Again, we can **economically interpret** the results. If the price of maple syrup changes by 1 CAD/kg the consumption increases by 0.27 million l. Which are the same results as in the structural form and it again confirm that maple syrup is Veblen good and its consumption increases with increasing price. Surprisingly high coefficient has yield for consumption function. That tells us that if yield increases by 1 kg/tap the consumption increases by 0.79 million l. Last variable is number of taps, which tells us that if we increase the number of taps by 1 million the consumption increases by 0.02 million kg. This is quite a small change with a huge increase of taps.

Interpreting production function we found out that if we increase the price by 1 CAD/kg. This is because producers can sell it for higher prices and make higher profit from it. If the yield increases by 1 kg/tap the production increases by 39.85 million kg. This is again a huge increase in number same as in structural form. This shows us that the intensification of the production is the best way how to improve it. Lastly, if the number of taps increases by 1 million, the production increases by 1.04 million kg. This change is not that big, taking into the account the losses and other maple product made from taps' sap.

For comparison of influence it is better to use elasticity. It was calculated according to the Equation 8. The results are summarized in the Table 12.

Table 12 Elasticities calculated from the reduced from of the model

	1st equation	**2nd equation**
Ex_2	0.939	0.01
Ex_5	0.488	0.88
Ex_7	0.486	0.02

Surprisingly the yield and number of taps have the same measurable influence on consumption, also it is not that low only, 50% lower than influence of price. This shows us how volatile the consumption really is and how the factors that affect yield and number of taps, like environment can negatively affect the consumption.

Another surprise was decrease in elasticity of number of taps for production. In the structural form both elasticities of taps and yield were very high and basically the same. Here elasticity for number of taps is very low and elasticity of yield is very high. Again, this confirm what has already been confirmed that it is the best to concentrate on improving the yield and intensify the production than increasing number of taps. Elasticity of price on production is very low and it has basically no effect.

4.2.3 Ex-post and Ex-ante prognosis

We already asses that the model is suitable for forecasting because all the parameters are statistically significant, there is no autocorrelation, no heteroscedasticity and residuals are normally distributed. Another way how to assess that is to do ex-post analysis, where we compare the real measured values with the predicted values.

In the Table 13, there are the real and estimated values of the model and standard deviation for both endogenous variables. For the year 2018, the estimated value for consumption was 1.851 million litres which is 11.7% different from the real value 2.097 million litres. Conducting the calculation for the rest of the variables we found out that the mean percentage error (MPE) for the 1st equation is 9.31% which is in the 90% interval. The estimations for the 2nd equations were better. For the year 2018 the estimated value only differed by 4.3% and if average by the all observations (MPE) the values are off only by 1.45% which is in the 95% interval. We can use the model for further prognosis.

Table 13 Ex-post prognosis

Year	Real value y_{1t}	Predicted value $\hat{y}_{1t}$	Stand. dev. y_{1t}	Real value y_{2t}	Predicted value $\hat{y}_{2t}$	Stand. dev. Y_{2t}
1999	0.879	0.837	0.029	31.16	31.49	0.235
2000	0.956	0.830	0.089	38.92	39.90	0.691
2001	0.666	0.799	0.094	28.30	24.62	2.605
2002	0.819	0.929	0.078	32.48	30.93	1.096
2003	0.973	1.086	0.080	39.01	39.23	0.157
2004	0.980	1.160	0.128	39.19	39.40	0.146
2005	0.986	1.043	0.040	33.57	33.49	0.056

2006	0.916	0.981	0.046	31.12	30.57	0.388
2007	1.077	0.948	0.092	27.99	27.13	0.606
2008	0.621	0.931	0.219	26.67	26.04	0.450
2009	1.255	1.717	0.326	49.62	49.72	0.066
2010	1.110	1.526	0.294	39.96	40.15	0.131
2011	1.201	1.675	0.335	46.22	46.48	0.185
2012	1.935	1.633	0.213	43.59	43.78	0.132
2013	1.784	1.895	0.078	54.57	54.28	0.201
2014	1.875	1.809	0.046	51.62	51.45	0.116
2015	2.126	1.771	0.251	48.63	48.93	0.215
2016	1.974	2.157	0.130	67.22	66.04	0.834
2017	1.992	2.152	0.114	69.06	66.41	1.877
2018	2.097	1.851	0.174	53.57	51.26	1.632
MPE	-9.31%			1.45%		

