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Effects of Price Insurance Programs on Supply Response: A Case Study of Corn Farmers in Quebec

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This study examines the supply response of corn in the province of Quebec.
Study Design: A time series design is implemented.
Place and Duration of Study: Our analysis covers the period from 1985 to 2013 and uses the data of corn production in the province of Quebec.
Methodology: A generalised autoregressive conditional heteroskedasticity (GARCH) process is used to model output price expectations and its volatility.
Results: We found that application of the Farm Income Stabilisation Insurance in Quebec neutralises the adverse effects of price volatilities on corn production and generates a market power for corn producers. The change in the producers' attitude towards risk is other implication of the insurance program.
Conclusion: These results imply that implementation of the insurance program in the province of Quebec leads to an increase of corn production and consequently this increase in production can impose more compensation cost (paid by the insurance program) to governments.

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1. INTRODUCTION

Many types of risks affect agricultural activities; they include the risk of production (including climate risk, production yield risk, and disease), the risk associated with a possible change in government policies, the risk associated with fluctuations in the exchange rate, price risk and the risk of competition in international markets [1]. These risks increase uncertainty for agricultural producers and affect their behaviour because they make it more difficult to estimate income, cost, and agricultural profit. The effects of these fluctuations on producers' well-being justify the implementation of risk management strategies, intended to reduce the adverse effects of risks through identifying potential risks and planning risk-handling activities.

Several studies show that price risk is perceived as an important source of risk in many countries [1,2,3] and [4]. Agricultural prices are very volatile and do not follow a particular trend [5,6] and [7]. Given the lag between the production decision and marketing, farmers make decisions based on their expectations about prices. Therefore, price volatility leads to income fluctuations and affects farmers' welfare. Several theoretical and empirical studies have focused on analysing the effect of price volatility on famers' production decisions.

Dalal and Alghalith [8] and Bobtcheff and Villeneuvey [9] theoretically analysed the impact of two sources of uncertainty, namely uncertainty on output price and input price. For these authors, increasing the price risks (inputs and outputs) should reduce production.

Behrmann [10] analysed the effects of variability of prices and yields on supply response of four major annual crops - rice, cassava, corn and kenaf in Thailand during the period of 1937-1963. He has examined the Nerlovian dynamic total supply response model incorporating the standard deviation of the price and yield in the last three periods, as risk factors, in this model. However, this was criticised for the fact that the Nerlovian price expectation model is not consistent with the changing variance of the subjective probability distributions.

Ryan [11] demonstrated the incorporation of risk variables in the supply function of pinto beans improves the statistical fit of the model. The author introduced a simple linear model in which price risk variables were initially constructed from the variance and covariance of pinto bean and sugar beet prices during the three preceding years. The fixed weight lag scheme proposed by Fisher is used to weight these variance terms.

Traille [12] analysed the US onion supply response to price risk. He has modelled the price risk using the difference between expected price and actual price. In this study, the expected price is assumed to be a function of past observations on price.

Seale and Shonkwiler [13] have developed sub-regional supply and production models in order to analyse the supply response of U.S. watermelons to risk factors. These authors modelled price expectation and price risk using rational expectation and the difference between expected and actual price respectively.

Holt and Aradhyula [14], Holt [15], Rezitis and Stavropoulos [16] and Rezitis and Stavropoulos [6] investigated the supply response of different agricultural products (broiler, beef, pork and beef respectively) to price risk. These authors have modelled price volatilities using a GARCH model. In these studies, Holt [15] used a rational price expectation model while the others suppose that prices follow an autoregressive form. Mbaga and Coyle [17] used the Autoregressive Distributed Lag model (ADL) to analyse the reaction of beef production to price risk. They modelled price expectations and price volatility by the naive expectations model and squared errors of prediction respectively.

The results of the study of Haile et al. [18] revealed the negative impact of price volatilities on the production of key agricultural products (wheat, corn, soybeans and rice) so that farmers shift land, other inputs and yield improving investments away to crops with less volatile prices. Ayinde et al. [19], modelling supply response of rice in Nigeria also concluded that rice producers respond significantly to price risk.

However, these studies assume that price volatility is a source of risk that reduces production, but this variable cannot be presented as a measure of risk in all conditions. Implementation of price insurance programs is an example of situations in which the price risk would not significantly affect the production decision. Price insurance is a risk management tool, which allows producers to protect themselves against unexpected output price declines beyond market expectations. Consequently, the application of these programs would result in the non-significant effect of price volatility on production and provide an incentive to increase production. In this study, we will show that the implication of a price insurance program, as a risk-handling tool, neutralises the adverse effects of price volatility on agricultural production.

This study focuses on price risk because of the high volatility of agricultural input and output prices [20 and 21]. The objective of our study is to explore the supply response of corn in the province of Quebec taking into consideration the presence of a price insurance program (ASRA) in this province and thus providing useful information to policymakers about the implications of Program ASRA.

