The Impact of Fruit Producer Prices on Nutrient Availability in North America: An Analysis of Calcium, Iron, Vitamin C, and Vitamin A

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Abstract

This research paper investigates the impact of producer prices for fruit on the availability of key nutrients—Calcium, Iron, Vitamin C, and Vitamin A—in North American countries, specifically The United States of America, Canada, and Mexico. The growing concern over the prevalence of nutrition deficits and the economic constraints to healthy eating means the economic determinants of nutrient availability need to be well researched. This paper uses both correlation analysis and linear regression to assess the relationship between producer prices and nutrient availability. Our findings indicate that the producer prices seem to have different impacts on nutrient availability among various countries and the nutrients involved.

Introduction

A lack of critical nutrients is a significant public health concern that directly affects the well-being and development of populations. Nutrient deficiencies in North America—particularly Calcium, Iron, Vitamin C, and Vitamin A—are issues that have been progressively raising concern among health professionals and policymakers. Price, availability, and other structural factors are meaningful barriers to fruit and vegetable consumption (Sacks et al., 2015). It is thereby necessary that the complex interplay between producer prices and nutrient availability is understood. Economic constraints are essential determinants of consumers' choices—for example, how much nutrient-rich food varieties like fruits are taken. High producer prices always translate to high retail prices, denying people the opportunity to include types of food with a rich supply of vitamins and minerals as part of their dietary intake. This can build up into a state of nutritional deficiency, which portends a great deal of health risk. However, there is an identified gap in the literature about how the specific impact of fruit producer prices on the availability of Calcium, Iron, Vitamin C, and Vitamin A might be.

Literature Review

Over the past few decades, researchers have focused on the relationship between economic factors and nutritional results. Research findings show that socioeconomic disparities in diet quality may be explained by the higher cost of a healthy diet, and food prices play an influential and vital role in the quality of diets, access to foods, and public health outcomes regarding nutrition (Darmon and Drewnowski, 2015). They concluded that economic constraints are a principal determinant of dietary choice, with the incentive towards less nutrient-dense foods at lower prices. According to them, most of the time, fruits and vegetables are priced higher than energy-dense, nutrient-poor foods, which lead to a diet low in essential vitamins and minerals. In addition, the study by Carlson and Frazão in 2014 built upon these results with the analysis of price elasticity with fruits and vegetables. Their research identified price volatility in agricultural markets as a critical factor influencing nutrient availability. They concluded that an increase in fruity and vegetable supplies leads to significantly reduced consumption, and this particularly affected lower-income families.

In a similar study, Monsivais and Drewnowski (2007) found that the continued increase in fruit prices over time has discouraged people who are economically vulnerable from raising their intake of such foods. Their analysis was rather longitudinal about dietary changes driven by relatively small increases in fruit prices. To some extent, the increased cost of such foods led to specific significant reductions in the intake of vitamins and minerals overall, thus contributing to public health problems related to nutrient deficiencies. The interaction of the effect of socioeconomic status on dietary behaviors has also been closely studied and reported. A study by Moore et al. strongly indicated that significant disparities concerning socioeconomic status greatly affected the accessibility of healthy, high-nutrient-dense foods. They found out that though higher-income families are resistant to price considering that they have a higher financial capability in making household food choices, people experiencing poverty tend to substitute away from nutrient-dense foods, which are typically more expensive when the cost rises.

The policy interventions for stabilizing the prices of fruits have been considered a potentially effective solution for mitigating the adverse effects on the availability of nutrients. The research by Powell and Chaloupka (2009) sought to determine whether there were targeted subsidies of a broad scope, promoting the consumption of fruits and vegetables. It turned out that targeted subsidies were associated with reduced prices and higher intake of primary nutrients, such as vitamins and calcium, from food; in particular, it was primarily observed in low-income and under-resourced groups, more effectively providing the policy levers related to better public health outcomes. Furthermore, Smith et al. (2013) cited international cases of successful government interventions to stabilize fruit prices based on case studies. According to them, countries with strong agricultural policies that supported the production of fruits and vegetables had increased nutrient access and no longer suffered from nutrient deficiencies; such approaches could be beneficial in North America.

Lately, diet affordability has been underlined as a worldwide issue. According to Our World in Data, 3 billion people's incomes do not allow them to buy a diet that would meet the nutritional recommendations (Ritchie, 2021). At the same time, such products have a significantly higher cost compared to energy-sufficient diets. Such economic inequality points toward the need for actions to lessen the cost of nutrient-dense foods. This issue is more emphasized in the report of FAO on pricing and affordability of healthy diets. It elaborates on some of the enormous economic barriers that many populations have to gain access to diets rich in essential nutrients for the body. It places a critical context within which food pricing policy has far-reaching implications for public health. A PLOS ONE study of 2023 looks into the other side of the coin about the economic determinants of dietary choices and, by extension, nutrient availability implications (Paiva, 2023). From the research, it can be inferred that economic constraints tend to strongly determine dietary patterns. Further, the NBER research brings out the economic mechanisms through which food prices can impact dietary quality; it provides ideas on the policy measures that can be taken to reduce the adverse effects of price variation on the availability of nutrients (Harding and Lovenheim, 2014).

The paper aims to contribute to this active research area by directly investigating how fruit producer prices impact nutrient availability (Calcium, Iron, Vitamin C, and Vitamin A) in North American countries.

Data and Methodology

For this analysis, data have been collected from the Food and Agriculture Organization of the United Nations (FAOSTAT) database, which contains a wide range of agricultural production and price information as well as nutrient availability. Two specific datasets are the Producer Price Dataset on average producer prices of different fruits by country and year, and the Nutrient Availability Dataset on the availability of Calcium, Iron, Vitamin C, and Vitamin A in respect of various countries for several years. Specifically, the dataset we use includes information from Canada, the United States of America, and Mexico covering the years 2010 to 2021.

Several data preparation tasks were involved in the preprocessing steps to ensure the data fit for the purpose of analysis. These steps were performed in a Google Collab notebook as it is a popular platform for data analysis and machine learning tasks. For this analysis, the programming language being used is Python. Google Collab also allows for the data to be displayed in various types of graphs which helps the user better interpret the results. The first step was to load the datasets into the Google Collab by importing them. This was then followed by grouping the producer price data into country-year categories using Pandas (a Python package for data analysis), where each combination's average producer price was calculated. Finally, the filtered nutrient availability dataset was merged with the grouped producer price dataset using country and year as keys to form one dataset for further analysis. The columns of the merged datasets are listed below.

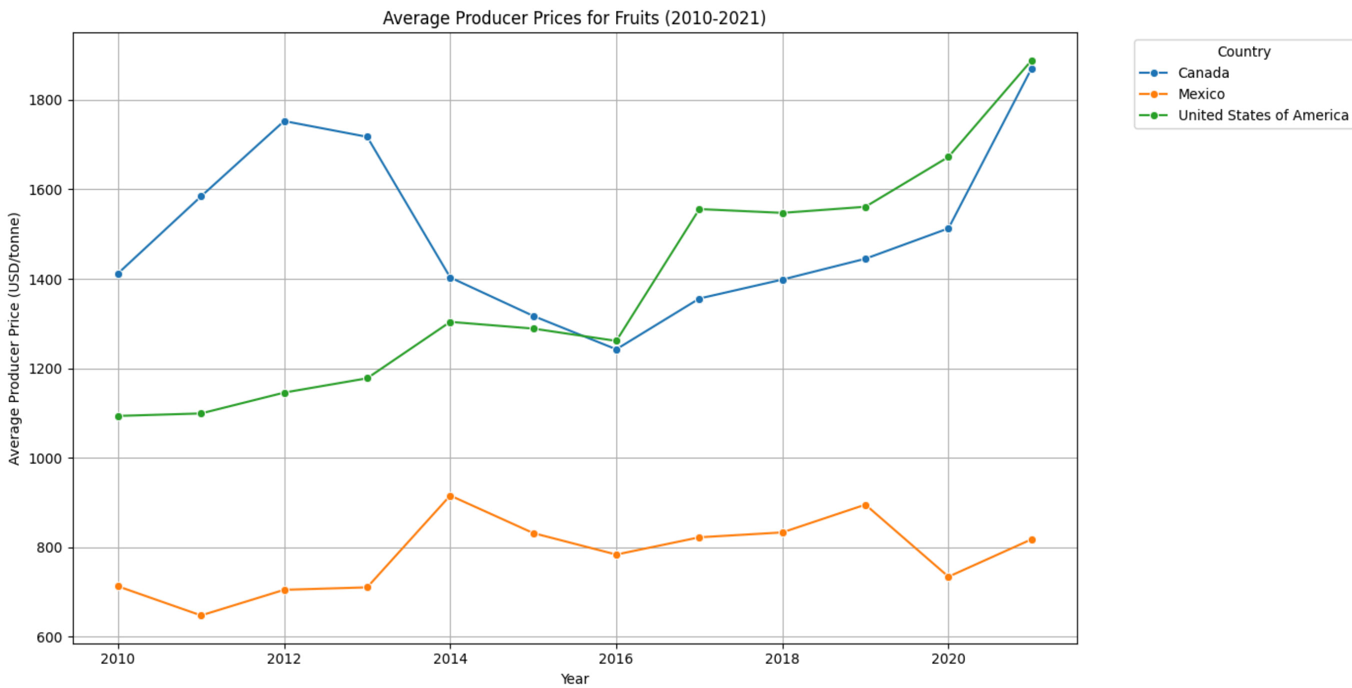
Area (Country)	Year	Indicator (type of nutrient)	Value (the amount of nutrients)	Average Producer Price

After preprocessing the data, a correlation data analysis was conducted to see the relationship between producer prices and nutrient availability. A correlation data analysis is a statistical method used to evaluate the strength and direction of the relationship between two or more variables. In this case, producer prices and nutrient availability are the two variables. Scatter plots of the correlation analysis were graphed to inspect the relationship within each country. Correlation analysis generates a number that determines the strength and direction of the relationship which is called the correlation coefficient. A positive number would signify that there is a positive correlation, meaning that as the producer prices for fruits increase, the availability of the specific nutrient also increases. A negative correlation indicates that as the producer prices for fruits increase, the availability of the specific nutrient decreases, and the zero correlation coefficient means there is no linear relationship between producer prices and nutrient availability.

