How Does a 10% Increase in Canola Prices Affect Production and CO2 Emissions in Canada?

ECO481H1 F Final Project

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ABSTRACT

This study attempts to examines how a 10% change in the price of Canadian canola seeds affect canola production and CO2 emissions from agriculture in the long run. Using OLS regression on a long-run supply model, we attempt to estimate the constant price elasticity of supply for canola in Canada. Our primary model is built upon logged form of prices and quantities, and included a supplementary model on differenced data, as a reference. The results suggest that the long-run price elasticity of supply is approximately 0.512 ($p < 0.05$), indicating a positively correlated response between canola price and production. A 10% price increase is estimated to result in a 5.12% rise in canola production. And the final result of carbon emission is estimated to be 454.7 kilotons of CO2-equivalents in the upcoming year. In addition, we also propose a policy recommendation to mitigate the additional carbon emission caused by this potential expansion in canola production.

INTRODUCTION

Recently, China announced an anti-dumping probe into Canadian canola imports, as a response to Canada's earlier implementation of a 100% surtax on all Chinese-made electrical vehicles effective October 2024 (Reuters, 2024). Canola is one of the major sources of oilseeds of Canada, with more than half of its exports sold to China. This is raising concerns about future trade relations and price volatility in the global canola market.

This study aims to explore how changes in canola price affect Canadian canola production and carbon emission from agriculture. In particular, we aim to quantify the production response to price change by estimating the long-run constant price elasticity of supply using OLS regression on reduced-form model. A counterfactual analysis is then conducted to estimate the additional CO_2 emission resulted by the potential expansion production, using historical data on canola cultivation and associated greenhouse gas emissions in Canada.

The results suggest that the long-run price elasticity of canola supply is approximately 0.512, with a p-value controlled at 0.05 level, indicating a positive, although inelastic response. Given this estimation, a 10% increase in canola prices would lead to a 5.12% rise in production. The counterfactual analysis shows that an additional 454.7 kilotons of CO_2 emissions in the upcoming year. This result illustrated the downside of agricultural expansion, and highlighted the necessity of mitigation policies.

In the following sections of this report, we shall present: the data, the methodology, regression results, counterfactual analysis, discussions, and policy recommendation.

DATA

Raw Data

This study utilizes data from two primary sources, focusing on canola production and price indices in Canada. The first dataset, *Supply and Disposition of Grains in Canada*, provides the amount of disposition of grains, including canola, measured in metric tonnes. Observations are recorded three times per year (March, July, and December) capturing seasonal variations in agricultural supply and demand. The second dataset, *Raw Materials Price Index for Crop Products*, reports monthly price indices for major crop products, including canola and soybeans. These indices are normalized to a base value of 100 in January 2020. Both datasets are sourced from Statistics Canada (Table 32-10-0013-01 and Table 18-10-0268-03, respectively).

Cleaned Dataset

To ensures consistency across all variables, the raw datasets were processed to align their frequencies and generated the key variables-required for analysis. And to facilitate the elasticity estimation, logged terms of total disposition ($\log Q_{canola}$) and canola price index ($\log P_{canola}$) were created. The price indices are adjusted to match the frequency of the grain disposition data (three times per year). The cleaned dataset contains 84 observations spanning 28 years. The primary variables include the total disposition of canola in metric tonnes and the price index for canola.

Figure 1.: This scatter plot shows the relationship between log-transformed canola price index vs. log-transformed canola production. The positive slope indicates a positive correlation between price and production, which aligns with economic expectations for supply behavior.

Figure 2.: This plot reflects the changes (differenced values) between log-transformed price index vs. log-transformed production. The color indicates the time lag, yellow for longer lags and dark purple for shorter. The clustering of points near zero suggests that changes in price and quantity are relatively small over short time intervals.