Corn cultivation is the third most important in the world after wheat and rice and remains one of the most important crops in Canada, particularly in the east [22]. Field corn is also Canada's third most important grain crop after wheat and barley [23]. The province of Quebec produces 33% of the corn representing the second corn producer of Canada [24]. It is worth mentioning that between the years 2009-2012, 76% of Quebec corn production was destined to animal feed [25].

In Quebec's agricultural sector, an important consideration is the existence of the Farm Income Stabilisation Insurance Program (Assurance Stabilisation du Revenue Agricole, ASRA). The sectors supported by ASRA, which reached their peak in 2002, comprise fattened calves, steers, grain-fed calves, piglets, pigs, lambs, oats, wheat, corn, potatoes, milk calves, canola, barley, soybeans and apples. Under this program, the government compensates producers when the market price is less than the production cost.

Consequently, ASRA reduces losses associated with price risk. Because of this insurance program, the market price is different from the price received by Quebec producers (effective price). This program may thus change supply response to prices. Consequently, we estimate two empirical models: one including corn supply response versus market prices (which represents the absence of ASRA) and other including corn supply response versus effective prices. Specification of the model including effective prices includes the premium paid to producers under program ASRA, Programme Canadien de Sstabilisation du Revenu Agricole (PCSRA,2003-2006) and program agri-stability (since 2007). Although over estimation period, program Regime d'assurance du revenu brut (RARB) is also applied in the province of Quebec, but this program is not directly linked to producer prices. For this reason, we supposed that this program is not directly linked to the production decision. However, ASRA directly affects the price received by the producer.

First, in this study, we analyse the behaviour of corn producers in Quebec towards risk in the absence of the price insurance program. Then we analyse if the implication of ASRA as an insurance program can manage the price risk and increase the welfare of producers. In other words, we analyse if under the insurance program the production decision is still sensitive to risk factors. Given that the insurance program is intended to protect Quebec producers against unexpected output price declines below production cost, we expect this program neutralises the negative effects of price volatility on the producer’s well-being. In addition, it would be of interest to study the implications of the insurance program on the sensitivity of production function to different risk factors. Furthermore, given that insurance program reduces losses associated with price risk, it is consistent to study if the implementation of this program affects the risk aversion of producers.

In this study, we assume that prices follow an autoregressive process, and an asymmetric generalised autoregressive conditional heteroskedasticity (Asymmetric GARCH) process is adapted to model the price volatility. This technique is appropriate when modelling agricultural price volatilities because it allows the unconditional variance to vary over time. Furthermore, modelling price volatilities by the Asymmetric GARCH model, allows us to investigate the possible asymmetric effects of price shocks. The possible existence of asymmetry of corn price volatility can provide useful information about the market structure.

The rest of the paper is structured as follows. The second section presents the econometric model of corn production and data. Then the empirical results are explained, and the final section presents the implications and conclusions of the study.

2. METHODOLOGY

2.1 Supply Response Function

Following Rude and Surry [26], we assume that producers have a constant absolute risk aversion and that the price distribution is normal. Under these conditions, the objective function of the producer is written as follows:

$$MAX: P^e S \quad - C(S) - \frac{\lambda}{2} S^2 \mathrm{h^e} \tag{1}$$

Where P^e is price expectations, h^e is price variance, S is corn production, λ is the absolute risk aversion parameter, S^2 is the square value of production and C(S) is the cost function. Profit maximisation by the producer allows us to derive the following production function:

$$S_t = \gamma_0 + \gamma_1 PC^e{}_t + \gamma_{21} PF^e{}_t + \gamma_3\, h^{\mathrm{e}}_{Ct} + \gamma_4\, h^{\mathrm{e}}_{Ft} + \gamma_5 \sum_i S_{t-i} + \gamma_6 \mathrm{T_t} + \varepsilon_{1t} \tag{2}$$

Where $PC^e{}_t$ is the expected price of corn (as output), $PF^e{}_t$ the expected price of fertiliser (as input), h^{e}_{Ct} the volatility of corn prices, h^{e}_{Ft} the fertiliser price volatility and $\varepsilon_{1t}$the error term.

Seeds and fertiliser are two key inputs in the production of corn. The autocorrelation between the residuals of the seed price equation led us to remove this input from the model.

We assume that, in the long term, production adjusts to its desired level [27] and we incorporate lagged dependent variables ($\sum_i S_{t-i}$) in the model. Production lags imposed on the model are determined by the VARSOC method. This method reports the final prediction error (FPE), Akaike's information criterion (AIC), Schwarz's Bayesian information criterion (SBIC), and the Hannan and Quinn information criterion (HQIC) lag order selection statistics for a series of vector autoregressions of order 1 to maximum lag. A sequence of likelihood-ratio test statistics for all the full variables of order less than or equal to the highest lag order is also reported. However, our tests suggest one lag in the model.