Besides correlation analysis, we also developed linear regression models between the average producer prices and nutrient availability in each country. Linear regression is also a statistical method, and it is used to model and analyze the relationship between a dependent variable and one or more independent variables by fitting a linear equation to the observed data. We developed country-nutrient regression models; for each nutrient, the regression models were developed separately for every country. This gives us the ability to analyze more precisely how producer prices drive the nutrient supply in each specific geographical location. R-squared from linear regression is a measure that explains what portion of the variance in the dependent variable can be explained from the independent variable. It presents a view of how well the independent variable explains the variation of the dependent variable. Another metric we used is Root Mean Squared Error (RMSE) which gives the magnitude of the error between the predicted and the actual values. The higher the values of R-squared are, the better the explanatory strength of producer prices in explaining nutrient availability. RMSE quantifies the model's prediction accuracy. Low values mean that predicted and actual nutrient levels are close to each other.

Results

First, after displaying the trend of Average Producer Prices for Fruits from 2010 to 2021 using Google Collab, it was shown that the Average Producer Prices for Fruits in the United States of America and Canada generally increased throughout the time period. However, there was not a noticeable consistency in the Average Producer Prices for Fruits in Mexico from 2010 to 2021.



The results from the correlation analysis presented different correlation coefficients among the countries. In North America, the relationship between producer prices and nutrient availability has some variations: higher producer prices generally indicate lower availability of nutrients such as Calcium and Vitamin A in Canada and the United States, which suggests that an increase in costs could hinder access to essential nutrients. For example, Canada shows a negative correlation of -0.32 for Calcium and -0.41 for Vitamin A supply. In Mexico, there are positive correlations of 0.49 for Calcium and 0.34 for Vitamin A supply with higher producer prices.

Correlation between Producer Prices and Calcium supply:

Canada: -0.32

United States of America: -0.64

Mexico: 0.49

Correlation between Producer Prices and Iron supply:

Canada: 0.00

United States of America: 0.33

Mexico: 0.38

Correlation between Producer Prices and Vitamin C supply:

Canada: 0.12

United States of America: -0.61

Mexico: 0.54

Correlation between Producer Prices and Vitamin A supply (retinol equivalents):

Canada: -0.41

United States of America: -0.62

Mexico: 0.34

Correlation between Producer Prices and Vitamin A supply (retinol activity equivalents):

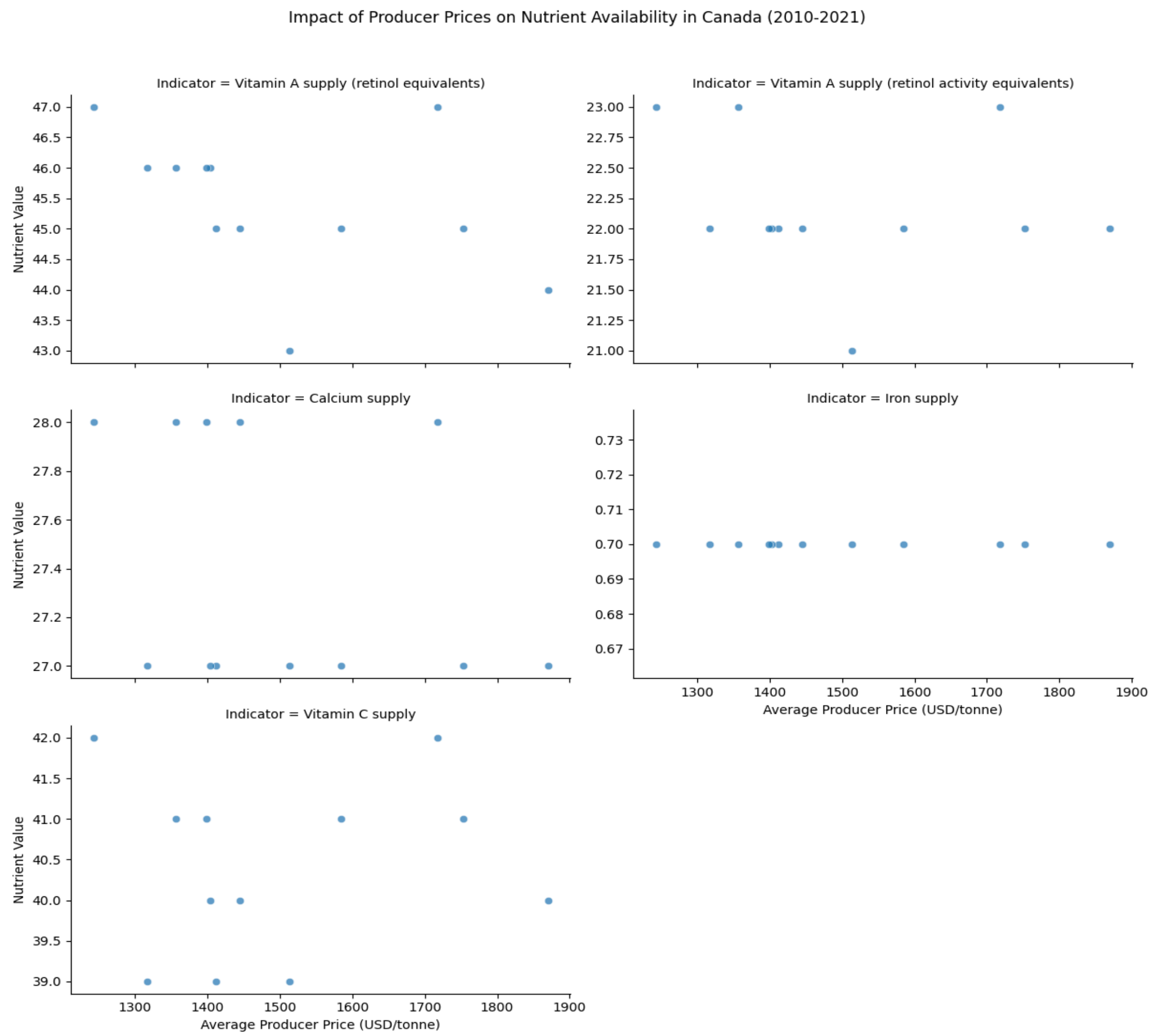
Canada: -0.16

United States of America: -0.77

Mexico: 0.35

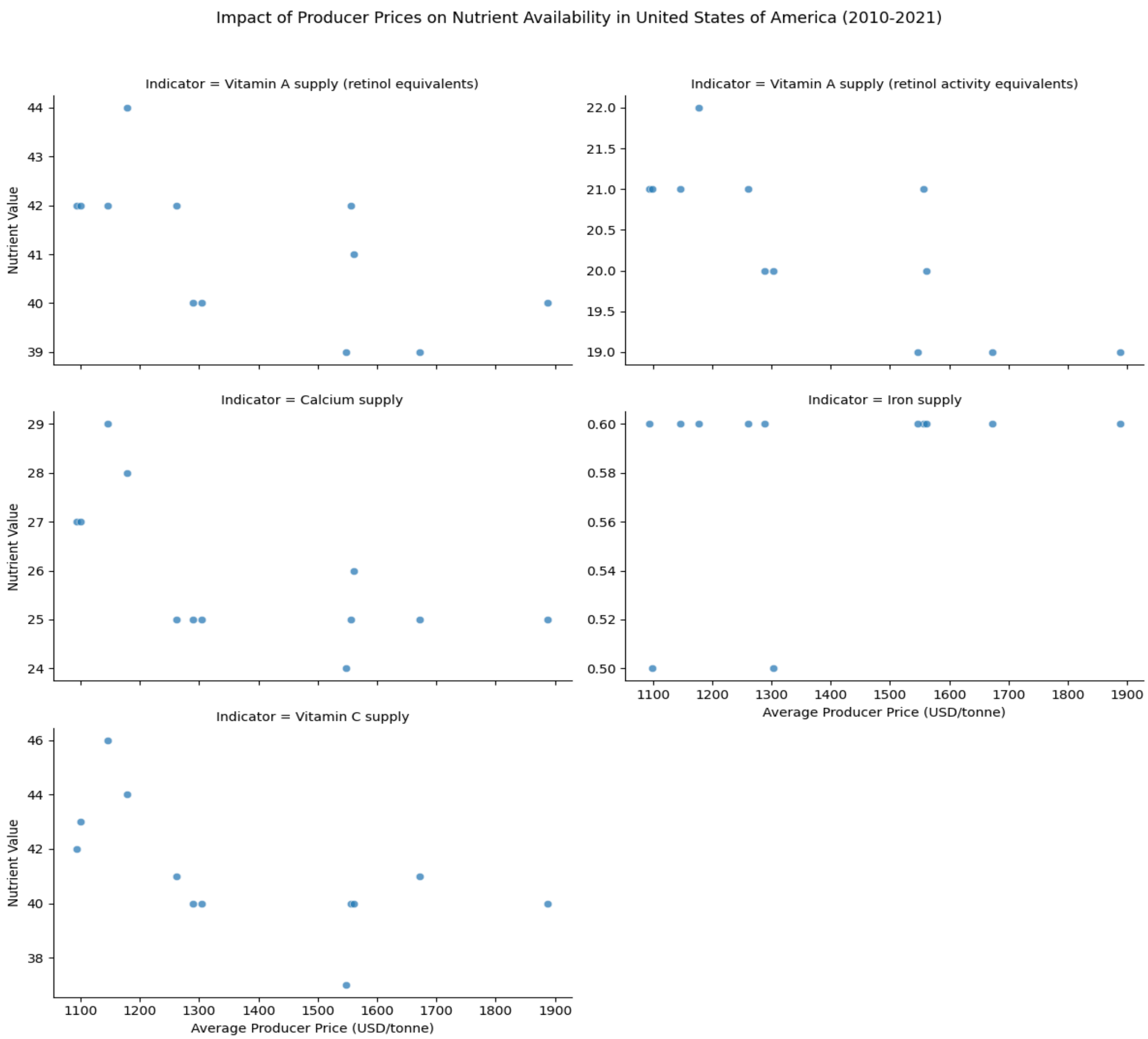
Canada Correlation Analysis

A negative correlation between the producer price and nutrient content for a host of nutrients is observed in the case of Canada. For instance, in the case of Vitamin A supply (retinol equivalents), it was -0.41, which means it was a moderate inverse relationship. This could even be further illustrated in the scatter plot, where higher producer prices correspond with lower Vitamin A levels that hold the estimated nutrient values between 43 and 47; the trend was also similar in the supply of calcium, which has a level of -0.32, where it was an indication that for producer prices that were increasing, calcium availability was indeed decreasing, with its values lying between 27.0 and 28.0. The correlation coefficient for Iron was 0, indicating that there was not a linear relationship. This could also be seen in the scatter plot which shows a flat line. The supply of Vitamin C was positively correlated at a weak level of 0.12. It meant that there was a little higher availability with a higher producer price, but the nutrient values were distributed in a range between 39.0 and 42.0.



