SUPPLY CHAIN VULNERABILITY

TO INTERNATIONAL TRADE COSTS:

AN APPLICATION TO AGRICULTURAL CHEMICALS

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Abstract

I develop a simple method for quantifying the increase in the level and volatility of international trade costs in recent years and the shifts in import sourcing that mitigated this vulnerability and increased supply chain resiliency. I apply the method to data for three industries in the U.S. agricultural chemical manufacturing sector. I find that the average level and volatility of international trade costs rose over the last ten years in all three agricultural chemicals industries, though shifts in import sourcing shares mitigated the increase in volatility. The magnitude of these changes and the contributions of specific source countries varied significantly across the three industries.

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1 Introduction

Imported inputs can provide a cost advantage to U.S. producers, but they can also increase their vulnerability to supply chain disruptions. U.S. producers can mitigate these risks by diversifying their import sourcing.[1] While some types of supply chain uncertainties are difficult to measure, including fluctuations in foreign production costs, changes in the direct costs of international trade are more easily quantifiable. These direct costs include tariffs and international freight costs.

There are a series of questions that we can investigate to better understand supply chain vulnerability to international trade costs. First, has the level and volatility of international trade costs risen over the past ten years, and if so by how much? Second, have U.S. importers taken steps to reduce their exposure to these trends? Is there evidence that U.S. importers adjusted their international sourcing to mitigate higher trade costs through diversification?

In this paper, I develop a simple empirical method for investigating these questions. The method can be easily applied to any imported commodities. It only requires publicly available data on U.S. imports. The method calculates changes in import sourcing over time within an industry and relates changes in sourcing shares to the volatility of trade costs over time and across countries.

I illustrate the method by applying it to three industries within the U.S. agricultural chemical manufacturing sector: nitrogenous fertilizer manufacturing, phosphatic fertilizer manufacturing, and pesticides. These industries are defined by NAICS codes 325311, 325312, and 325320. Table 1 reports summary statistics for U.S. imports in each of these three industries. The data on U.S. import values in 2017 are from the U.S. International Trade

[1] There is a large and expanding literature on how global supply chains have evolved to deal with different types of uncertainty and other economic conditions. Recent theoretical contributions include Jiang, Rigobon and Rigobon (2020) and Antràs and De Gortari (2020). Recent theoretical contributions are summarized in Antràs (2020).

Commission's Trade Dataweb.[2] The calculations of U.S. import penetration rate in 2017 use import and export data from this website, and the value of total shipments of each industry from the 2017 Economic Census.[3] The import penetration rate for each industry is the ratio of the value of its imports to the sum of the value of its imports and the total value of shipments of U.S. producers net of their exports.

Imports were a significant share of total supply in all three U.S. industries. Of the three, phosphoric fertilizers had the largest value of U.S. imports in 2017 and the largest import penetration rate, while pesticides had the smallest value and penetration rate.

Table 1: Summary Statistics for U.S. Agricultural Chemicals Industries in 2017

Industry	Total U.S. Imports ($ Billion)	U.S. Import Penetration Rate (%)
Nitrogenous Fertilizers	3.29	38.84
Phosphatic Fertilizers	3.66	52.99
Pesticides and Other Agricultural Chemicals	1.92	14.68

In the empirical analysis below, I find that the average level and volatility of international trade costs rose over the past ten years in all three agricultural chemicals industries, though shifts in import sourcing shares mitigated the increase in volatility. The magnitude of these changes and the contributions of specific source countries varied significantly across the three industries.

The rest of the paper is organized into six sections. Section 2 describes the data and analytical approach. Sections 3, 4, and 5 apply the method to the three industries, one at a time. Section 6 reports and econometric analysis. Section 7 concludes.

[2]These trade data are publicly available at `https://dataweb.usitc.gov/`.

[3]These U.S. shipments data are publicly available at `https://www.census.gov/programs-surveys/economic-census/data/tables.html`.

2 Data and Analytical Approach

I measure international trade costs as the ratio of the landed duty-paid value of U.S. imports to their customs value.[4] The landed-duty paid value includes freight and insurance costs of importing as well as duties. I calculate this trade cost measure for each industry, source country, and year. I examine the most recent ten years of trade data. I divide these ten years equally into two five-year time periods, 2012–16 and 2017–21.