To capture the effect of technological progress, we incorporate a trend variable (T_t).

2.2 Price Expectation

Following Rezitis and Stavropoulos [6], we assume that prices follow the autoregressive process (AR):

$$P_t = \beta(L) P_t + \mathcal{E}_{2t} \tag{3}$$

$$\mathcal{E}_{2t} | \Omega_{t-1} \sim N(0, h_t)$$

Where $\beta(\mathrm{L})$ is a polynomial lag operator, P_t is current price, $\mathcal{E}_{2t}$ is an error term, Ω_{t-1} is the information set of all past states available in period t-1 and h_t is the conditional variance of $\mathcal{E}_{\mathrm{t}}$.

The Bayes Information Criterion (BIC) was used to determine the appropriate order of corn market and effective price equations. Using BIC to determine the order of the fertilizer price equation has caused autocorrelation between the residual of the input price equation, thus we used the General to Specific method of selecting the appropriate order of the fertiliser price equation. Consequently, price equations are as follows:

$$PC_t = b_0 + \sum_{i=1}^{L} b_i PC_{t-i} + c_1 G_t + c_2 T_t + \mathcal{E}_{2t} \tag{4}$$

With:

L=3 If our model includes market prices.
L=1 If our model includes effective prices.

$$PF_t = b_0'' + b_1'' PF_{t-1} + b_2'' PF_{t-8} + b_3'' PF_{t-9} + + c_1'' G_t + c_2'' T_t + \mathcal{E}_{3t} \tag{5}$$

Where $\mathrm{PC_t}$, and $\mathrm{PF_t}$ represent corn price and fertiliser price respectively. The dummy variable (G_t) is introduced to capture the effect of structural changes. These structural changes generated by the oil price increase after 2006, engender the rise in agricultural prices [28]. The study of Avalos [29] confirms the changes in dynamic of corn price after 2006, which is related to oil price variation. $\mathrm{T_t}$ captures the effect of a trend on prices.

2.3 Variance Modeling

Unlike the other time series models, generalised autoregressive conditional heteroskedasticity models (GARCH) allow the conditional variance to vary over time, which is very relevant given the dynamics of agricultural prices. This characteristic of these models led us to use GARCH models to model price volatilities.

An asymmetric GARCH model is used to investigate the possible asymmetric effects of price shocks. In this model, the past values of the error terms ($\sum_{i=1}^{q} \gamma_i \mathcal{E}_{2(t-i)}$) are added to the price variance equation. These terms allow positive and negative shocks to have different effects on volatility. In this model, the volatility is defined as:

$$VAR(\varepsilon_t]\varepsilon_u, u < t) = h_t^e = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{2(t-i)}^2 + \sum_{i=1}^{p} \beta_i h_{t-i} + \sum_{i=1}^{q} \gamma_i \varepsilon_{2(t-i)} \quad (6)$$

According to equation 6, the conditional variance (h_t^e) is defined as a linear function of q lagged squared residuals and p lagged past conditional variances. The following restrictions are imposed to ensure that the conditional variance is strictly positive:

$$\alpha_0 > 0, \alpha_i > 0 \text{ and } \beta_i > 0$$

The stationarity of variance is guaranteed by $\sum_i \alpha_i + \sum_i \beta_i < 1$ [30]. Further, if the prices do not show the ARCH effect, we use simple moving variance to incorporate price volatility in the model.

The residual test of price equations reveals the presence of serial auto-correlations in the squared residuals of the market and effective price of corn. This is one of the implications of the ARCH effect in the model, which led us to run the Lagrange Multiplier test to ensure the presence of heteroskedasticity in these equations. The results of this test, applied to equation 4 indicate that the hypothesis of no ARCH effect can be rejected at the 5% level of significance (Table A1 and Table A2). Consequently, we have modelled the volatility of the market and effective price of corn by a GARCH model. Visual examination of the correlogram of the squared residual of the price equation and the results of the Ljung-Box (1976) Q test [31] proposed ARCH(1) model for modelling market price and effective price variance. Then, to model corn price volatility, equation 6 can be written as follows:

$$h_{ct} = \alpha_0 + \alpha_1 \varepsilon^2_{2(t-1)} + \theta_1 \varepsilon_{2(t-1)} \quad (7)$$

Where h_{ct} is the volatility of the corn price.

Further, the residual test of the fertiliser price equation and the Lagrange Multiplier test (Table A3) confirm the lack of ARCH effect in the fertiliser price equation. For this reason, we have incorporated a simple moving variance of fertiliser price in the model.