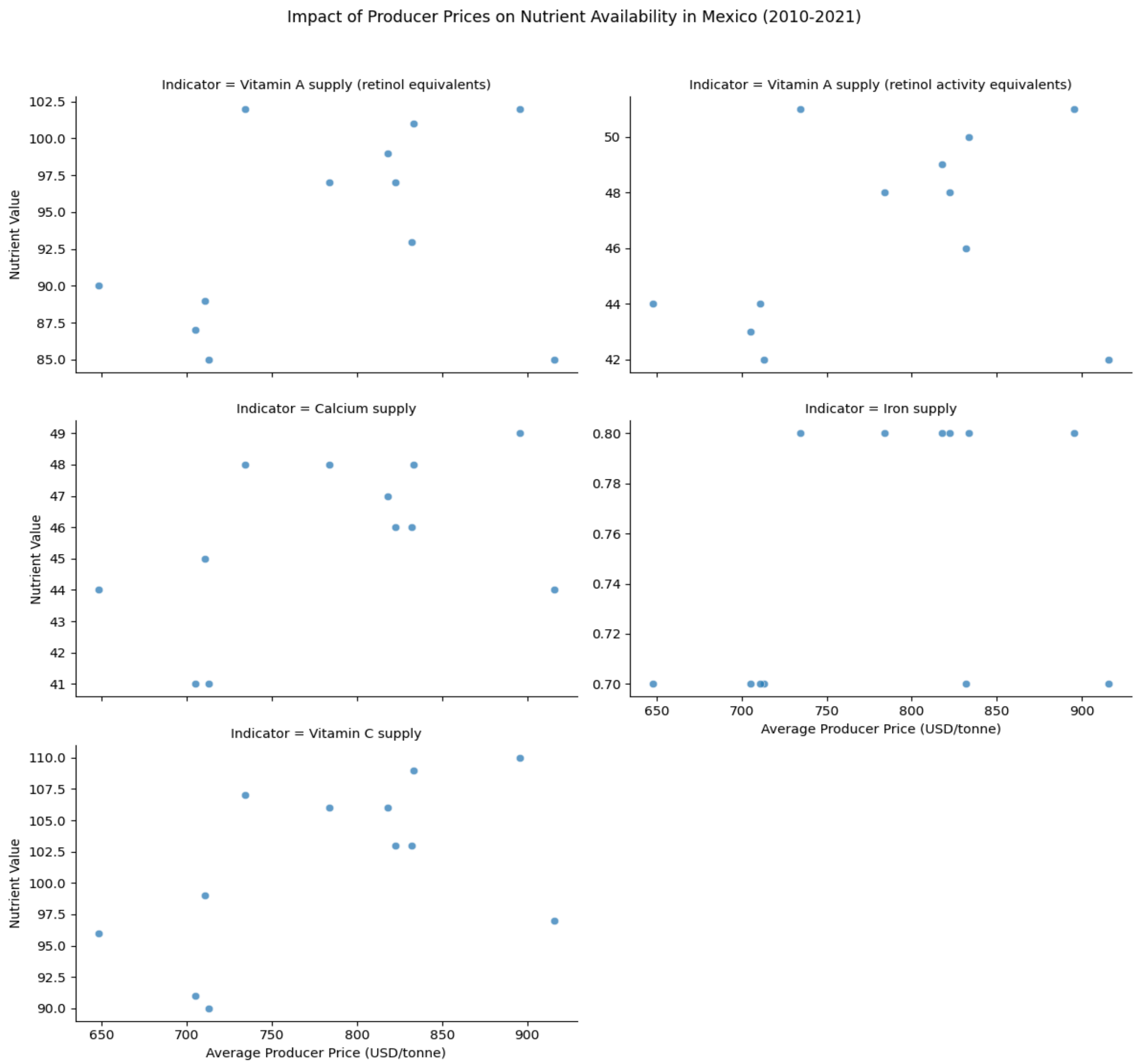
United States Correlation Analysis

The analysis showed that in the United States, producer prices were negatively correlated with nutrient availability for a number of key nutrients. The correlation coefficient for Vitamin A supply -retinol equivalents is -0.62 (strong inverse) where a simple scatter plot shows that higher producer prices are associated with lower Vitamin A levels and the nutrient value range is approximately 39-44. An even stronger negative correlation was observed with vitamin A supply (retinol activity equivalents) with a correlation of -0.77. Similarly high producer prices were negatively correlated (-0.64) with calcium supply indicating (lower calcium availability) which was 24 to 29. Iron supply had a small, positive correlation (0.33) showing an improvement in availability with higher producer prices. There was also a negative correlation between Vitamin C supply with the value of -0.61 revealing a strong inverse association between producer prices and Vitamin C availability, including nutrient values of 38 to 46.



Mexico Correlation Analysis

In Mexico, there were positive correlations between producer prices and nutrient availability for several major nutrients. The correlation with the Vitamin A supply (retinol equivalents) was a lean 0.34, suggesting a moderate positive relationship. In the scatter plot, we see that producer prices are also higher with increasing Vitamin A levels, with nutrient values falling



between approximately 85 to 102.5. This was consistent with the latter also showing a similar positive correlation (0.35) in vitamin A supply (retinol activity equivalents). A positive correlation (0.49) was observed for calcium supply, meaning that calcium availability increased with an increase in producer prices to 41-49. The correlation was moderately positive (0.38) for iron-supply, showing some positive relationship with producer value (values were scattered between 0.70 and 0.80). Last but not least, Vitamin C supply reported the highest positive correlation (0.54), indicating that producer prices are positively correlated with Vitamin C availability with nutrient values ranging from 90-110.

Canada Linear Regression

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generating linear regression model for nutrient Vitamin A supply (retinol activity equivalents) in Canada
The r2 is:  0.02654785062861509
The rmse is:  0.5453840044481715
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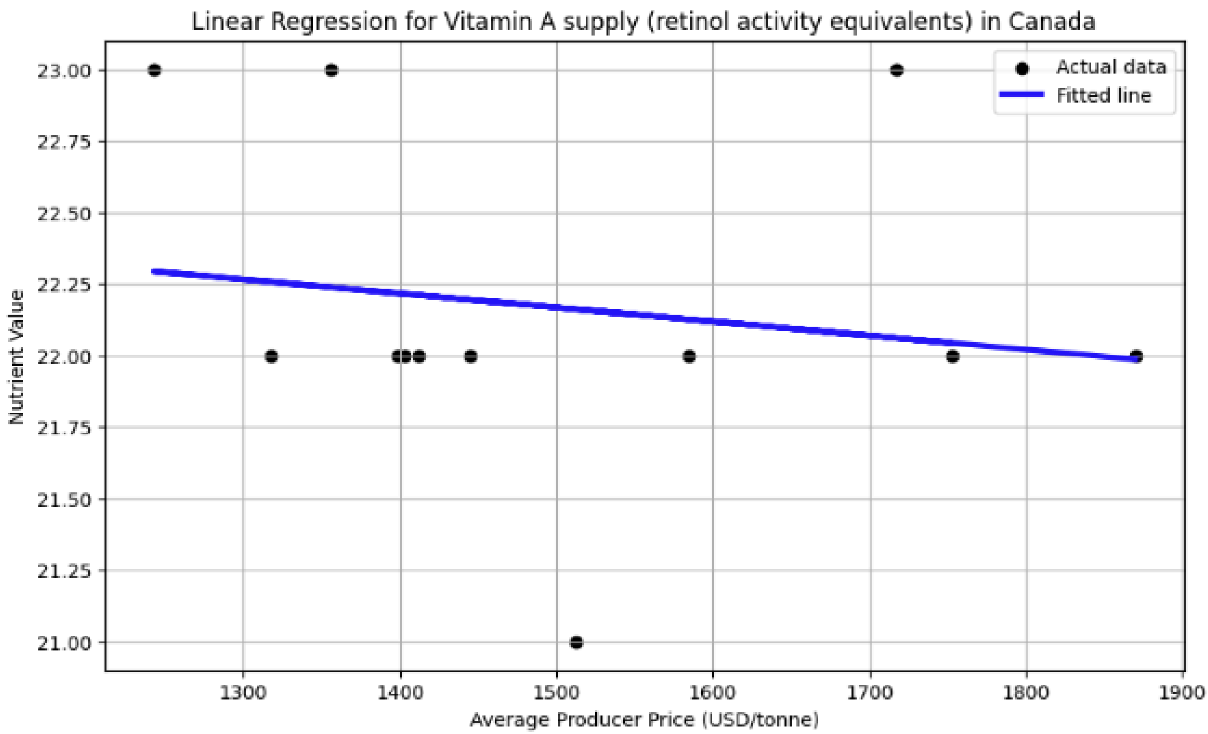