Different way how to assess this suitability is by Normalized standardized variation (N_{it}), which is calculated as a share of difference between theoretical and real value of endogenous variable and its standard deviation, this division is then squared and summed through all observations as seen in Equation 21. In the equation the N_i is normalized standard deviation for *i*-th endogenous variable and *n* number of observations.

$$N_i = \sqrt{\frac{\sum_{i=1} N_{it}^2}{n}} \tag{21}$$

Normalized standardized deviation are in the span <0,1> and the closer the value is to 0, the better the utility for forecasting is. Calculations for each year are in Table 14. For the 1st equation N_1= 0.2 and for the 2nd equation N_2= 0.08. Values limiting to zero shows that the model can be used for the prognosis, where both equations have low values, especially 2nd equation has great potential for the prognosis.

Table 14 Normalized standardized deviation

y_{1t}	$\hat{y}_{1t}$	N_{1t}	y_{2t}	$\hat{y}_{2t}$	N_{2t}
0.879	0.837	0.262	31.16	31.49	-0.066
0.956	0.830	0.408	38.92	39.90	-0.123
0.666	0.799	-0.210	28.30	24.62	0.261
0.819	0.929	-0.086	32.48	30.93	0.088
0.973	1.086	-0.030	39.01	39.23	-0.057
0.980	1.160	-0.147	39.19	39.40	-0.054
0.986	1.043	0.081	33.57	33.49	-0.036
0.916	0.981	0.051	31.12	30.57	0.005
1.077	0.948	0.419	27.99	27.13	0.021
0.621	0.931	-0.416	26.67	26.04	0.018
1.255	1.717	-0.628	49.62	49.72	-0.039
1.110	1.526	-0,535	39.96	40.15	-0.049
1.201	1.675	-0.642	46.22	46.48	-0.053
1.935	1.633	0.847	43.59	43.78	-0.077
1.784	1.895	0.046	54.57	54.28	-0.023
1.875	1.809	0.383	51.62	51.45	-0.039
2.126	1.771	0.959	48.63	48.93	-0.088
1.974	2.157	-0.126	67.22	66.04	0.052
1.992	2.152	-0.143	69.06	66.41	0.170
2.097	1.851	0.654	53.57	51.26	0.125

Prognosis itself will be done in the horizon of three years 2019-2021. First, the predicted values of predetermined variables will be calculated based on the trend functions. Values of the predetermined variables in next three years are in the Table 15. They were obtained from MS Excel using Forecasting linear function.

Table 15 Prognosis of the predetermined variables obtained from Excel function FORECAST.linear

year	x_{2t}	x_{5t}	x_{7t}
2019	7.00	1.31	46
2020	7.18	1.35	47
2021	7.27	1.41	47

The trend functions are depicted in the Figure 18. For all the parameters the slope of the function is positive, so increase is expected, with the biggest slope having number of taps. Price of maple syrup, based on its trend function, will be 7.27 CAD/kg which is 4% more than in 2018. For yield it is expected to see an increase by 7.6% which is the highest out of those parameters if we take into consideration the units. In 2021 the yield will be 1.41 kg/tap. And lastly number of taps is expected to increase by 1 million, which is 2% change.