2.4 Estimation Approach

Variables $PC^e{}_t$, $PF^e{}_t$, $h^e{}_{ct}$ and $h^e{}_{ft}$ generated by the GARCH model can be used to estimate equation 2. Pagan [32] concluded that using variables generated by stochastic models to estimate a structural equation could cause biased estimates of the parameters' standard deviations. One of the methods used to avoid this problem is the Full Information Maximum Likelihood (FIML) method. This method simultaneously estimates the supply response function, the price equation and the GARCH process parameters. Considering a system of equations 8 (the model of market prices) and 9 (the model of effective prices), the joint distribution of ε_{1t}, ε_{2t} and ε_{3t} is written as follows:

$$\left[\begin{array}{c} S_t = \gamma_0 + \gamma_1 PC^e{}_t + \gamma_{21} PF^e{}_t + \gamma_3 h^e_{Ct} + \gamma_4 h^e_{Ft} + \gamma_5 \sum_i S_{t-i} + \gamma_6 T_t + \varepsilon_{1t} \\ PC_t = b_0 + \sum_{i=1}^{3} b_i PC_{t-i} + c_1 G_t + c_2 T_t\, \varepsilon_{2t} \\ PF_t = b_0' + b_1' PF_{t-1} + b_2' PF_{t-8} + b_3' PF_{t-9} + + c_1' G_t + c_2' T_t + \varepsilon_{3t} \end{array}\right. \quad (8)$$

$$\left[\begin{array}{c} S_t = \gamma_0 + \gamma_1 PC^e{}_t + \gamma_{21} PF^e{}_t + \gamma_3 h^e_{Ct} + \gamma_4 h^e_{Ft} + \gamma_5 \sum_i S_{t-i} + \gamma_6 T_t + \varepsilon_{1t} \\ PC_t = b_0 + b_1 PC_{t-1} + c_1 G_t + c_2 T_t + \varepsilon_{2t} \\ PF_t = b_0' + b_1' PF_{t-1} + b_2' PF_{t-8} + b_3' PF_{t-9} + + c_1' G_t + c_2' T_t + \varepsilon_{3t} \end{array}\right. \quad (9)$$

$$\varepsilon_t = \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{bmatrix} \sim N \left[\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{12} & h_{Ct} & \sigma_{23} \\ \sigma_{13} & \sigma_{23} & h_{Ft} \end{bmatrix} \right] \quad (10)$$

Where $\begin{bmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{12} & h_{Ct} & \sigma_{23} \\ \sigma_{13} & \sigma_{23} & h_{Ft} \end{bmatrix} = \prod_t$ represents the variance-covariance matrix. The log-likelihood function of the above system is given as follows:

Table 1. Data analysis

Variable	Mean	Minimum	Maximum	Standard-deviation
PC (Corn market price explained by dollars per ton)	1.7	0.99	3.03	0.41
PF (fertiliser price explained by dollars per ton)	0.38	0.23	0.77	0.14
S (Corn supply explained by hectare)	340 350	225 000	449 000	68 336.9
PCEF(Corn effective price explained by dollars per ton)	2.15	1.35	3.91	0.5

$$l_T(\Theta) = 0.5\sum_{t=1}^{T} l_t(\Theta) \quad (11)$$

$$l_t(\Theta) = -log|\prod_t| - \mathcal{E}'_t \prod_t{}^{-1} \mathcal{E}_t \quad (12)$$

2.5 Data

Our analysis covers the period of 1985 to 2013, and the supply response model is based on annual data. Data on seeded area of corn (corn production) are obtained from Statistics Canada (Table 001-0010), and are expressed in Hectares.

Corn market prices and are obtained from Statistics Canada (Table 002-0043). The effective prices are built by adding compensation under the Farm Income Stabilisation Insurance program, Agri-Stability program and Canadian Farm Income Stabilisation program (PCRA) to market prices (these programs are complementary). Compensation values are from the La Financière agricole (provincial government agency) website [33].

Fertiliser prices are from Statistics Canada (Tables 3280001 and 3280015). Following Rezitis and Stavropoulos (2010), all prices are deflated by the consumer price index (2002 = 100). Table 1 presents some statistics of the data used in the analyses.

3. RESULTS AND DISCUSSION

Table 2 provides the results of unit root tests. Augmented Dickey-Fuller (ADF) and Philips-Perron (PP) tests were conducted. The VARSOC method was used to determine the optimal lag of variables.

Corn seeded area and fertiliser price variables are non-stationary, while the results regarding corn market and effective price are mixed. This justifies the incorporation of trend variable in price equations as well as in production equation.

3.1 Price Analysis

Tables 3 and 4 present the results of output and input price equations used to construct output and input price expectations. The equations of predictions are used as structural model equations.

The estimation results of the output price equations are presented in Table 3.