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generating linear regression model for nutrient Vitamin A supply (retinol equivalents) in Canada
The r2 is:  0.16703343231958967
The rmse is:  1.0175577229558905
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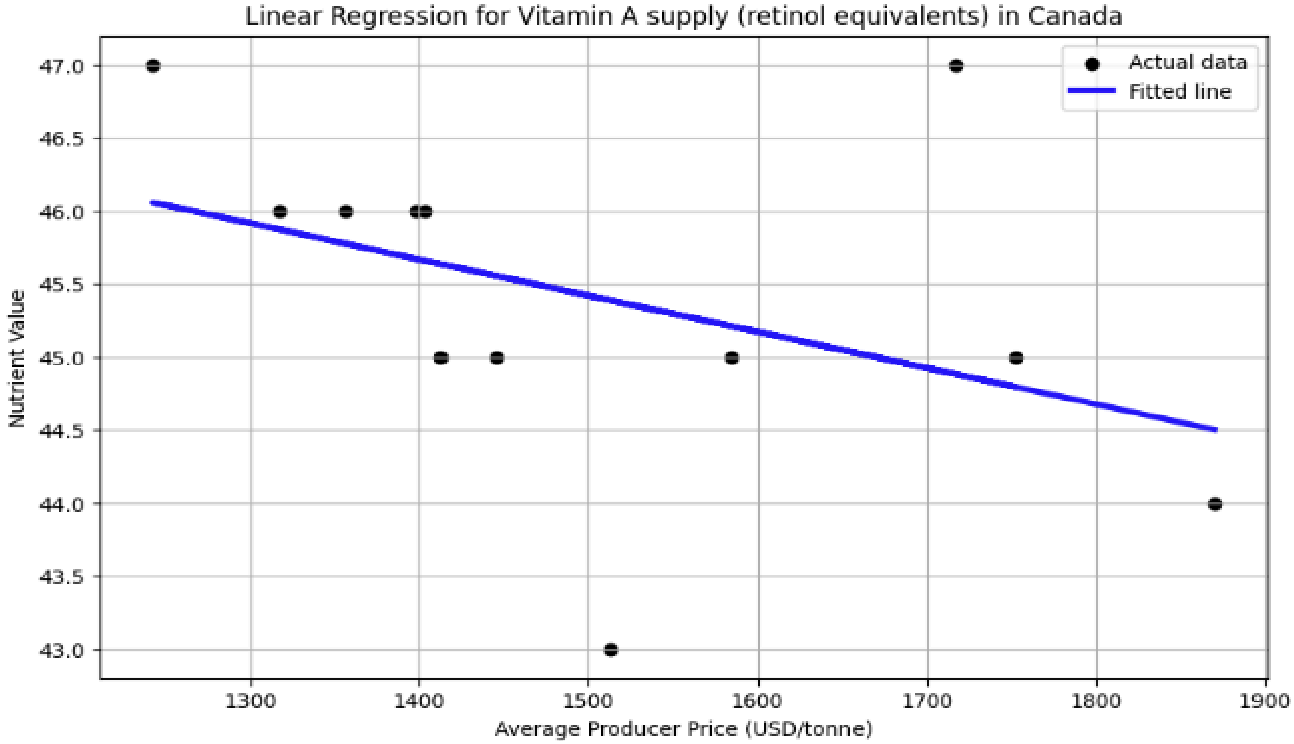


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generating linear regression model for nutrient Calcium supply in Canada
The r2 is:  0.10080582142181871
The rmse is:  0.46749774398026916
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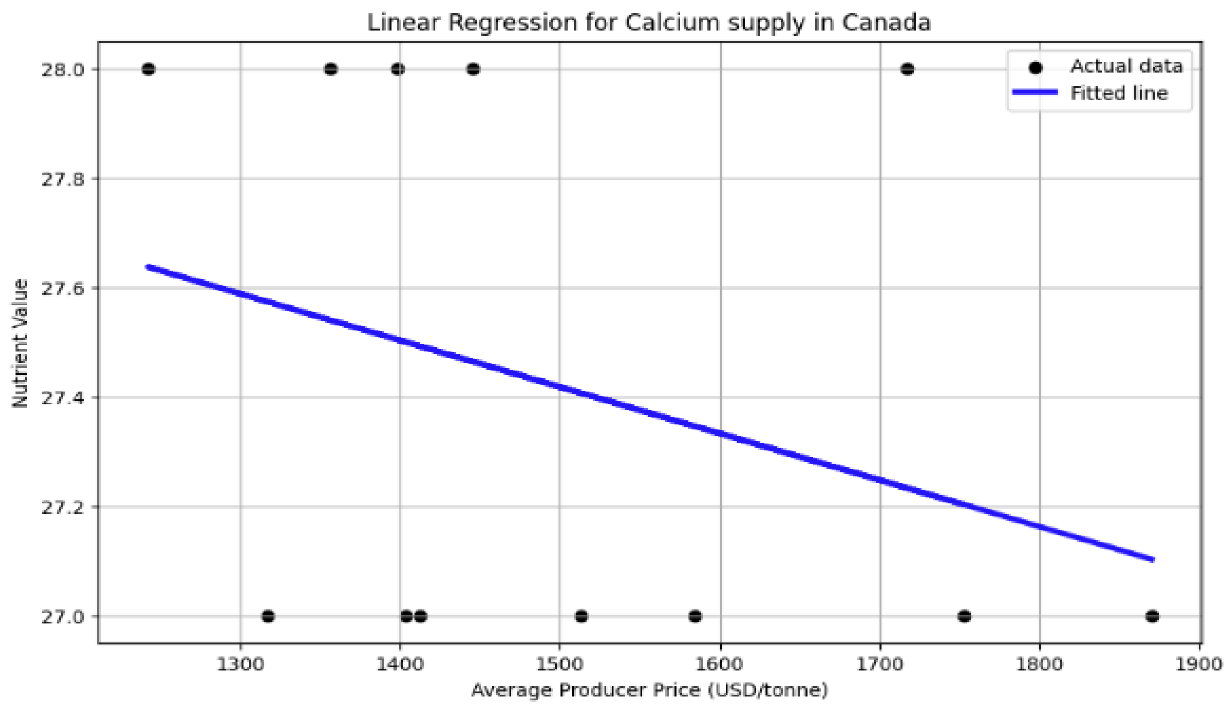

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generating linear regression model for nutrient Iron supply in Canada
The r2 is:  0.0
The rmse is:  1.1102230246251565e-16
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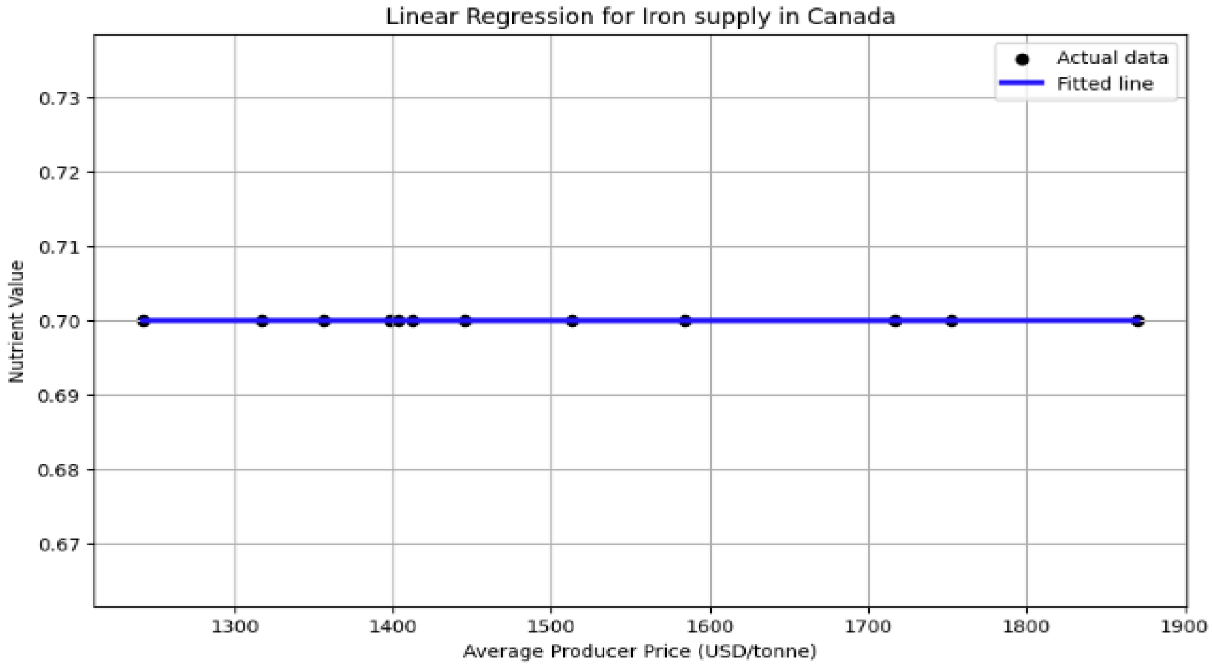