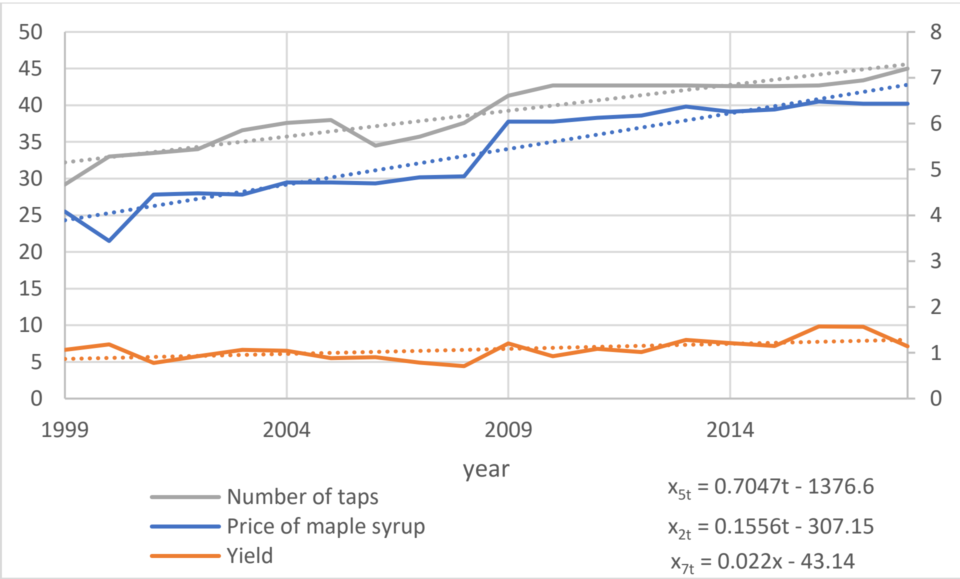

Figure 18 Linear trend function of the exogenous variables.

Second stage is determining the values of the endogenous variable based on the reduced form of the model in the Equations 19 and 20. Predicted values of the predetermined variables and graph of the trends are in the Table 16, respectively in Figure 19.

Table 16 Prognosed values of endogenous variable

year	y_{1t}	y_{2t}
2019	2.155	59,14
2020	2.255	61,80
2021	2,327	64,20

From the model, we predicted that both consumption and production of maple syrup in the period of next three years will increase by 7.9% for consumption, respectively 8% for production. The changes are relatively the same in percentual value. Both examined variables are going to growth almost at the same rate in this period. Comparing to the values of 2019 season, according to the University of Massachusetts maple production in last year was in all-time high, which corresponds to our forecast. (*Fritz*, "Maple sugaring expected to decline drastically by century´s end")

However, year 2020 is already very unexpected, with the Covid-19 outbreak during the maple season taping, the production can be severely affected. Also, the compulsive buying and hoarding during the pandemic the consumption can be unexpectedly affected.

It will be interesting to calculate this prognosis in next years to compare it to our prognosed values.

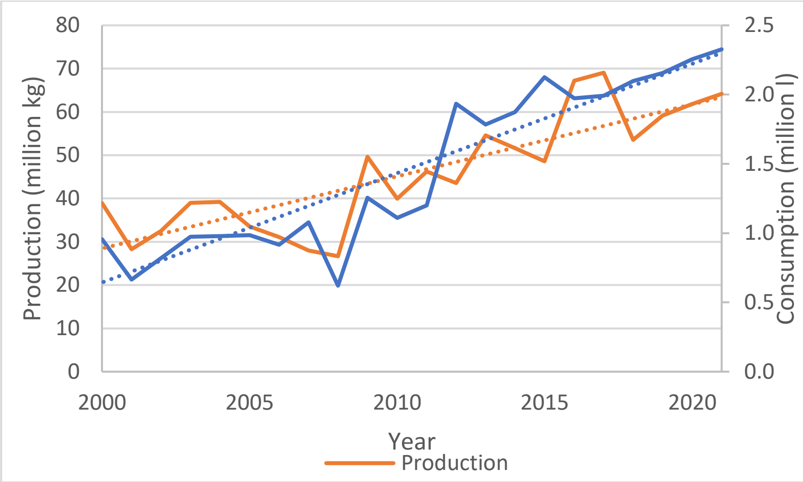

Figure 19 Prognosed values of endogenous variable

5 Results and Discussion

In the thesis we research relationships between consumption of maple syrup and its determinants, and production of maple syrup and factors influencing it. For consumption price maple syrup was used as an determinant, based on the law of demand. For production yield and number of taps were chosen as the most relevant factors. Originally several other explanatory variables were chosen for the analysis, but from the preliminary analysis they were omitted for their statistical insignificance. Results show that some of the hypothesis based on economic theory were confirmed and some of them were disproved. Here is the summary of the results of the structural form of the model.

- If all the other parameters are zero, the consumption is negative in height 0.86 million l. Only after certain threshold of production there is some consumption. This shows us that the maple syrup is a luxury item and will be consume after other needs are satisfied. Also, no whole maple production is used and sold in stores which is part of the original data for consumption.
- If the production increases by 1 million kg, the consumption increases by 0.02 million l, ceretis paribus. Which is according to our assumptions and economic theory. The more is available on the market the more people can physically consume.
- If the price of maple syrup increases by 1 CAD/kg, the consumption increases by 0.23 million l. This type of goods is called Veblen goods. For these types the consumption increases with increasing price, because people view higher prices as a sign of quality, "Snob effect".
- Base on the elasticities the highest influence on the consumption has price (Ex_2 = 0.88%) rather than production (Ey_2 = 0.61%).
- If the yield increases by 1 kg/tap, the production increases by 39.46 million kg, ceretis paribus. This is according to the economic theory and shows importance of yield increase for the production, because its elasticity is one of the highest. And it has been proven several times during the analysis that yield has always the highest influence on the production.