Table 2. Results of unit roots tests

	Model without intercept and without trend		Model with intercept and without trend		Model with intercept and trend	
	Augemented Dickney Fuller (ADF)	Philips-Perron (PP)	Augemented Dickney Fuller (ADF)	Philips-Perron (PP)	Augemented Dickney Fuller (ADF)	Philips-Perron (PP)
PC (3 lags)	-1.418	-1.181	-4.036[c]	-3.715[c]	-3.992[c]	-3.680[a]
PF (2 lags)	-0.560	-0.44	-0.616	-0.993	-2.106	-2.373
S (1 lag)	1.1	-1. 534	-1.529	1.143	-1.428	-1.651
PCEF (1 lag) (4 lag)	-0.807	-0.738	-4.191[c]	-3.765[c]	-4.601[c]	-4.097[c]

Table 3. Results of corn price equation

Parameter	Variable	Coefficient (Model including market prices)	Coefficient (Model including effective prices)
Conditional mean			
b_0	1	0.29(0.000) (0.000)	0.43 (0.000) (0.000)
b_1	PC_{t-1}	1.37 (0.000)	0.85 (0.000)
b_2	PC_{t-2}	-0.58(0.000)	-
b_3	PC_{t-3}	0.10(0.000)	-
c_1	G_t	0.06(0.000)	0.003(0.90)
c_2	T_t	-0.0009(0.000)	0.0009 (0.001)
Conditional Variance			
α_0	1	0. 005 (0.000)	0. 02 (0.000)
α_1	$\varepsilon^2_{2(t-1)}$	0.94 (0.000)	0.30 (0.000)
θ_1	$\varepsilon_{2(t-1)}$	0.06 (0.000)	0.12 (0.000)
Test of market price equation's residual generated by the autoregressive (AR) model (ε_{2t})			
Q(6)		6.5 (0.37)	5.57 (0.47)
Q(12)		12.19 (0.43)	15.860 (0.20)
Q(18)		13.58 (0.76)	20.14 (0.32)
Q(24)		15.17 (0.91)	31.13 (0.15)
Q^2 (6)		32.93 (0.000)	8.94 (0.18)
Q^2 (12)		77.41 (0.000)	30.64 (0.002)
Q^2 (18)		81.16 (0.000)	37.90 (0.004)
Q^2 (24)		82.43 (0.000)	48.82 (0.002)
Test of market price equation's residual generated by the SAARCH model ($\varepsilon_{2t} * h_t^{-0.5}$)			
Q(6)		8.66(0.19)	6.00 (0.42)
Q(12)		11.28(0.51)	12. 17 (0.43)
Q(18)		12.87(0.80)	15.20 (0.65)
Q(24)		19.5 (0.72)	28.65 (0.23)
Q^2 (6)		1.03(0.98)	3.24 (0.77)
Q^2 (12)		18.39(0.11)	21.20 (0.26)
Q^2 (18)		19.78 (0.34)	13.92 (0.73)
Q^2 (24)		25.90 (0.35)	31.42 (0.14)

P-values are in parentheses

According to the results, the coefficients of autoregressive terms of the price (b_1, b_2 and b_3) are significant at the 1% level. The coefficient of the conditional variance expressed by α_1 is significant, which indicates time-varying volatility. Furthermore the coefficients of conditional variance of market price and effective price sum less than unity ($\sum_{i=1}^{2} \alpha_i + \beta_i$ = 0.94 and 0.30 respectively), implying persistent volatility.

The coefficient of the asymmetry factor of shocks (θ_1) is significant at 1%, which confirms the presence of an asymmetric effect of shocks on volatility. The positive sign of θ_1 indicates that a positive shock in price causes more volatility than a negative shock of the same magnitude. This can be justified by strong position of corn producers in Quebec market, in the way that they can benefit unexpected positive shifts in demand by increasing the price but in the case of unexpected negative shifts, they are not forced to cut their prices [6]. This is consistent with the structure of the Quebec corn industry which is characterised by small numbers of big producers so that 6160 corn farms devoted 402,441 Hectares of land in 2011(Statistic Canada, table 004-0003). This market power can also be justified by the implementation of the insurance program which compensates the negative shocks of price and consequently leads to less volatility in the case of negative shocks than positive shocks.

Finally, the Ljung-Box Q statistic test was applied to the residuals ($\mathcal{E}_{2t}$) and the squared residuals ($\mathcal{E}^2_{2t}$) of corn price equations to analyse the performance of the model. The results of this test on $\mathcal{E}_{2t}$ and $\mathcal{E}^2_{2t}$ support the non-rejection of the hypothesis that the residuals of the output price equations are white noise, and the hypothesis for the absence of the ARCH effect is rejected. These results are one of the implications of the GARCH model presented by equations 4 and 7 [34]. The application of an appropriate order of GARCH removes the correlation of squared residuals [35]. The Ljung-Box test applied to residuals and squared residuals of the SAARCH model indicates the absence of correlation between the residuals and squared residuals.

Table 4 presents the estimated parameters of fertiliser price (equation 5).

According to the results of Table 4, the coefficients of autoregressive terms of fertiliser (b''_1, b''_2 and b''_3) are significant at the 1% level.

The Ljung-Box Q statistic test, applied to the residuals (ε_{3t}) and the squared residuals ($\varepsilon^2{}_{3t}$) of the fertiliser price equation, affirms the absence of correlation between the residuals and the squared residuals of the input price equation.