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generating linear regression model for nutrient Vitamin C supply in Canada
The r2 is:  0.013311397866249353
The rmse is:  1.0305632674077214
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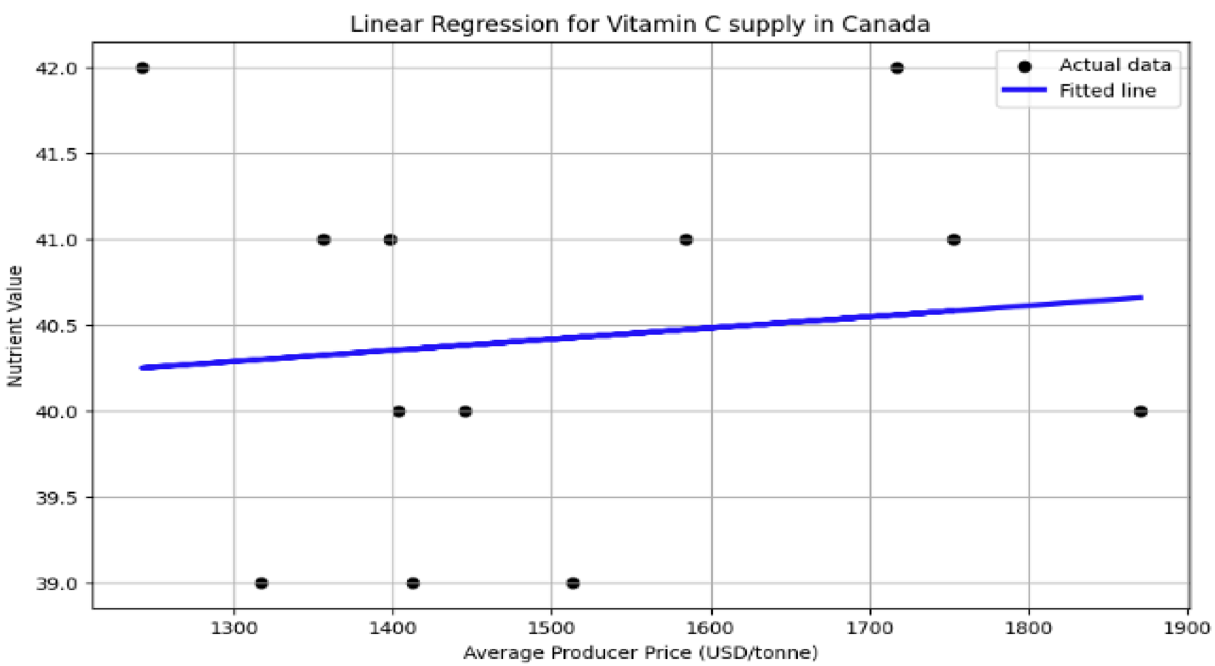

For Vitamin A supply (retinol equivalents), the R-squared value is 0.167, indicating that 16.7% of the variability in Vitamin A supply can be explained by producer prices, with an RMSE of 1.02. For Vitamin A supply (retinol activity equivalents), the R-squared value is 0.027, with an RMSE of 0.55, indicating a very weak relationship. The linear regression model for Calcium supply shows an R-squared of 0.101 and an RMSE of 0.47, indicating a weak correlation. The Iron supply model has an R-squared of 0, indicating no explanatory power. Vitamin C supply has an R-squared of 0.013 and an RMSE of 1.03, suggesting a very weak correlation.

<u>United States Linear Regression</u>

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generating linear regression model for nutrient Vitamin A supply (retinol equivalents) in United States of America
The r2 is:  0.38088124469935924
The rmse is:  1.1338127289852453
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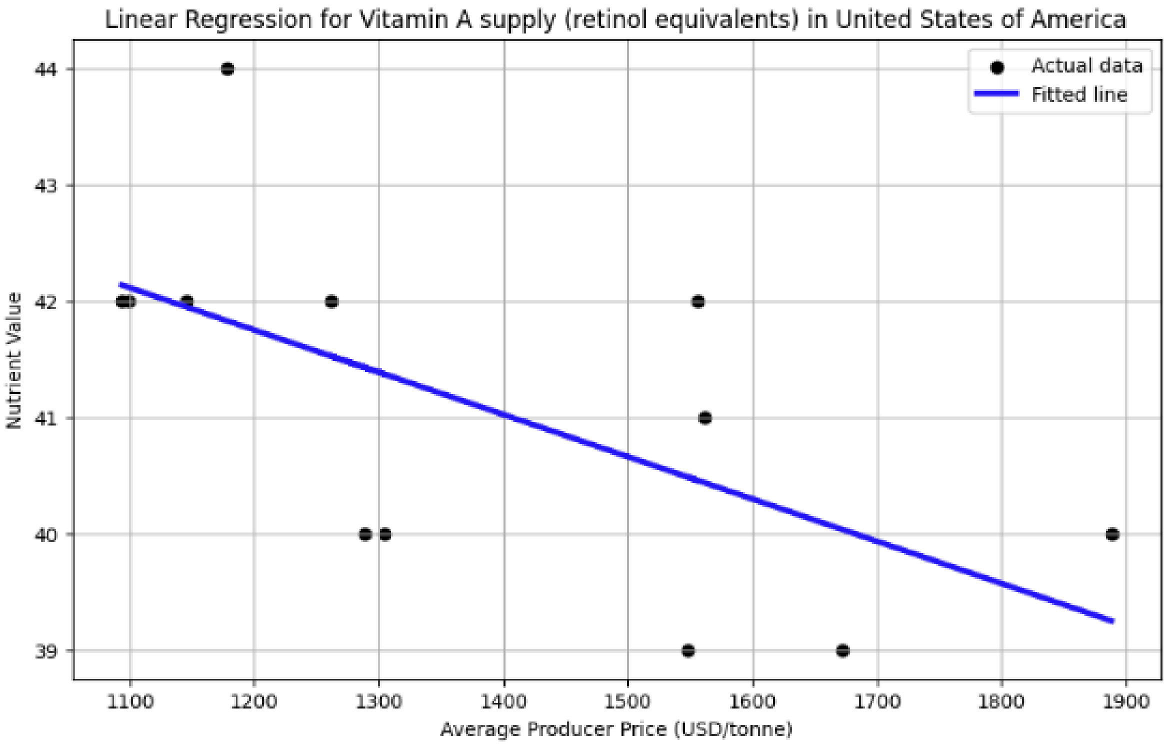

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generating linear regression model for nutrient Vitamin A supply (retinol activity equivalents) in United States of America
The r2 is:  0.5896968164550391
The rmse is:  0.6039155081042828
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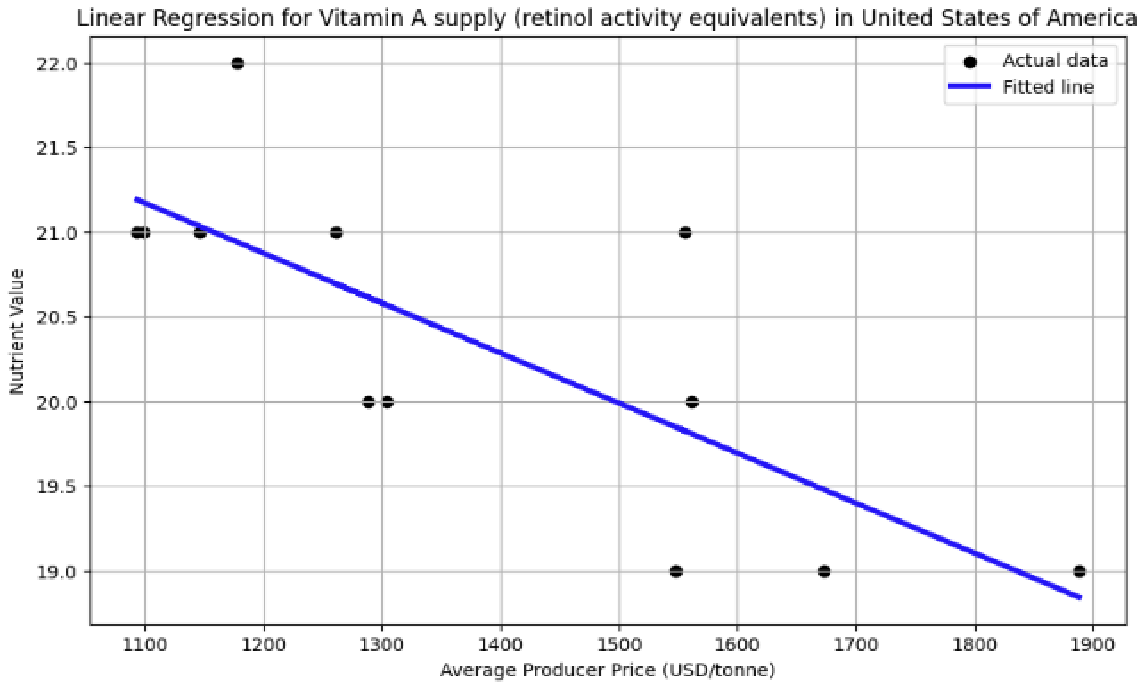


