# EXPOSURE TO IMPORT COST SHOCKS:

# AN ANALYSIS OF U.S. PESTICIDE IMPORTS

David Riker

ECONOMICS WORKING PAPER SERIES
Working Paper 2024–08–C

U.S. INTERNATIONAL TRADE COMMISSION
500 E Street SW
Washington, DC 20436

August 2024

The author thanks Peter Herman for helpful comments and suggestions on an earlier draft. 

Exposure to Import Cost Shocks: An Analysis of U.S. Pesticide Imports
David Riker
Economics Working Paper 2024–08–C
August 2024

**Abstract**

I develop a model that quantifies the effects of changes in country-specific import costs on consumer prices in different parts of the United States, and then I compare the non-linear estimates from the model to simpler log-linear approximations based only on import value shares. I apply the model to U.S. imports of pesticides to illustrate that the non-linear estimates are much more suitable than log-linear approximations when the changes in import costs and the elasticity of substitution between imports from different source countries are large and the import cost shocks are source country-specific.

David Riker
Research Division, Office of Economics
david.riker@usitc.gov

# 1 Introduction

The exposure of U.S. consumers to fluctuations in tariffs and other import costs is mitigated when the consumers can flexibly substitute to other import sources. The easiest way to estimate the consumer effects of import cost shocks is to use a log-linear approximation of the percent change in an industry price index: the log-linear approximation for a constant elasticity of substitution (CES) price index is the import value share-weighted average of the percent changes in the prices of imports from individual source countries. However, this approximation can be improved by incorporating information on consumers' elasticity of substitution.

In this paper, I use a structural model of import demand to generate an econometric estimate of the elasticity of substitution between imports from different source countries, and then I use this estimate to calculate the price effects of a hypothetical reduction in import costs. Intuitively, exposure to import cost shocks should depend not only on the composition of imports that consumers face (reflected in import shares) but also on how readily the consumers can shift to other import sources (reflected in the elasticity of substitution). The resulting non-linear estimates have practical data requirements and are still easy to calculate.

I use this econometric approach to analyze the exposure of consumers in different parts of the United States to fluctuations in the costs of imports of pesticides and other agricultural chemicals (represented by NAICS code 325320). The import cost shocks might be due to changes in tariffs or foreign production costs. The estimates focus on the price effects of potential future changes in the costs of these imports from China and from three other source countries. The estimates indicate significant differences in exposure to each of the source countries in different parts of the country, and this leads to differences in the sub-national effects on prices to consumers, including downstream agricultural producers. The log-linear approximations always fall short of the non-linear estimates in absolute value, since the econometric estimate of the elasticity of substitution is significantly greater than one. This gap between the two alternative measures of price effects is increasing in the elasticity of substitution and the size of the cost shocks and is declining in the number of import source countries experiencing the shock.

The rest of the paper is organized in four parts. Section 2 reports the sub-national import shares for U.S. imports of pesticides from China in 2023 and the log-linear approximation of the local price effects of import cost shocks. Section 3 presents the CES model of import demand, the econometric estimates of the elasticity of substitution, and estimates the non-linear estimates of the price effects. Section 4 analyzes the sensitivity of the estimates to model parameters and to the source countries of the import cost shocks. Section 5 concludes.

## 2 Import Shares and the Log-Linear Approximation

The log-linear approximation of the effects on a CES price index is the value share-weighted average of the changes in source country-specific import prices.

$$\hat{I}_d = \sum_f \left( \frac{v_{fd}}{\sum_{f'} v_{f'd}} \right) \hat{p}_{fd} \tag{1}$$

The variable $d$ indexes customs district within the United States, and the variables $f$ and $f'$ index foreign source countries.[1] $\hat{I}_d$ is the percent change in the price index in a specific year, $\hat{p}_{fd}$ is the percent change in the price of industry imports from country $f$ into district $d$, and $v_{fd}$ is the landed duty-paid value of these imports. For example, the effect of changing only the price of imports from China (country $c$), holding all other import prices constant in this partial equilibrium analysis, is simply $\left( \frac{v_{cd}}{\sum_{f'} v_{f'd}} \right) \hat{p}_{cd}$. The log-linear approximation in equation (1) is a common and convenient way to summarize the effects on average market prices in models of trade policy.

[1] A customs district is a cluster of neighboring U.S. ports.