- If the number of taps increases by 1 million, the production increases by 1.04 million kg, ceretis paribus. This is also according to the economic theory, increasing number of taps can significantly increase the production because it has the highest elasticity coefficient. But later in the analysis we have proven that yield has much higher and much more important relevance to production.
- The highest impact on the production has both yield and number of taps, where 1% increase in yield or number of taps, induce increase in production by 0.86% respectively 0.89%.
- By F-test it has been proven that the structural form of the model is statistically significant on $\alpha = 0.05$. And by p-value it has been proven that all the parameters are statistically significant on $\alpha = 0.05$.
- For the model application, econometric verification was conducted, where in none of the equation autocorrelation of 4th order or heteroscedasticity was occurring, and residuals were normally distributed. 76.8% of data variability was explained by the 1st equation and 98.9% of data variability was explained by the 2nd equation.
- For the prognosis of the production and consumption of maple syrup in the next three years, reduced form of a model was formed. In reduced form we found interesting relation between variables. We found out that yield and number of taps have a significant influence on the consumption, both around 0.5%. And we found out that in reduced form influence of number of taps on production decreases and the most important becomes yield with elasticity 0.88%.
- In the prognoses was found out that it is expected increase in production by 7.9% for consumption, and 8.5% for production. Which increase in the year 2019, has already been proven to be true by University of Massachusetts. Which stated that the season 2019 was a record one. However, this trend might change in the future with the current ongoing crises during 2020 tapping season and the future development of the climate.

6 Conclusion

Main goal of this thesis was to create and apply model of maple syrup production and consumption in Quebec between years 1999–2018. Before modelling was applied, literature research was conducted. Data was collected from mainly STACAN (Statistical office of Canada), publication from Federation de producteur et productricex acéricole du Quebec (FPAQ), publication of Government of Quebec, Institut de la Statistique Quebec, and Nielsen publication on sales in shops. Data was than transformed from pounds to kilograms, so all the data have the same unit.

Simultaneous model was conducted based on simultaneous model with two equations. Where in the first equation the consumption of maple syrup was endogenous variable and in the second equation the production of maple syrup was endogenous variable. Each equation was modelled separately based on the Two-Stage Least Square method in the software Gretl. Model was then applied for the prognosis in short-term period. Main goal of the thesis was fulfilled.

First model proven not to be ideal and several parameters were omitted in the final presented model. Model was then applied for 3-year prognosis. We predicted that both consumption and production of maple syrup in this period will increase by 7.9% for consumption, and 8% for production. According to the University of Massachusetts maple production in 2019 was the highest from the observed period, so our prognosis seems to be true at least in one-year horizon. However, with the recent development of the climate and the Covic-19 crises which happened exactly at the start of the maple tapping season the future trends might be unpredictable.