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generating linear regression model for nutrient Calcium supply in United States of America
The r2 is:  0.4052677653403757
The rmse is:  1.1112584775430525
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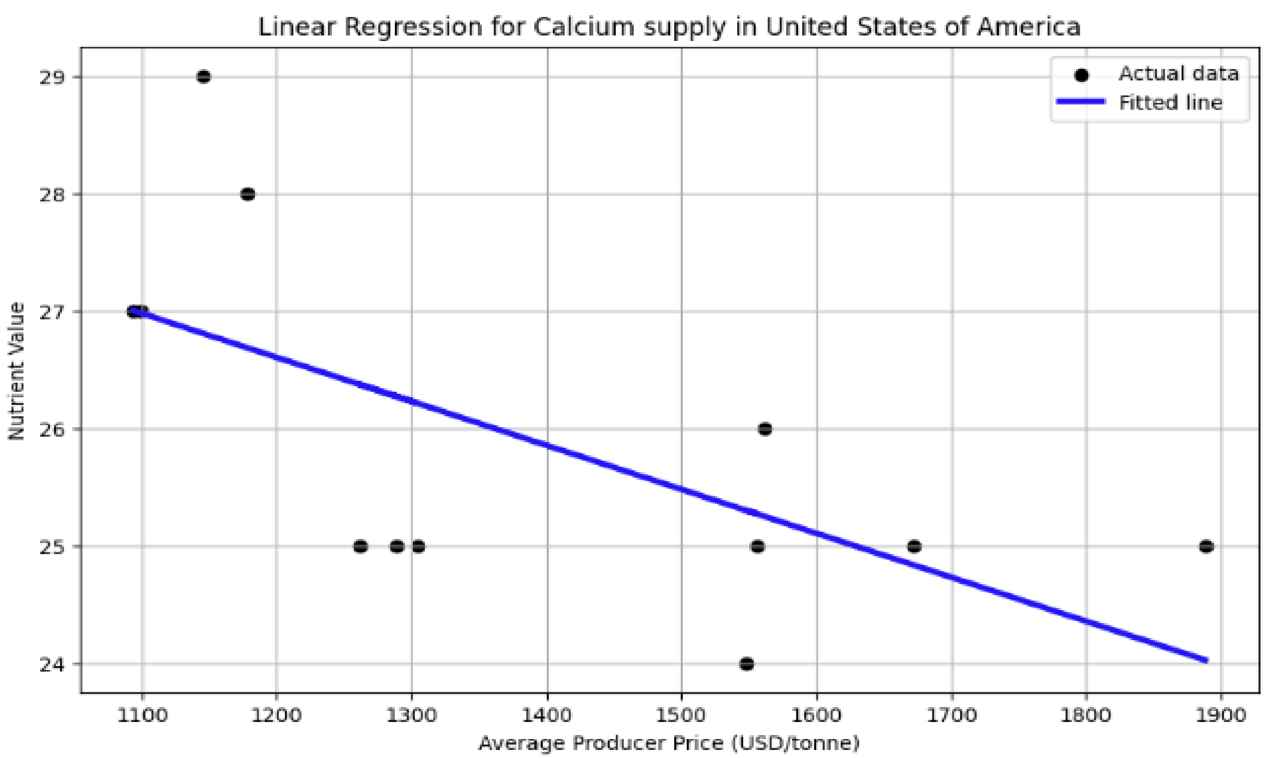

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generating linear regression model for nutrient Iron supply in United States of America
The r2 is:  0.10967253986943681
The rmse is:  0.035164839212599906
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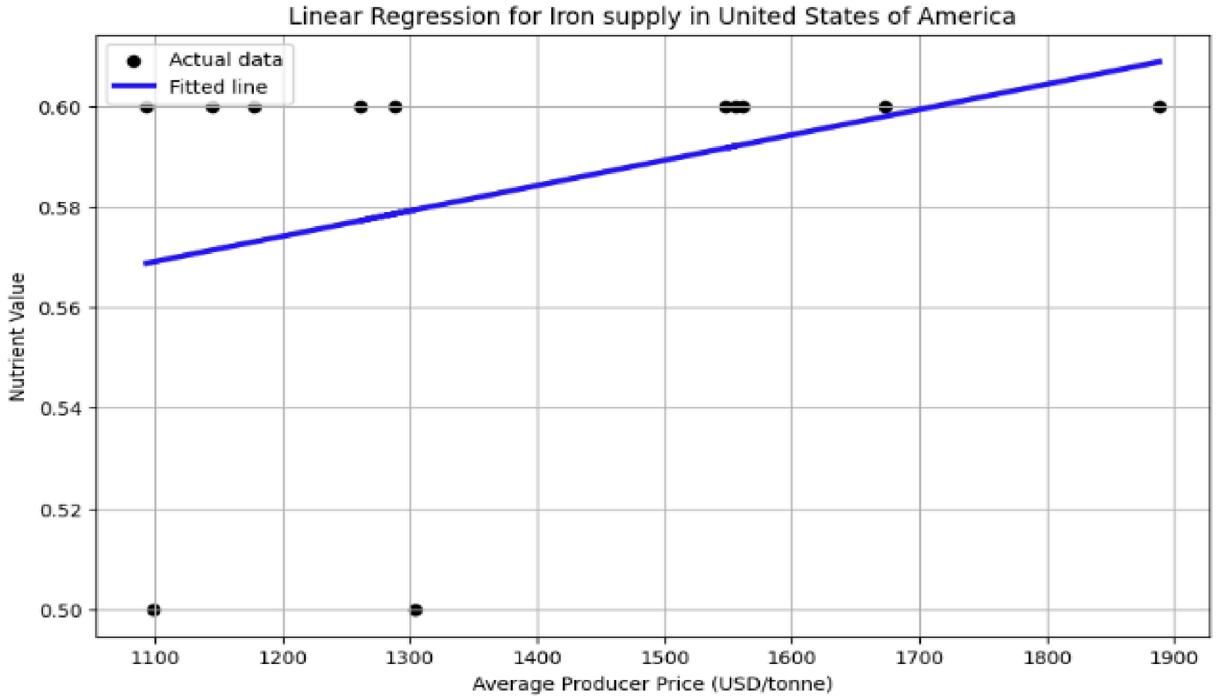


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generating linear regression model for nutrient Vitamin C supply in United States of America
The r2 is:  0.3721859605547789
The rmse is:  1.766813775798861
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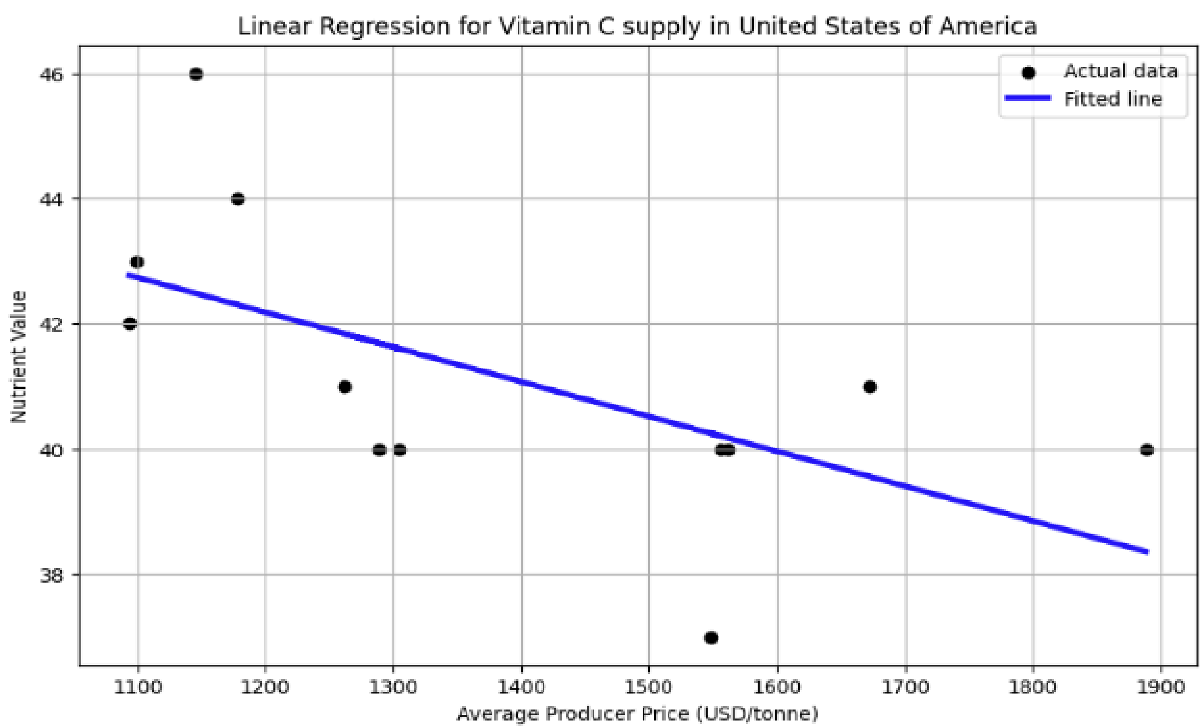

As far as the linear regression model for Vitamin A supply (Retinol Equivalents) goes in the United States of America, it turns out to be a more strong but somewhat still moderate relationship with an R-squared of 0.381 and an RMSE of 1.13. The R-squared value increased to 0.590 indicating a moderate to strong correlation for Vitamin A supply (retinol activity equivalents), a RMSE of 0.60. The model for Calcium supply shows R-squared=0.405, RMSE=1.11 (moderate). The R-squared value for Iron supply is 0.110 and its RMSE value is 0.035, suggesting there is a weak relationship. The supply of Vitamin C has an R-squared value of 0.372 and RMSE is 1.77, so there is a moderate correlation.