I apply this calculation to imports of pesticides and other agricultural chemicals (NAICS code 325320). Table 1 reports the log-linear approximation of the percent change in a CES price index from a hypothetical future 10% reduction in the delivered cost of these imports from China, using annual import data for 2023 for 15 U.S. customs districts. There were large differences in China's share of imports across the 15 districts. The largest Chinese share of imports was in New Orleans, followed by Seattle, Cleveland, Los Angeles, Chicago, and San Francisco. While the share of imports from China was generally higher in West Coast districts, New Orleans and Cleveland were clear exceptions. The log-linear approximations of $\hat{I}_d$ in the final column in Table 1 are proportional to these Chinese shares of imports, so the absolute values of the price effects have the same relative magnitudes as the Chinese shares.

Table 1: Imports and China Shares by District in 2023

| Customs District | Delivered Value of All Imports ($ million) | China's Share of Imports (%) | Log-Linear Approximation of $\hat{I}_d$ (%) |
|---|---:|---:|---:|
| New Orleans, LA | 21 | 54.95 | -5.50 |
| Seattle, WA | 26 | 41.15 | -4.11 |
| Cleveland, OH | 18 | 39.18 | -3.92 |
| Los Angeles, CA | 113 | 32.59 | -3.26 |
| Chicago, IL | 53 | 27.48 | -2.75 |
| San Francisco, CA | 24 | 24.00 | -2.40 |
| Houston-Galveston, TX | 160 | 18.49 | -1.85 |
| New York, NY | 75 | 12.11 | -1.21 |
| St. Louis, MO | 270 | 10.55 | -1.06 |
| Savannah, GA | 180 | 8.70 | -0.87 |
| Detroit, MI | 31 | 8.55 | -0.85 |
| Charleston, SC | 281 | 5.27 | -0.53 |
| Norfolk, VA | 105 | 4.27 | -0.43 |
| Minneapolis, MN | 468 | 2.53 | -0.25 |
| Miami, FL | 10 | 0.45 | -0.05 |

# 3 Structural Model and Econometric Estimation

The log-linear approximations in Table 1 are generally easier to calculate than a structural model, because they do not require any information about the elasticity of substitution, only the shares of imports from each source country.[2] However, the approximation is only accurate if the elasticity of substitution is close to one. It is straightforward to estimate this structural parameter and improve the estimates of the price effects of the import cost shocks.

## 3.1 Modeling Framework

We assume that consumers who are served by imports into each of the districts have CES demands with elasticity $\sigma$. Equation (2) is the CES price index of industry imports into district $d$.

$$I_d = \left( \sum_f b_{fd} \, (p_{fd})^{1 - \sigma} \right)^{\frac{1}{1 - \sigma}} \tag{2}$$

$b_{fd}$ are calibrated demand parameters that indicate preferences for imports from different source countries. After assigning one import country ($r$) as the reference and setting $b_{rd} = 1$, the $b_{fd}$ parameters are calibrated according to equation (3).

$$b_{fd} = \frac{v_{fd}}{v_{rd}} \left( \frac{p_{fd}}{p_{rd}} \right)^{\sigma - 1} \tag{3}$$

Equation (4) is the non-linear estimate of the price effect based on the CES price index in equation (2).

[2]The shares implicitly reflects a combination of many fundamentals, including the relative cost competitiveness of different import sources, as well as the elasticity of substitution.

$$\hat{I}_d = \left( \frac{\sum_f b_{fd} \, (p_{fd} \, (1 \; + \; \hat{p}_{fd}))^{1 \; - \; \sigma}}{\sum_f b_{fd} \, (p_{fd})^{1 \; - \; \sigma}} \right)^{\frac{1}{1 \; - \; \sigma}} \; - \; 1 \tag{4}$$

$\hat{p}_{fd}$ is the percent change in the price of imports from country $f$ into district $d$. This partial equilibrium calculation treats import prices as exogenous. The log-linear approximation in equation (1) is a special case of equation (4) in which $\sigma$ is set equal to one and the expenditure shares are fixed and do not adjust to changes in relative prices.

## 3.2 Econometric Estimate of the Elasticity of Substitution

Next, I derive an econometric specification for estimating $\sigma$.[3] Equation (5) is the CES demand for imports from country $f$ into district $d$ in year $t$.

$$v_{fdt} = E_{dt} \;\; (Z_{dt})^{\theta \; - \; 1} \; (I_{dt})^{\sigma \; + \; \theta} \; (p_{ft} \; \phi_{fdt})^{1 \; - \; \sigma} \tag{5}$$

$p_{ft}$ is the producer price of imports from country $f$ in year $t$. $\phi_{fdt}$ is the trade cost factor for imports from country $f$ into district $d$. $E_{dt}$ is aggregate expenditure on products of the industry in the market served by imports into district $d$ in year $t$, including imports and domestic products.[4] $Z_{dt}$ is the CES price index for domestic products and the composite of imports, with elasticity $\theta$. Equation (6) is a log-linearization of the model in equation (5).

$$ln \; v_{fdt} = \alpha_{dt} \; + \; \beta_{ft} \; + \; \gamma_{fd} \; + \; (1 \; - \; \sigma) \; ln \; \phi_{fdt} \tag{6}$$

Equation (7) is a Poisson version of this econometric specification.

$$v_{fdt} = \exp \left[ \; \alpha_{dt} \; + \; \beta_{ft} \; + \; \gamma_{fd} \; + \; (1 \; - \; \sigma) \; ln \; \phi_{fdt} \; \right] \; \eta_{fdt} \tag{7}$$

[3]The derivation is described in more detail in Riker (2020).