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8 Appendix

Table 17 Data set for the model

	y_{1t}	x_{2t}	x_{3t}	x_{4t}	x_{4t}^{*}	$y_{1(t-1)}$	y_{2t}	x_{5t}	x_{6t}	x_{7t}	x_{8t}	x_{9t}
1999	0.879	4.08	2.61	35600	900	0.875	31.16	1.07	7666	29.2	2.5	-5.6
2000	0.956	3.44	2.97	36600	1000	0.879	38.92	1.18	7666	33	4.2	-5.6
2001	0.666	4.45	3	37400	800	0.956	28.30	0.78	7966	33.5	-0.6	-11.3
2002	0.819	4.48	4.4	37700	300	0.666	32.48	0.93	7966	34	0.5	-10.5
2003	0.973	4.45	5.29	37500	-200	0.819	39.01	1.07	6400	36.6	-0.2	-12.6
2004	0.980	4.72	6.01	38400	900	0.973	39.19	1.04	7140	37.6	2.1	-8.5
2005	0.986	4.72	5.2	37700	-700	0.980	33.57	0.88	7324	38	0.1	-9.4
2006	0.916	4.70	4.84	38400	700	0.986	31.12	0.90	6540	34.5	2.4	-7.6
2007	1.077	4.83	5.34	39100	700	0.916	27.99	0.78	6509	35.7	0.3	-11.2
2008	0.621	4.85	5.82	38400	-700	1.077	26.67	0.71	6453	37.6	-1	-14.3
2009	1.255	6.04	6.49	39000	600	0.621	49.62	1.20	6637	41.3	1.6	-8.8
2010	1.110	6.04	5.88	39000	0	1.255	39.96	0.93	6765	42.7	5.1	-5.3
2011	1.201	6.13	6.53	39900	900	1.110	46.22	1.08	6790	42.7	0.7	-9.1
2012	1.935	6.17	6.19	40500	600	1.201	43.59	1.02	6676	42.7	5	-5.7
2013	1.784	6.37	7.11	40700	200	1.935	54.57	1.28	6613	42.7	2.4	-4
2014	1.875	6.26	7.03	40900	200	1.784	51.62	1.21	6506	42.6	-2.5	-15
2015	2.126	6.31	7.02	40300	-600	1.875	48.63	1.15	6431	42.6	-1.2	-12.1
2016	1.974	6.48	7.63	41900	1600	2.126	67.22	1.57	6385	42.7	1.5	-8.6

2017	1.992	6.44	8.08	42200	300	1.974	69.06	1.56	6609	43.4	-1.5	-11.4
2018	2.097	6.44	7.57	39540	-2660	1.992	53.57	1.14	6628	45	-0.9	-11.9

$$y_{1t} = \gamma_{11}x_{1t} + \beta_{12}y_{2t} + \gamma_{12}x_{2t} + \gamma_{13}x_{3t} + \gamma_{24}x_{4t} + \beta_{11}^{*}y_{1(t-1)} + \varepsilon_{1t} \quad (22)$$

$$y_{2t} = \gamma_{21}x_{1t} + \beta_{21}y_{1t} + \gamma_{25}x_{5t} + \gamma_{26}x_{6t} + \gamma_{27}x_{7t} + \gamma_{28}x_{8t} + \gamma_{29}x_{9t} + \varepsilon_{2t} \quad (23)$$

Table 18 First unused model, where most of the variables are not significant and this model was not used for application. Asterixis in the last column shows the statistical verification of the model where: * is statistically significant on α=0.1; ** α=0.05; * α=0.01. Red rows depict the variables which are not according to economic theory.**

Model 1: TSLSM, using observations 1999-2018 (T=20) Endogenous variable: y_{1t}				
	Coefficient	**Standard deviation**	**p-value**	
x_{1t}	-0.6495	0.3565	0.090	*
y_{2t}	0.017	0.0092	0.091	*
x_{2t}	0.2110	0.1342	0.138	
x_{3t}	-0.0563	0.0872	0.529	
x_{4t}^{*}	$-5.9 \cdot 10^{-5}$	$7.06 \cdot 10^{-5}$	0.417	
$y_{1(t-1)}$	0.0167	0.0092	0.091	*
Mean dependent var.	1.311	S.D. dependent var.	0.521	
Sum squared resid.	0.761	S.E. of regression	0.233	
R-squared	0.852	Adjusted R-squared	0.799	
F (5, 14)	16.19	P-value	0.000022	

Model 2. TSLSM, using observations 1999-2018 (T = 20) Endogenous variable y_{2t}				
	Coefficient	**Standard deviation**	**p-value**	
x_{1t}	-49.76	8.76	$7.52 \cdot 10^{-5}$	***
y_{1t}	3.08	1.079	0.780	
x_{5t}	39.50	1.79	$1.17 \cdot 10^{-11}$	***
x_{6t}	$9.89 \text{-} 10^{-4}$	0.00071	0.1902	
x_{7t}	1.11	0.11	$1.83 \cdot 10^{-7}$	***
x_{8t}	-0.32	0.334	0.355	
x_{9t}	0.028	0.238	0.908	

Mean dependent var.	42.62	S.D. dependent var.	12.38
Sum squared resid.	17.59	S.E. of regression	1.16
R-squared	0.994	Adjusted R-squared	0.991
F (6,16)	356.68	P-value	$1.19*10^{-13}$