Mexico Linear Regression

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generating linear regression model for nutrient Vitamin A supply (retinol equivalents) in Mexico
The r2 is:  0.11249480547469215
The rmse is:  5.914079234083839
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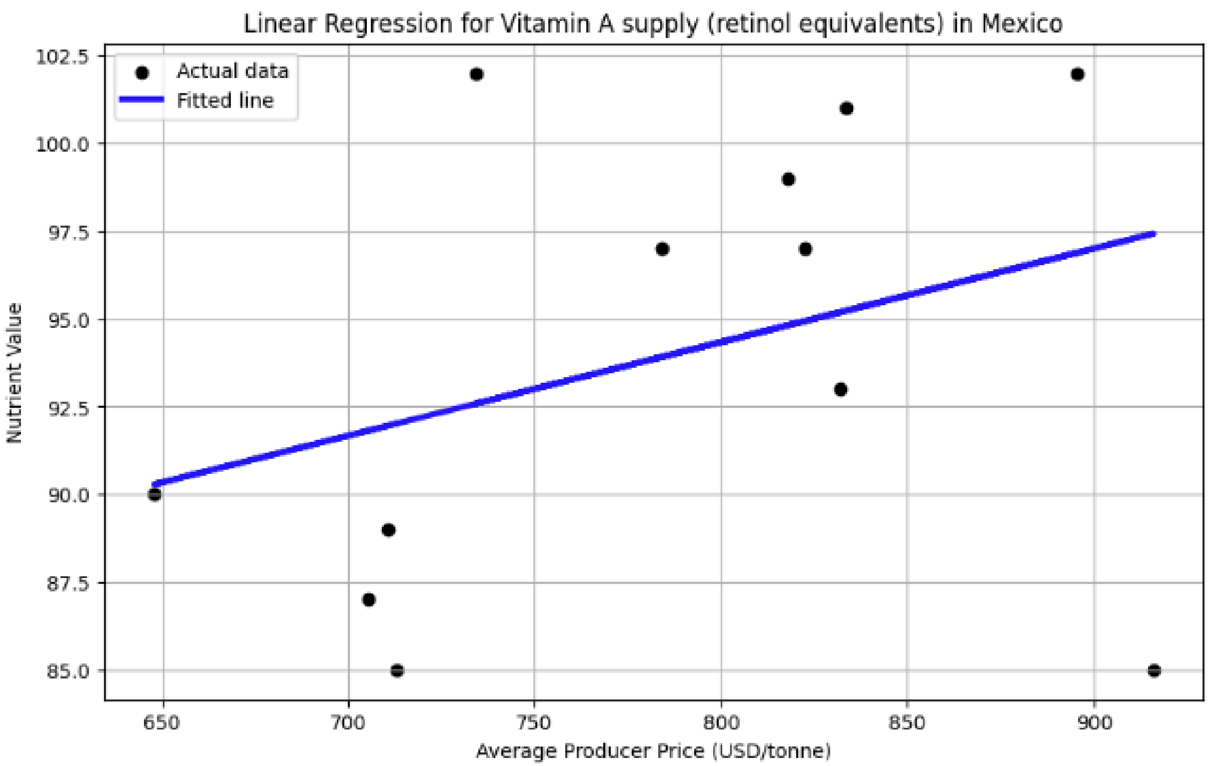

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generating linear regression model for nutrient Vitamin A supply (retinol activity equivalents) in Mexico
The r2 is:  0.12454085517777824
The rmse is:  3.067765604937718
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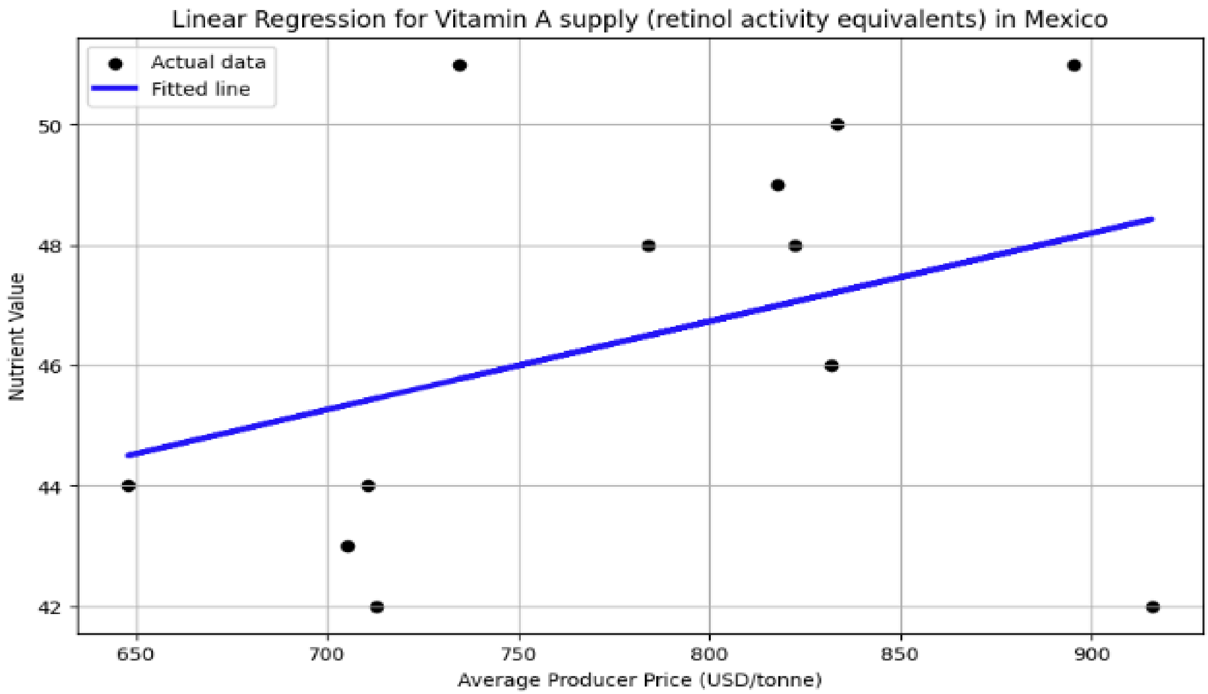


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generating linear regression model for nutrient Calcium supply in Mexico
The r2 is:  0.24436989763701344
The rmse is:  2.2291965838144288
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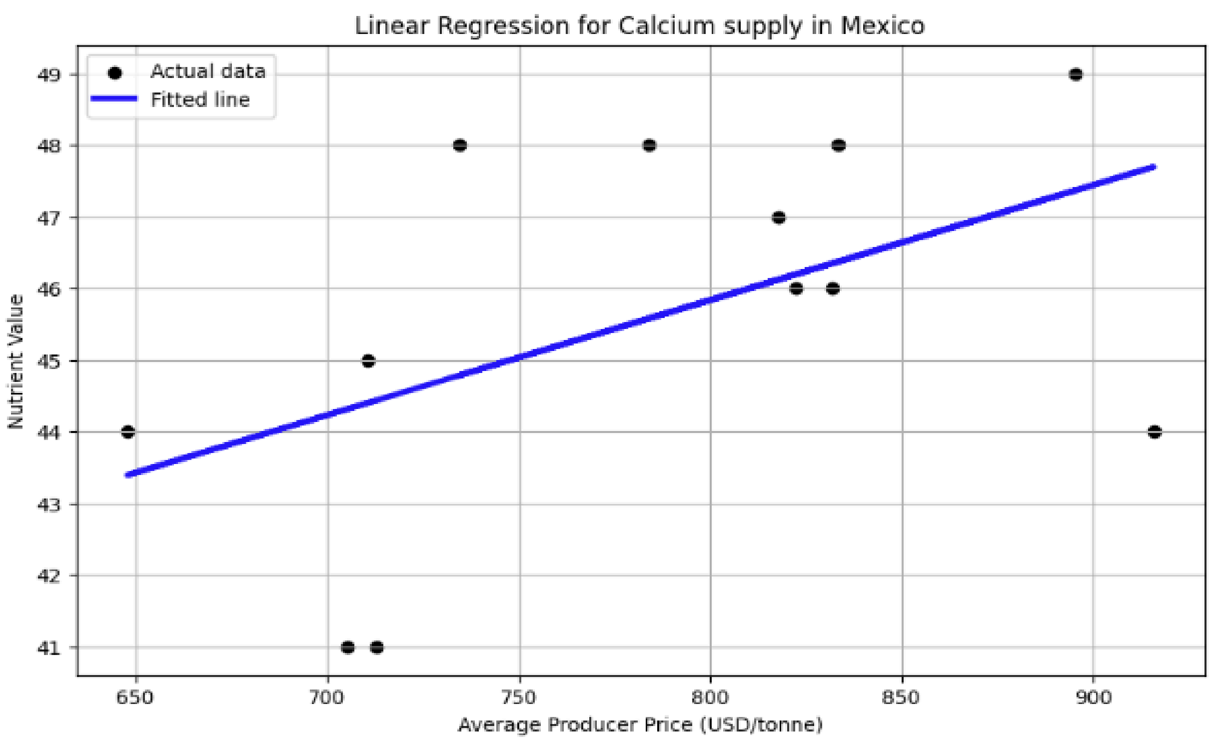

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generating linear regression model for nutrient Iron supply in Mexico
The r2 is:  0.14705630713308082
The rmse is:  0.046177475376716966
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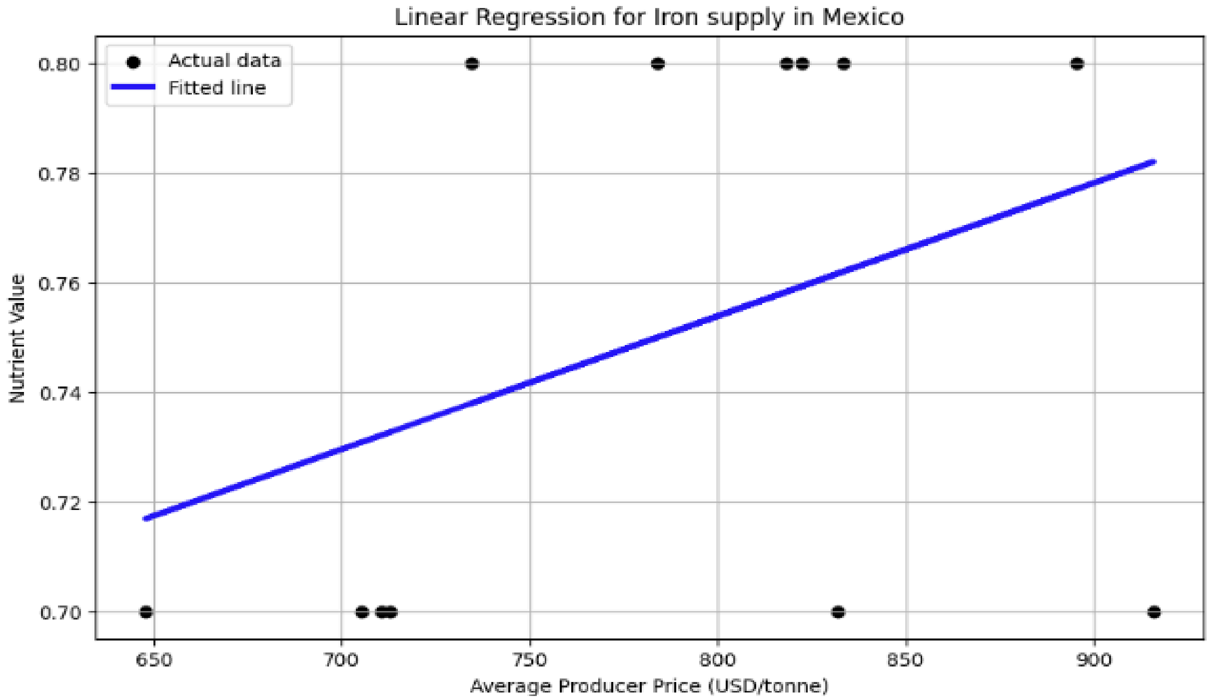