3.2 Supply Response

A Maximum Likelihood method was used to estimate the equations of the structural model. The estimation of the coefficient of determination (R^2) confirms the good specification of the model (Table 5). Finally, the Ljung-Box Q statistic test, applied to the squared residuals of supply response equations attests absence of ARCH effect in the model (Table 5). The autocorrelation between the residuals of the model was examined by several tests, namely Ljung-Box (Table 5), Harvey, and Guilkey (Table A4 and A5). There is concordance between the results of these tests regarding the absence of residual autocorrelation of the model.

Table 5 presents the results of the estimation of the structural model constructed by output price expectation, input price expectations, output price volatility and supply response equation.

Table 4. Results of fertiliser price equation

Parameter	Variable	Coefficient
	Mean	
b''_0	1	0.05(0.01) (0.000)
b''_1	PF_{t-1}	0.88 (0.000)
b''_2	PF_{t-8}	-0.49(0.000)
b''_3	PF_{t-9}	0.42(0.000)
c''_1	G_t	0.04(0.013)
c''_2	T_t	0.0002(0.25)
	Residual test of fertiliser price equation (ε_{3t})	
Q(6)		2.95 (0.81)
Q(12)		9.81 (0.63)
Q(18)		10.68 (0.91)
Q(24)		13.55 (0.95)
Q^2 (6)		1.22 (0.98)
Q^2 (12)		6.56 (0.88)
Q^2 (18)		7.94 (0.98)
Q^2 (24)		8.22 (0.99)

P-values are in parentheses

Table 5. Results of corn supply response

Parameter	Variable	Coefficient (Model including market prices)	Coefficient (Model including effective prices)
γ_0	1	-17800000 (0.000)	-18800000 (0.001)
γ_1	PC_t^e	88128.6 (0.05)	85171.38 (0.10)
γ_{21}	PF_t^e	-49029.8 (0.005)	-29913.13 (0. 10)
γ_3	$h^e{}_{ct}$	-1267520 (0.08)	-995104.9 (0.38)
$\gamma_{4\ 1}$	$h^e{}_{Ft}$	-3283563 (0.008)	-3064009 (0.11)
γ_5	SU_{t-1}	0.55 (0.001)	0.45 (0.009)
γ_6	T_t	8953.5 (0.002)	9477.14 (0.001)

Parameter	Variable	Coefficient (Model including market prices)	Coefficient (Model including effective prices)
		Residual test of supply equation (ε_{1t})	
Q(3)	2.42 (0.48)		4.84 (0.18)
Q(6)	2.65 (0.85)		6.07(0.41)
Q(9)	3.60 (0.93)		7.71 (0.56)
Q(12)	4.10 (0 98)		9.33 (0.67)
Q2 (3)	0.27 (096)		1.78 (0.62)
Q^2 (6)	0.28 (0.99)		2.85 (0.83)
Q^2 (9)	0.30 (1.00)		5.13 (0.82)
Q^2 12)	0.37 (1.00)		8.16 (0.77)
	Adjusted R^2=0.67		Adjusted R^2=0.88

P-values are in parentheses

The coefficient of the expected price of corn (γ_1) has a positive sign, as expected. However, the coefficient of the expected price of fertiliser (γ_{21}) is negative, implying a decrease in corn production following an increase in the input price, which is also expected. The negative sign of the coefficients of corn price volatility and fertiliser price volatility (respectively γ_3 and $\gamma_{4\ 1}$) implies that production responds negatively to an increase in volatility. These results are consistent with prior studies (such as Rezitis and Stavropoulos [6], Holt and Aradhyula [14], Holt [15], Rezitis and Stavropoulos [16], and Rude and Surry [26]). The coefficient γ_5 shows the adjustment speed to desired output. The coefficient γ_6 captures the effects of the corn production trend.

The results illustrate the significant effect of risk factors (expected output and input price, as well as the variance of input and output price) on corn production in the absence of the insurance program. However, the variance of output and input price cannot affect corn production when the insurance program is implemented. It is not surprising since the insurance program is intended to stabilise the producers' income in Quebec. In other words, this program prevents producers' income fluctuations following price volatility, and thus this insurance program engenders corn production (as a product covered by the insurance program) not to be affected by price volatilities. Consequently, we can conclude that the implementation of the insurance program in the province of Quebec was successful to neutralise the adverse effects of price volatilities on corn production. Furthermore, a comparison between the supply response of the model including market prices and the model including effective prices provides important information for policymakers. As illustrated in Fig. 1 implementation of insurance program increases corn production; thus we can conclude that the premium paid to corn producers has a positive effect on corn production in the province of Quebec.

Implementation of the insurance program in the province of Quebec leads to an increase in corn production through motivating actual producers as well as potential producers. The premium paid to corn producers, by neutralising the negative effects of price volatility, motivates producers to increase their production. On the other hand, this premium helps small producers to manage the risk and to be able to compete in the market.