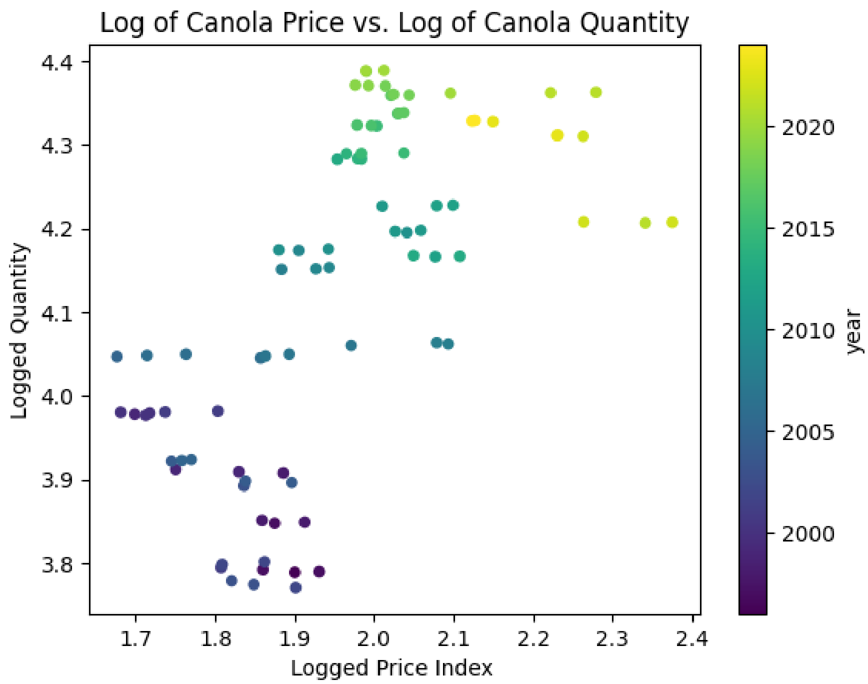

Figure 1. Log of Canola Price Index vs. Log of Canola Quantity

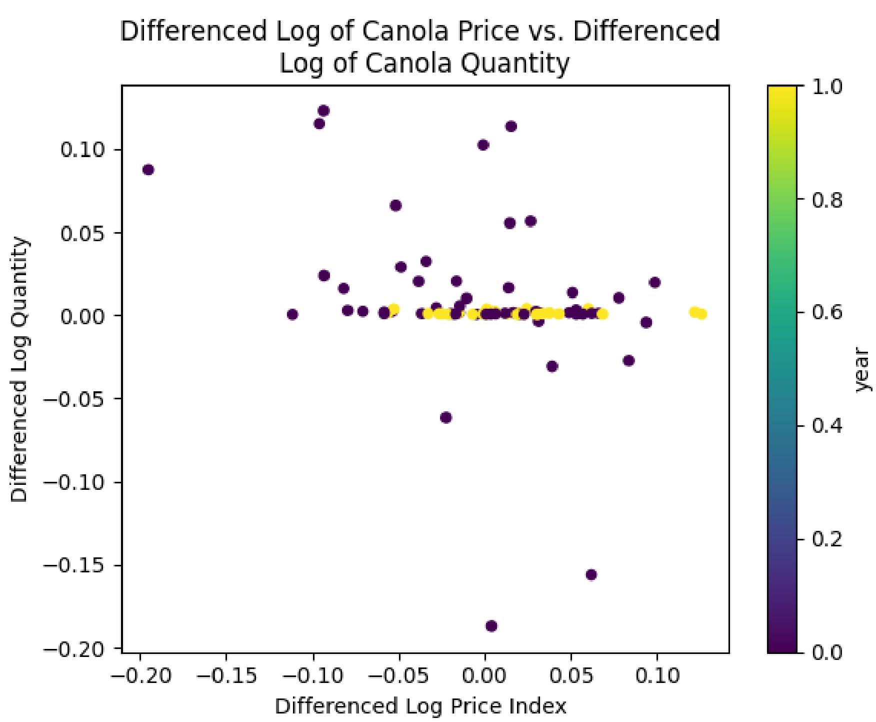

Figure 2. Differenced Log of Canola Price vs. Differenced Log of Canola Quantity

MODEL DESCRIPTION

The research question translates into a price shock (a 10% increase in the price of canola) to evaluate the potential change in production. The model captures long-run supply responses, where the producers of canola are assumed to have sufficient time to adjust their output over time in, response to market conditions. The model employes an ordinary least squares (OLS) framework, with a standard log-linear model. Log-transforming the variable allows the estimation to reflect percentage changes.

In practice, the price and the quantity are endogenous. They are determined simultaneously by the interaction of supply and demand. In equilibrium, each data point represents an outcome where the quantity supplied equals the quantity demanded, at a given market price. The structural model is as follows:

$$\log q_{it}^{S} = \alpha + \beta \log p_{it} + \gamma x_{it} + \eta_{it} \qquad \text{(Supply)}$$
$$\log q_{it}^{D} = \mu - \delta \log p_{it} + \kappa y_{it} + \epsilon_{it} \qquad \text{(Demand)}$$
$$\log q_{it}^{S} = \log q_{it}^{D} \qquad \text{(Equilibrium)}$$

- $\log {q_{it}}^{D}, \log {q_{it}}^{S}$: Log of canola quantities, demanded and supplied.
- $\log p_{it}$: Log of canola price index.
- α, μ: Constant terms for interception.
- η_{it}, ϵ_{it}: Error terms capturing unobserved factors affecting production.
- x_{it}, y_{it}: Exogenous supply and demand shifters, with coefficients γ, κ measuring their strengths.

The direct effect of the demand shifter (y_{it}) on quantity ($\log {q_{it}}^{D}$), holding all else constant, is captured by κ. However, it also has an indirect effect on both $\log p_{it}$ and $\log q_{it}$ simultaneously, making the price endogenous. To address this problem, we shall estimate the supply elasticity by isolating movements along the supply curve. In particular, we shall use a reduced-form model for our regression. The essential assumption is that the observed variation in prices is caused by shifts in the demand curve, while holding the supply curve stable. In other words, we assume there is no additional supply-side factors, such as input costs or technology. This allows us to observe how producers respond to changes in price, holding other supply-side factors constant.