Next, I calculate a weighted average trade cost for each industry in each year. I average across the countries using annual import customs values as weights. I calculate the mean value of these industry-year trade costs for each industry in each five-year period. Then, as a measure of variation in the trade cost measure, I calculate the standard deviation of the industry-year trade costs, again for each industry and period. Finally, to make the measure of variation comparable across countries and time periods, I calculate the coefficient of variation, which is the ratio of the standard deviation to the mean. I examine how these three summary statistics changed between the two time periods, how country-specific changes in the coefficient of variation correlated with the changes in the countries' import sourcing shares, and how much additional variation in industry-period trade costs there *would have been* if the import sourcing shares had not shifted between the two periods.

3 Nitrogenous Fertilizers

Table 2 reports the top ten countries of origin of U.S. imports of nitrogenous fertilizers in 2017, the midpoint of the ten years and an Economic Census year in the United States. Together these ten countries accounted for 87.02% of industry imports in 2017. Canada and Trinidad and Tobago each accounted for over a quarter of the total. The top ten also include Russia, China, and smaller, petroleum-producing countries.

[4]These data are available at `https://dataweb.usitc.gov/`.

Table 2: Nitrogenous Fertilizers:
Top Ten Import Sources in 2017

Country of Origin	Share of U.S. Imports (%)
Canada	28.91
Trinidad and Tobago	23.95
Qatar	8.76
Russia	6.89
Saudi Arabia	4.38
United Arab Emirates	4.04
China	3.34
Egypt	2.41
Kuwait	2.38
Algeria	1.96
Total for the Top Ten	87.02

Table 3 reports the coefficient of variation and the share of each of the top ten source countries in the two time periods. For seven of the ten countries, the coefficient of variation in trade costs and the sourcing share moved in opposite directions, suggesting shifts in international sourcing to reduce exposure to trade cost volatility.[5] The coefficient of variation fell in Canada, Russia, and Algeria, while the countries' shares rose. The coefficient of variation rose in Trinidad and Tobago, United Arab Emirates, China, and Kuwait, while their shares fell. (The three exceptions were Qatar, Saudi Arabia, and Egypt.) Overall, import sourcing became more concentrated: the combined shares of the top ten countries increased from 80.47% to 85.34%.

Next, I focus on statistics that aggregate over the source countries. Table 4 reports that the mean, standard deviation, and coefficient of variation of the industry-year trade costs all increased from the first period to the second. This is reflected in differences between the second and first columns of numbers in Table 4. The third column of numbers recalculates

[5]This simple comparison is meant to be indicative but is not conclusive: there are many other factors that contributed to the changes in sourcing shares in these industries, and the numbers in the table are not trying to control for these other factors.

Table 3: Nitrogenous Fertilizers:
Changes in Volatility and Sourcing Shares

Country of Origin	2012-16 Coefficient of Variation	2017-21 Coefficient of Variation	2012-16 Sourcing Share	2017-21 Sourcing Share
Canada	0.0097	0.0077	23.19	28.23
Trinidad and Tobago	0.0149	0.0214	27.79	19.75
Qatar	0.0054	0.0203	5.55	10.67
Russia	0.0206	0.0190	8.63	12.46
Saudi Arabia	0.0158	0.0320	3.26	4.87
United Arab Emirates	0.0030	0.0326	2.50	1.74
China	0.0226	0.1102	5.08	1.03
Egypt	0.0225	0.0108	1.88	1.66
Kuwait	0.0115	0.0202	2.08	0.74
Algeria	0.0149	0.0137	0.51	4.19
Total for the Top Ten			80.47	85.34

the statistics for 2017–2021 using counterfactual sourcing shares from the earlier period (2012–16), *as if the sourcing shares had not shifted*. The actual shift in shares between the two periods increased the mean in the second period but reduced the standard deviation and coefficient of variation. This is reflected in the differences between the third and second columns of numbers in Table 4.