We used the estimated parameters of the model and the simple average of variables to estimate supply elasticities relative to effective prices.

Estimation of corn supply elasticity relative to expectations of corn effective price (0.523 in the short-term and 0.952 in the long-term), to expectations of fertilisers price (-0.124 in the short-term and -0.275 in the long-term), to corn price volatility (-0.069 in the short-term and -0.126 in the long-term) and to fertiliser price volatility (-0.037 in the short-term and -0.082 in the long-term) confirm the Le Chatelier principle [36], which implies that long-term elasticities of supply and demand are more important than short-term elasticities. These estimations imply that the corn supply response is more sensitive to output prices and input price than to volatilities (Price volatilities are not significant). This can be justified by the application of the insurance program, which neutralises the effects of price fluctuations on the supply of corn.

These estimates also imply that corn supply response is more sensitive to the expected price of output than to the expected price of inputs. Several reasons may explain this result. First, the gap between the production decision and the

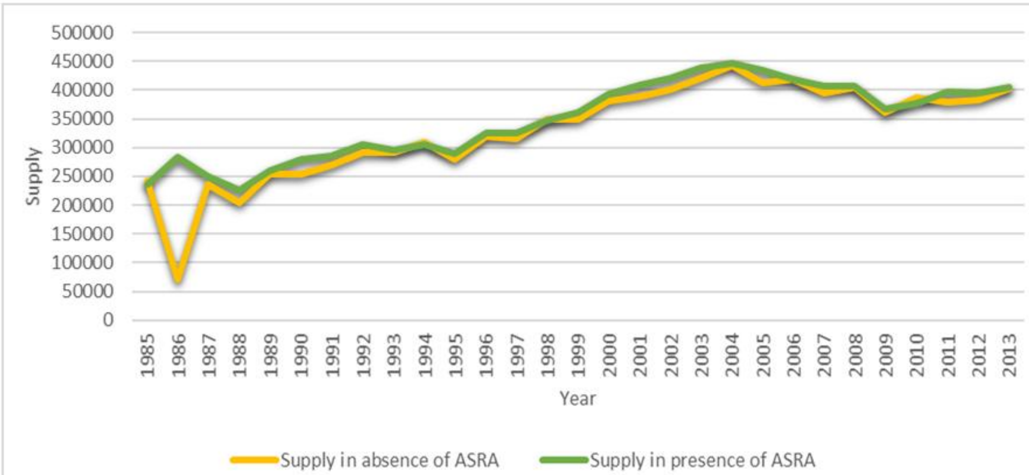

Fig.1: Predicted corn supply in the province of Quebec (1985-2013)

purchase of inputs is shorter than that between production decisions and marketing [37]. Further, input prices are positively correlated to the price of outputs. In other words, the increase in input prices causes a rise in output prices. Therefore, production is less affected by input price variations than by that of output price.

Estimation of supply elasticities in the model including market prices (supply elasticities are 0.43, -0.2, -0.08 and -0.04 in the short-term and 0.958, -0.45, -0.19 and -0.088 in the long-term relative to expected output price, expected input price, output price volatility and input price volatility respectively) reveals that implementation of the insurance program decreases the sensitivity of corn supply response relative to risk factors in the long-term.

Furthermore, our estimation of supply response elasticity relative to corn market price is consistent with that obtained by Haile et al. [38] In United States. The fact that agricultural prices in Canada and United-States are integrated, and absence of the studies measuring Canadian corn supply elasticity relative to market price justifies this comparison.

3.3 Relative Marginal Risk Premium Index

Finally, we analysed the behavior of corn producers in Quebec towards risk by calculating the Relative marginal Risk Premium (RRP). This index is determined by the negative of the ratio of the variance and price elasticity of supply [39]:

$$RRP_t = -\gamma_{ab} \cdot \frac{h_t^e}{P_t^e} \qquad (13)$$

Where

$$\gamma_{ab} = \left\{ \frac{\gamma_3}{\gamma_1}, \; -\frac{\gamma_{4\;1}}{\gamma_{2\;1}} \right\}$$

$$h_t^e = h_{ct}^e \text{ If } \gamma_{ab} = \frac{\gamma_3}{\gamma_1}$$

$$h_t^e = h_{ft}^e \text{ If } \gamma_{ab} = -\frac{\gamma_{4\;1}}{\gamma_{2\;1}}$$

The positive and significantly different from zero (coefficient of all risk factors are significant) value of input and output mean RRP (indicated in Table 6) in the models including market prices implies risk-averse behavior of corn producers rather than risk-neutral behavior in the absence of the insurance program [6]. However, non-significant coefficients of output and input price volatilities in the model including effective prices imply risk neutral behavior of corn producer in the presence of the insurance program. In other words, implementation of the insurance program, through managing and neutralising the risks associated with negative shocks of price, changes the behavior of corn producers towards price risk. This behavior change from risk aversity to risk neutrality of corn producers affects corn supply and thus well-being of producers.