ESTIMATION

Reduced-form model:

$$\log q_{it}^{S} = \alpha + \beta \log p_{it} + \eta_{it}$$

- $\log q_{it}{}^{S}$: Log of canola quantity supplied.
- $\log p_{it}$: Log of canola price index.
- α: Constant term for interception.
- η_{it}: Error terms capturing unobserved factors affecting production.

The key elasticity is the long-run price elasticity of supply (β). It represents the percentage change in canola production a 1% change in price, assuming constant elasticity across price and quantity levels.

In addition to the primary model, we include a differenced OLS model as a reference, to provide additional context to the analysis:

$$\Delta\log q_{it} = \alpha + \beta\Delta \log p_{it} + \eta_{it}$$

Differencing the data removes the long-term trends, and allows to capture short-run supply dynamics, where production adjustments are constrained by fixed inputs and immediate conditions within a single growing season.

The estimation results are presented in the regression table *Table 1*.

Table 1. Regression Results

	log_P_canola	log_P_canola_diff
log_Q_canola	0.512***	
	(0.066)	
log_canola_Q_diff		-0.418***
		(0.140)
Observations	84	83
R^2	0.427	0.099
Adjusted R^2	0.420	0.088
Residual Std. Error	0.119 (df=82)	0.052 (df=81)
F Statistic	61.100*** (df=1; 82)	8.920*** (df=1; 81)
Note:		*p<0.1; **p<0.05; ***p<0.01

RESULTS

Estimate

The estimated price elasticity of supply for canola β is approximately 0.512 (Column 1 of the regression table). This elasticity indicates that a 1% increase in canola price is expected to result in a 0.512% increase in canola production in the long run. The positive sign aligns with economic theory and the assumption of an upward-sloping supply curve, where higher prices incentivize greater production over time. Although the positive coefficient aligns with economic theory, that higher prices incentivize greater production, the value still suggests an inelastic response.