Table 4: Nitrogenous Fertilizers:
Industry-Year Trade Costs in the Two Time Periods

Summary Statistic	In 2012–16 Using Actual 2012-16 Shares	In 2017–21 Using Actual 2017-21 Shares	In 2017–21 Using Counterfactual 2012-16 Shares
Mean	1.0664	1.0876	1.0372
Standard Deviation	0.0082	0.0118	0.0260
Coefficient of Variation	0.0077	0.0108	0.0251

4 Phosphatic Fertilizers

Table 5 reports the top ten countries of origin of U.S. imports of phosphatic fertilizers in 2017. Together these ten countries accounted for almost all industry imports in 2017. Canada was the top source, accounting for over half of all imports, and Russia and China were again significant sources.

Table 5: Phosphatic Fertilizers:
Top Ten Import Sources in 2017

Country of Origin	Share of U.S. Imports (%)
Canada	58.92
Morocco	13.28
Russia	9.34
Israel	3.62
Belarus	3.24
China	2.76
Germany	1.85
Belgium	1.61
Mexico	1.26
Chile	0.62
Total for the Top Ten	96.50

Table 6 reports the coefficient of variation and the sourcing share of the top ten source countries in each of the two time periods. For eight of the ten countries, the coefficient of variation in trade costs and the sourcing share moved in opposite directions, again suggesting shifts in international sourcing to reduce exposure to trade cost volatility. The coefficient of variation fell in Morocco, Belarus, and Belgium, while the countries' shares rose. The coefficient of variation rose in Canada, Russia, Israel, China, and Chile, while their shares fell. (The two exceptions were Germany and Mexico.) Overall, import sourcing became significantly less concentrated: the combined shares of the top ten countries decreased from 97.43% to 89.10%.

Table 6: Phosphatic Fertilizers:
Changes in Volatility and Sourcing Shares

Country of Origin	2012-16 Coefficient of Variation	2017-21 Coefficient of Variation	2012-16 Sourcing Share	2017-21 Sourcing Share
Canada	0.0050	0.0136	67.27	53.64
Morocco	0.0096	0.0050	6.44	10.97
Russia	0.0116	0.0157	9.73	9.40
Israel	0.0156	0.0195	4.71	3.95
Belarus	0.0377	0.0063	0.56	3.98
China	0.0390	0.1058	3.47	1.01
Germany	0.0213	0.0309	1.36	1.47
Belgium	0.0331	0.0070	1.03	1.65
Mexico	0.0052	0.0118	1.60	2.48
Chile	0.0127	0.0268	1.26	0.55
Total for the Top Ten			97.43	89.10

Table 7 reports that the mean, standard deviation, and coefficient of variation of the industry-year trade costs all increased from the first period to the second. This is reflected in the differences between the second and first columns of numbers in Table 7. However, the actual shift in sourcing shares in the second period reduced the mean, standard deviation and coefficient of variation. This is reflected in the differences between the second and third columns of numbers in Table 7.

Table 7: Phosphatic Fertilizers:
Industry-Year Trade Costs in the Two Time Periods

Summary Statistic	In 2012–16 Using Actual 2012-16 Shares	In 2017–21 Using Actual 2017-21 Shares	In 2017–21 Using Counterfactual 2012-16 Shares
Mean	1.0315	1.0468	1.0494
Standard Deviation	0.0057	0.0119	0.0153
Coefficient of Variation	0.0055	0.0113	0.0146

5 Pesticides and Other Agricultural Chemicals

Table 8 reports the top ten countries of origin of U.S. imports of pesticides in 2017. Together these ten accounted for 84.52% of industry imports in 2017. Imports in this industry are significantly less concentrated. No source country accounted for more than a quarter of total imports. Germany was the top source, at 24.63%, and China and India also had shares above 10%. Compared to the fertilizer industries, advanced industrial countries are more important import sources in pesticides industry.

Table 8: Pesticides and Others:
Top Ten Import Sources in 2017

Country of Origin	Share of U.S. Imports (%)
Germany	24.63
China	16.68
India	12.26
United Kingdom	9.03
Switzerland	7.72
Mexico	3.54
France	3.00
Israel	2.89
Japan	2.39
Canada	2.38
Total for the Top Ten	84.52

Table 9 reports the coefficient of variation and the share of each of the top ten source countries in the two time periods. For six of the ten countries, the coefficient of variation in trade costs and the sourcing share moved in opposite direction, suggesting shifts in international sourcing to reduce exposure to trade cost volatility. The coefficient of variation fell in Switzerland and Israel, while the countries' shares rose. The coefficient of variation rose in Germany, Mexico, France, and Japan, while their shares fell. (The four exceptions were China, India, the United Kingdom, and Canada.) Overall, the concentration of import

sourcing remained steady.