[4]The model assumes separability of demand across industries, following a common assumption in trade models that preferences are Cobb-Douglas across industries or sectors.

I construct an estimation sample that includes bilateral, district-specific import values for 2021–2023. There are 55 countries, 39 districts, and 3 years for a total of 6,435 potential country-district-year trade flows. Of these, there are 1,136 with non-zero import values and 5,299 with zero import values. The zero values are not a problem per se for the PPML estimator; the issue is that it is not possible to directly measure $\phi_{fdt}$ when there are zero import values.

For country-district-year combinations with positive import values, the trade cost factor is directly measured as the ratio of the landed duty-paid value of the imports to their customs value. If there are no imports for a particular country-district-year combination, then it is not possible to directly calculate this ratio. However, it can be proxied by calculating the ratio for the same country-district-year but for an industry more broadly defined than NAICS 325320, either NAICS 3253 or NAICS 325. The model only uses these proxies for trade costs when there is no direct measure for a specific country-district-year combination.

I estimate the parameters of equation (7) using the high-dimension fixed effects Poisson Pseudo Maximum Likelihood estimator in Stata (HDFE PPML), with county-year, district-year, and country-district fixed effects. The estimates for different imputations of trade costs factors are reported in Table 2, with robust standard errors in parentheses.

Table 2: Econometric Estimates

| Estimate of $\sigma$ | Actual Trade Costs Only | Pseudo $R^2$ | Number of Observations |
|---|---|---|---|
| Actual Trade Costs Only | 6.485 | 0.9727 | 936 |
| | (1.167) | | |
| Proxy with Other 3253 Imports | 5.762 | 0.9709 | 1,189 |
| | (1.009) | | |
| Proxy with Other 325 Imports | 4.337 | 0.9690 | 1,528 |
| | (1.072) | | |

Using the proxies when direct trade costs are not available increases the estimation sample, but the proxies appear to be less relevant than the direct measures of trade costs, and the estimates that include the proxies appear to be biased toward zero. For this reason, I prefer the first specification without any imputations.[5] I use this estimate that $\sigma$ is equal to 6.485 in most of the non-linear estimates of price effects below.

### 3.3 Non-Linear Estimates of Price Effects

Table 3 compares the non-linear estimates of price effects with $\sigma$ set equal to 6.485 to the log-linear approximations in Table 1. Although the ratio of the non-linear estimate to the log-linear approximation is always greater than one, it varies in magnitude across the districts. It is decreasing in the absolute magnitude of $\hat{I}_d$. The ratio ranges from a low of 1.15 for imports into New Orleans to a high of 1.42 for imports into Miami. Incorporating the estimates of $\sigma$ through the non-linear estimator changes the magnitudes in all the districts but not the ranking of the absolute magnitudes of the price effects in the districts.

[5] As a further sensitivity analysis of the econometric estimates, I re-estimated the model using the two sets of proxies and no direct measures of trade costs. If I do not use the direct measures at all, the estimate of $\sigma$ is closer to zero. The point estimate is 5.426 with a standard error of 1.221 if I use the NAICS 3253 trade cost factors *even when* NAICS 325320 trade costs are available. It is 2.064, with a standard error of 2.040, if I use NAICS 325 trade cost factors.

Table 3: Non-linear versus Log-linear Estimates

| District | Non-linear $\hat{I}_d$ (%) | Log-linear $\hat{I}_d$ (%) | Ratio of the Two |
|---|---|---|---|
| New Orleans, LA | -6.31 | -5.50 | 1.15 |
| Seattle, WA | -4.96 | -4.11 | 1.21 |
| Cleveland, OH | -4.76 | -3.92 | 1.21 |
| Los Angeles, CA | -4.06 | -3.26 | 1.24 |
| Chicago, IL | -3.49 | -2.75 | 1.27 |
| San Francisco, CA | -3.09 | -2.40 | 1.29 |
| Houston-Galveston, TX | -2.43 | -1.85 | 1.32 |
| New York, NY | -1.64 | -1.21 | 1.35 |
| St. Louis, MO | -1.44 | -1.06 | 1.36 |
| Savannah, GA | -1.19 | -0.87 | 1.37 |
| Detroit, MI | -1.17 | -0.85 | 1.37 |
| Charleston, SC | -0.73 | -0.73 | 1.39 |
| Norfolk, VA | -0.60 | -0.43 | 1.40 |
| Minneapolis, MN | -0.36 | -0.25 | 1.41 |
| Miami, FL | -0.06 | -0.05 | 1.42 |