Significance and Goodness of Fit

The p-value for the coefficient is below the 0.01 threshold, which provides statistical evidence to reject the null hypothesis that the true elasticity is zero. This does not confirm that the estimated elasticity is constant across price and quantity levels, nor that the model fully captures the causal relationship between price and production. However, the result indicates a positive correlation between prices and production in the data, which can be utilized in predicting the amount increased in canola production. Additionally, the R^2 value of 0.427 indicates that the model explains 42.7% of the variation in canola production, which suggests moderate explanatory power.

Supplementary Model

Using differenced data, the model in Column 2 estimates the short-run price elasticity of supply for canola as -0.418. Despite being significant at $p < 0.001$ level, the $R^2 = 0.099$ reflects limited explanatory power. We shall not approach with this model because it does not align with economic theory as a valid estimate of price elasticity of supply. The negative coefficient is inconsistent with the expectation of an upward-sloping supply curve. Instead of interpreting it as an elasticity, this result may reflect noise in short-run data or potential confounding factors, which are not captured in the framework.

COUNTERFACTUAL ANALYSIS

This study attempts to estimate the magnitude of effect on CO2 emission with data from multiple sources. The regression model estimated a price elasticity of supply of 0.512, meaning that per 1% increase in canola price is expected to result in a 0.512% increase in canola production after the market has fully adjusted.

$$q_{t+1} = q_t \times (1 + 0.512\%)$$

The most recent measure of canola disposition is 21,325.3 metric tonnes (as of July 2024). Assuming the market reaches a long-run equilibrium after a 1% price increase, this would predict an additional in production of:

$$21325.3 \times (1 + 0.512\%) = 21434.49 \text{ metric tonnes}$$

or approximately 70882.34 tons annually.

The Canola Council of Canada reported the provincial share of canola production as follows: Saskatchewan 53%; Alberta 29%; Manitoba 17%. (Baron, 2021) And according to a report by the European Commission (EC), the greenhouse gas emissions from cultivation of canola in Canada, by province, are as follows, presented in *Table 2* (EC, 2016).

Single emissions (kg CO2eq/dry-ton)							Total emissions	
Province	Region	Seeding	Fertilizer Production	N2O field emissions	Pesticide production	Field operation	**(kgCO2eq /dry-ton)**	Eq / MJKg CO2
MB	RU 23	2.4	262.5	523.5	4.2	73.1	**865.7**	33
MB	RU 24	2.2	266.5	510.6	3.7	64.9	**847.9**	33
SK	RU 28	2.5	212.8	499.5	3.8	71.4	**790**	30
SK	RU 29	2.5	203.1	319.4	3.6	63.4	**592**	23
SK	RU 30	2.2	190.2	206.5	2.8	55.1	**456.8**	18
AB	RU 34	2.2	170.4	421.2	3.3	57.7	**654.8**	25
AB	RU 35	1.9	154.2	338.4	2.6	54.9	**552**	21
AB	RU 37	2.1	166.6	198.2	2.8	58.3	**428**	16

Table 2. (CO2 emissions from canola cultivation, by region)

Using the data from these two sources, with the predicted domestic production of canola, we are able to calculate: 1. The historical share of canola production, for each of the three provinces; 2. The estimated canola production, by province; 3. Estimated CO2 emission due to production expansion in these provinces. The calculation results are presented below in *Table 3*.