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generating linear regression model for nutrient Vitamin C supply in Mexico
The r2 is:  0.2915502075593164
The rmse is:  5.448938796644722
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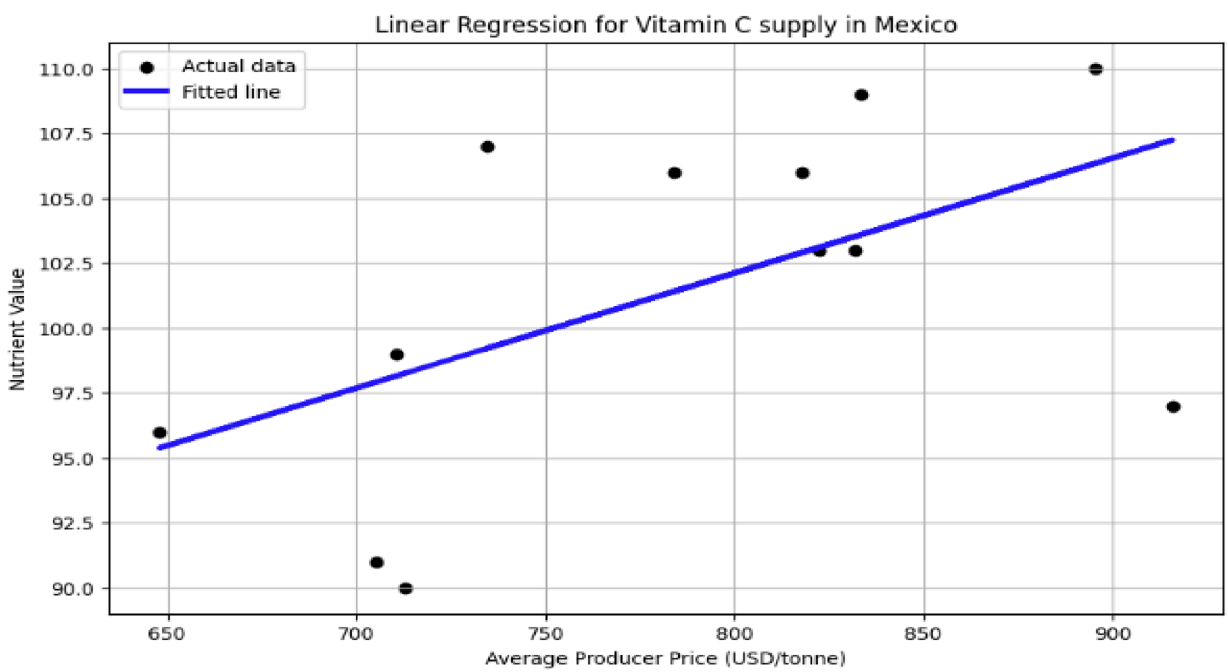

In Mexico, the linear regression model for Vitamin A supply (retinol equivalents) has an R-squared value of 0.112 and an RMSE of 5.91, indicating a weak correlation. For Vitamin A supply (retinol activity equivalents), the R-squared value is 0.125 with an RMSE of 3.07, indicating a weak relationship. The model for Calcium supply shows an R-squared of 0.244 and an RMSE of 2.23, indicating a moderate correlation. For Iron supply, the R-squared value is 0.147 with an RMSE of 0.046, suggesting a weak relationship. Vitamin C supply has an R-squared of 0.292 and an RMSE of 5.45, indicating a moderate correlation.

Discussion

Implications

The following results indicate that the impact of producer prices on nutrient availability widely varies not only from one country to another but also within individual countries, namely, Canada, the United States, and Mexico, and in line with the literature review conducted. In Canada and the United States, negative correlations exist between producer prices and the availability of Calcium and Vitamin A, meaning that higher costs can hamper access to these nutrients. For instance, Canada reported a correlation of -0.32 in Calcium supply and -0.41 in Vitamin A supply, and the United States had -0.64 in Calcium supply and -0.62 in Vitamin A supply. This would mean that an increase in the prices of fruits results in a reduced supply of these nutrients, therefore may culminate in more deficiencies of the same. The present analysis supports past research by Drewnowski and Darmon (2005) and Carlson and Frazão (2014), which suggest that economic restrictions become a driver to lower levels of nutrient-dense food consumption.

Contrary to this, Mexico demonstrates positive correlations between most nutrients and producer prices, where these positive correlations indicate increased nutrient availability. The correlation in Mexico is 0.49 for Calcium supply, and it is 0.34 for Vitamin A supply (retinol equivalents). The presented positive correlations between most nutrients and producer prices indicate increased availability of nutrients within the Mexican market possibly supported by their agricultural policies, as discussed by Smith et al. in their work on effective agrarian policies.

Linear regression models provide further insight, yet they also point out certain limitations. This is because the relatively low R-squared values of nutrients in all countries show that the producer prices alone poorly explain the variation in nutrient availability. For example, the R-squared of Vitamin A supply (retinol equivalents) for Canada is 0.167, meaning it only accounts for 16.7% of the variance of Vitamin A supply. Other factors, such as levels of income, dietary habits, and agricultural policies, likely have a huge impact on deciding the state of nutrient availability, as indicated by the findings of the report published by FAO on the pricing and affordability of healthy diets.

The linear regression model for Vitamin A supply (retinol activity equivalents) in the United States has a relatively higher R-squared of 0.590, indicating a stronger level of association with nutrient availability. However, the RMSE values for all models are overwhelmingly high and imply great error between the predicted and actual nutrient levels;

hence, nutrient level availability may require a multifaceted approach toward understanding and addressing this. The situation is not very different in Mexico; its R-squared values stand at 0.112 for the supply of Vitamin A in retinol equivalents and at 0.244 for Calcium. This reinforces the idea that even with some influence from producer prices, other variables have to be included in explaining nutrient availability trends.

Overall, these results stress how complicated the impact of economic factors is on nutritional outcomes. That this is different for countries indicates strongly that regional contexts—the economic conditions and the policies towards agriculture—largely determine the effect of producer prices on nutrient availability. Nutrition deficiencies are going to require varied strategies that take these points into account and promote affordable access to nutrients from foods to ensure a change in public health across North America. This corroborates the fact that there should be targeted subsidies and policy interventions made to stabilize food prices and better nutrient availability, as argued by Powell and Chaloupka (2009) and in Our World in Data.

Limitations

The data used for this study is very comprehensive from the FAOSTAT database; however, it may not capture all factors that have a bearing on nutrient availability. Other datasets or sources of information could offer additional insights to improve the robustness of the analysis. A second limitation is related to the fact that only three countries are considered in this study: Canada, the United States, and Mexico. They are likely to provide varied economic and agricultural backgrounds, but this does not imply that the findings can be generalized to other regions with different social and farming characteristics. Future research could benefit from including a broader range of countries to explore how producer prices affect nutrient availability in various global contexts.

Another limitation is the period of the data. Some data runs from 2010 to 2021, which is a reasonable period to cover, but it does not consider long-term trends or the impacts of recent economic or policy changes. The study period may be further expanded, or more recent data could be included in the analyses to give a broader picture of those observed trends and relationships. Not all the variations in nutrient availability can be explained by the producer prices, as evident in the relatively low R-squared value across most models. This, therefore, implies the working of other variables such as income levels, dietary habits, agricultural policies, and market dynamics that are crucial in determining the availability of nutrients. The study does not account for these additional factors.

Furthermore, linear regression models in the current study assume linearity in the relationship between producer prices and nutrient availability, which might oversimplify the fundamental dynamics. Nonlinear models or more sophisticated econometric techniques could better capture the subtleties of these relationships and provide more accuracy in prediction. Finally, the effect of external shocks on producer prices and nutrient availability is not taken into account. These could be factors that, when analyzed, will give a realistic assessment of the resilience and vulnerabilities in food systems across the countries studied. Though this research has produced many results on the relationship between producer price and nutrient availability, the findings within this framework may be cautioned in terms of limitations. Research in the future will have to take up the challenge of filling in these gaps to establish a much more comprehensive view of what nutrient availability is all about, and the information will assist in more appropriate policy.

Future Studies

One possible way to build on the limitations of the current study and find other dimensions of the relationship between producer prices and nutrient availability is through multivariate linear regression models. Such models could include several independent variables: levels of income, dietary habits, agricultural policies, and external shocks like natural disasters and pandemics, to explicate in a broader sense the factors that affect nutrient availability. Moreover, a broader geographic reach regarding country representation across diverse socio-economic and agricultural contexts would permit greater generalizability of the results. This would also allow researchers to pinpoint global patterns and regional differences in producer prices affecting nutrient availability. More extended studies could also shed light on the long-term trend and the effect of relatively recent economic or policy changes. The integration of more current data would capture the present situation in nutrient availability and the ongoing impacts of fluctuating producer prices. Future research should also consider using non-linear models or more advanced econometric techniques to capture the complexities of the relationships between producer prices and nutrient availability. This would help give more accurate and detailed forecasts with which to design policies more effectively by involving more effective interventions. These qualitative research methods could be interviews and case studies carried out at the same time as the quantitative analyses to provide insight into how these economic factors influence dietary choices and nutrient availability. This mixed methods approach would pave the way for more effective means of improving public health outcomes.

Citations

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