Table 6. Estimation of relative marginal risk premium index (RRP) of quebec corn producers

	Mean RRP in the model including the market price	Mean RRP in the model including the effective price
Output	0.2	0
Input	0.2	0

4. CONCLUSION

The impact of price fluctuations on the supply response of agricultural products has been considered one of the major issues in the literature. Many theoretical and empirical studies have analysed the effects of price risk on the supply response of different agricultural products. They mainly defined price fluctuation as a source of risk that can reduce production. However, implementation of price insurance programs, as risk management tools, helps producers to insure themselves against unexpected negative shocks of the price. Consequently, the application of these programs would result in the non-significant effect of price volatility on the supply response and provide an incentive to increase production.

This paper investigates the supply response of corn in the province of Quebec where a price insurance program has been implemented. Given that the insurance program could affect the agricultural supply response to prices, we studied the supply response of corn to market prices, along with the effective prices defined as market prices plus compensation of the insurance program. An asymmetric GARCH procedure is used to model output price expectations and its volatility. However, the absence of the ARCH effect in input prices led us to model input price volatility by a simple moving variance. The model parameters were estimated by the Full Information Maximum Likelihood (FIML) method.

We have shown that the application of the insurance program in Quebec affects the supply response of corn to risk factors and neutralises the adverse effects of price volatilities on corn supply response. In other words, despite the emphasis of the literature on the importance of price volatilities on the supply of agricultural products, the results of our study show that output and input price volatilities are not significant risk factors for corn producer in Quebec. These results are justified by application of the insurance program, which stabilises corn price and prevents production decision to be sensitive to price volatilities. Although the output and input price expectation are still significant risk factors in Quebec corn production, the results show that the implication of the insurance program decreases the sensitivity of corn supply to these factors of risk.

We have analysed the structure of the corn market in the province of Quebec. The results imply market power of corn producers in Quebec in a way that they can benefit of the positive shocks in demand, but they are not forced to reduce the prices in the case of negative demand shocks. This market power can be justified by the structure of the Quebec corn industry as well as by implementation of the insurance program.

We have also estimated supply elasticity relative to output and input price expectations, as well as to price volatilities. These estimations demonstrate that corn producers in Quebec perceive output price expectations as the most important risk factor. Further, results show lower sensitivity of supply to input prices than to output prices. This is justified by the correlation between output and input prices as well as the less important delay between production decision and input purchase than between production decision and marketing. Another important finding is that the corn supply elasticity estimate relative to output price expectation is of a similar order of magnitude to that of prior studies.

Finally, we discovered that the application of the insurance program in Quebec changes the attitude of corn producers from risk-averse to risk neutral. This behavior change, through motivating actual producers and potential producers, increases corn production and consequently, this increase in production can impose more compensation cost (paid by the insurance program) to governments.

Further research could be conducted to compare the economic benefits of ASRA provided to farmers and the financial burden that an increase in production (due to the implementation of ASRA) imposes to governments.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Table A1. Lagrange multiplier test (ARCHLM) for corn market prices (AR(3))

Chi2	Degrees of freedom	Prob>chi2
40.59	1	0.000
Null hypothesis: No ARCH effect	Alternative hypothesis: ARCH(p) disturbance	

Table A2. Lagrange Multiplier Test (ARCHLM) for corn effective prices (AR(3))

Chi2	Degrees of freedom	Prob>chi2
20.782	10	0.02
Null hypothesis: No ARCH effect	Alternative hypothesis: ARCH(p) disturbance	

Table A3. Lagrange Multiplier Test (ARCHLM) for fertiliser price

Chi2	Degrees of freedom	Prob>chi2
3.813	8	0.87
Null hypothesis: No ARCH effect	Alternative hypothesis: ARCH(p) disturbance	

Table A4. Harvey and Guilkey autocorrelation test applied to corn supply function versus market price

Single Equation Autocorrelation Tests			
	Harvey LM test	Rho	Pvalue>chi2
Supply equation	0.005	0.0003	0.94
Corn market price equation	0.10	0.0057	0.74
Corn volatility equation	0.74	0.0392	0.39
Fertiliser price equation	0.64	0.0338	0.42
Fertiliser volatility equation	2.4	0.1266	0.12
Rho: Correlation coefficient Null hypothesis: No Autocorrelation			

Table A5. Harvey and Guilkey autocorrelation test applied to corn supply function versus effective price

Single Equation Autocorrelation Tests			
	Harvey LM test	Rho	Pvalue>chi2
Supply equation	0.93	0.05	0.33
Corn volatility equation	0.66	0.03	0.41
Fertiliser price equation	2.62	0.13	0.11
Fertiliser volatility equation	2.66	0.13	0.11
Rho: Correlation coefficient Null hypothesis: No Autocorrelation			

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