Table 9: Pesticides and Others:
Changes in Volatility and Sourcing Shares

Country of Origin	2012-16 Coefficient of Variation	2017-21 Coefficient of Variation	2012-16 Sourcing Share	2017-21 Sourcing Share
Germany	0.0050	0.0091	24.86	19.18
China	0.0026	0.0958	16.52	16.60
India	0.0073	0.0141	7.58	10.71
United Kingdom	0.0072	0.0131	9.64	10.28
Switzerland	0.0064	0.0038	2.53	7.06
Mexico	0.0028	0.0064	6.32	6.30
France	0.0116	0.0172	4.00	3.62
Israel	0.0200	0.0078	3.23	3.74
Japan	0.0050	0.0180	3.19	2.54
Canada	0.0101	0.0047	5.62	3.73
Total for the Top Ten			83.49	83.76

Table 10 reports that the mean, standard deviation, and coefficient of variation of the industry-year trade costs all increased from the first period to the second. This is reflected in the differences between the second and first columns of numbers in Table 10. The actual shift in sourcing shares in the second period slightly increased the mean but reduced the standard deviation and coefficient of variation. This is reflected in the differences between the second and third columns.

Table 10: Pesticides and Others:
Industry-Year Trade Costs in the Two Time Periods

Summary Statistic	In 2012–16 Using Actual 2012-16 Shares	In 2017–21 Using Actual 2017-21 Shares	In 2017–21 Using Counterfactual 2012-16 Shares
Mean	1.0697	1.0863	1.0853
Standard Deviation	0.0047	0.0118	0.0217
Coefficient of Variation	0.0044	0.0108	0.0200

6 Econometric Model

Finally, I estimated a simple econometric model of import sourcing and trade costs. The dependent variable is the log of the customs value of imports by industry, country and year. The explanatory variables are the log of the trade cost measure and the log of teh coefficient of variation of the trade cost measure. The model is estimated with panel data for the period 2012–21. The panel pools together the three agricultural chemical industries, and the model includes industry fixed effects and year fixed effects.

Table 11 reports estimates for two versions of the econometric specification. Model A includes the log of the trade cost measure without controlling for volatility. The log of the trade cost measure has a statistically significant negative effect on imports from the source country. Model B also includes the log of the industry-specific coefficient of variation of the trade cost measure as an explanatory variable. This measure of volatility also has a statistically significant negative effect on imports from the source country. The log of the trade cost measure continues to have a statistically significant negative effect on imports in Model B. This econometric analysis provides additional evidence that sourcing shifted in response to the volatility of trade costs.

Table 11: Econometric Model

Dependant Variable: Log of the Value of Imports

Explanatory Variable	Model A	Model B
Log of Trade Costs	-8.5356	-1.8964
standard error	(0.8974)	(0.8760)
p-value	[0.000]	[0.031]
Log of the Coefficient of Variation		-1.8139
standard error		(0.0933)
p-value		[0.000]
Year Fixed Effects	Yes	Yes
Industry Fixed Effects	Yes	Yes
Number of Observations	1,600	1,600
$\bar{R}^2$	0.0596	0.2401

7 Conclusions

In all three industries, the average level and volatility of international trade costs rose over the last ten years, though shifts in import sourcing shares mitigated the increase in volatility. The magnitude of these changes and the contributions of specific source countries varied significantly across the three agricultural chemical industries.

References

Antràs, P. (2020). Conceptual Aspects of Global Value Chains, *World Bank Economic Review* **34**(3): 551–574.

Antràs, P. and De Gortari, A. (2020). On the Geography of Global Value Chains, *Econometrica* **88**(4): 1553–1598.

Jiang, B., Rigobon, D. and Rigobon, R. (2020). From Just-in-Time, to Just-in-Case, to Just-in-*Worst* Case: Simple Models of a Global Supply Chainunder Uncertain Aggregate Shocks, *IMF Economic Review* **70**(1): 141–184.