Predicted Production Increase, Based on 1% Price Increase (kilotons)	Provinces	Historical Production Share by Province (%) [1]	Predicted Increase in Production by Province (kilotons) [2]	Historical CO_2 Emissions (kg CO_2eq per kiloton of canola) [3]	Estimated CO_2 Emissions for Production Increase (kg CO_2eq)	**Total Estimated CO_2 Emissions (kg CO_2eq)**
70.88	Alberta	53%	37.57	544,933.33	20,471,859.40	**45,469,981.5**
	Manitoba	29%	20.56	856,800.00	17,612,276.78	
	Saskatchewan	17%	12.05	612,933.33	7,385,845.32	

[1]. Historical data according to *Canola Council*.
[2]. Calculated as total predicted increase times historical production share.
[3]. Historical data on CO2 emission per unit of canola produced, according to EC.

Table 3. (calculation based on per 1% increase in canola production)

A 1% increase in the price of canola seeds in Canada is estimated to result in approximately 45.47 kilotons of CO_2 emissions (45,469,981.5 kg CO_2-equivalents). And for a 10% price increase, this translates to 454.7 kilotons of CO_2 emissions.

DISCUSSION AND CONCLUSION

The analysis predicts that for every 10% increase in the price of canola, total CO_2 emissions from production would increase by approximately 454.7 kilotons CO_2-equivalents. This estimate reflects the environmental impact of expanded cultivation in response to price changes, driven by the high elasticity of supply. A provincial breakdown reveals that 99% of domestic canola production occurs in Saskatchewan, Alberta, and Manitoba, with Saskatchewan contributing the largest share of emissions, followed by Alberta and Manitoba.

Limitations and Potential Improvements

This study has limitations that could affect its findings. The small sample size ($n=84$) risks inflated Type-1 Errors. Statistical assumptions, such as normality, homoscedasticity, and error independence, remain untested. Violation to these assumptions can undermine the accuracy and efficiency of the OLS estimator, and therefore, weaken the model's prediction performance. These violations can also lead to underestimated standard errors, increasing Type-1 error rates, where the model falsely rejects the null hypothesis. Also, in practical settings, several factors may violate the assumption for the reduced form regression. For example, weather variability can lead to endogeneity by influencing both quantity yielded and market prices at the same time.

The next step of this analysis is incorporating an instrumental variable (IV) to address the endogeneity issue in the price variable. As demand shocks and supply shocks influence the price and quantity simultaneously, the reduced-form approach assumes the demand-side shifts dominant. The use of an IV, however, actively controls for endogeneity in the price variable. By leveraging an exogenous IV, which influences quantity only through price but no other unobserved factors, the it isolates the variation in price driven only by external factors.

Future work could expand the dataset to finer-grained or cross-sectional production data, and include additional variables to account for confounders. Alternatively, due to the likely dependency patterns in the time series data, a time series model can be used to capture autocorrelations and provide reliable prediction results.

Policy Recommendation

The notable rise in CO_2 emissions underscores the challenge of increasing agricultural production while reducing environmental impacts. Potential strategies are to continue promoting low-emission farming practices, and to invest in technological innovations.

Policymakers may consider introducing incentives such as subsidies or tax credits to encourage farmers to adopt sustainable cropping practices. For instance, early-planting is proven to be capable of both providing sustainable carbon footprints, and allowing economic flexibility in crop rotation plan, as suggested by the Canola Council of Canada (Baron, 2021). Policymakers may also support the innovation of new canola varieties that can produce higher yield per land use. According to the Canola Council of Canada, such advancements have already contributed to increased efficiency and reduced emissions over the past three decades (Baron, 2021). Considering the large scale of canola production in Canada, particularly in high-share provinces such as Saskatchewan, such sustainable practices can expect to be highly effective in mitigating the CO_2 emission due to expanded production.

Conclusion

In conclusion, the estimate of long-run price elasticity of supply suggests a positive responsiveness of canola producers to price increases in Canada. However, this high responsiveness also raises challenges in balancing the expansion in agriculture with reduction of carbon emissions. To address this, policymakers may implement mitigation policies, and thereby, promote a more environmentally friendly economy.

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