# 4 Sensitivity of the Estimates

Table 4 compares the non-linear estimates to the log-linear approximation for different values of the cost shocks on imports of pesticides from China, $\hat{p}_{cd}$. In all simulations reported in this table, $\sigma$ is set equal to 6.485. When there is a larger price shock, there is a larger ratio of the non-linear estimate to the log-linear approximation. This is a consistent pattern across the 15 districts.

Table 4: Sensitivity of the Estimates to $\hat{p}_{chn}$

| | $\hat{p}_{cd} = -5\%$ | $\hat{p}_{cd} = -5\%$ | $\hat{p}_{cd} = -15\%$ | $\hat{p}_{cd} = -15\%$ |
|---|---|---|---|---|
| | Non-linear | Log-linear | Non-linear | Log-linear |
| District | $\hat{I}_d$ (%) | $\hat{I}_d$ (%) | $\hat{I}_d$ (%) | $\hat{I}_d$ (%) |
| New Orleans, LA | -2.95 | -2.75 | -10.08 | -8.24 |
| Seattle, WA | -2.26 | -2.06 | -8.13 | -6.17 |
| Cleveland, OH | -2.16 | -1.96 | -7.83 | -5.88 |
| Los Angeles, CA | -1.82 | -1.63 | -6.77 | -4.89 |
| Chicago, IL | -1.55 | -1.37 | -5.89 | -4.12 |
| San Francisco, CA | -1.36 | -1.20 | -5.26 | -3.60 |
| Houston-Galveston, TX | -1.06 | -0.92 | -4.21 | -2.77 |
| New York, NY | -0.70 | -0.61 | -2.88 | -1.82 |
| St. Louis, MO | -0.61 | -0.53 | -2.54 | -1.58 |
| Savannah, GA | -0.51 | -0.43 | -2.13 | -1.30 |
| Detroit, MI | -0.50 | -0.43 | -2.09 | -1.28 |
| Charleston, SC | -0.31 | -0.26 | -1.32 | -0.79 |
| Norfolk, VA | -0.25 | -0.21 | -1.08 | -0.64 |
| Minneapolis, MN | -0.15 | -0.13 | -0.65 | -0.38 |
| Miami, FL | -0.03 | -0.02 | -0.12 | -0.07 |

Table 5 compares the non-linear estimates for different values of the elasticity of substitution $\sigma$, returning to the assumption that there is a 10% reduction in costs that are specific to imports from China ($\hat{p}_{cd} = -10\%$). When there is a larger value of $\sigma$, there is a larger ratio of the non-linear estimate to the linear approximation. Again, the pattern is consistent across the 15 districts.

Table 5: Non-linear Estimate for Different Values of $\sigma$

| District | $\sigma = 4$ <br> $\hat{I}_d$ (%) | $\sigma = 7$ <br> $\hat{I}_d$ (%) |
|---|---|---|
| New Orleans, LA | -6.01 | -6.37 |
| Seattle, WA | -4.63 | -5.03 |
| Cleveland, OH | -2.81 | -4.83 |
| Los Angeles, CA | -3.74 | -4.12 |
| Chicago, IL | -3.19 | -3.55 |
| San Francisco, CA | -2.81 | -3.15 |
| Houston-Galveston, TX | -2.19 | -2.47 |
| New York, NY | -1.46 | -1.68 |
| St. Louis, MO | -1.27 | -1.47 |
| Savannah, GA | -1.06 | -1.22 |
| Detroit, MI | -1.04 | -1.20 |
| Charleston, SC | -0.64 | -0.75 |
| Norfolk, VA | -0.52 | -0.61 |
| Minneapolis, MN | -0.31 | -0.37 |
| Miami, FL | -0.06 | -0.07 |

Table 6 compares the non-linear estimates for country-specific cost shocks on imports from four different sources – China, Germany, India, and the UK – restoring the assumption that the elasticity of substitution $\sigma$ is equal to 6.485 and that the shock is a 10% reduction in the costs of imports from the specific source country. Imports from China, and the resulting price effects of the import cost shocks, are relatively concentrated in districts on the West Coast and Gulf Coast and in the Midwest. The top three districts are New Orleans, Seattle, and Cleveland. The average price effect is -2.42%, and the average ratio of the non-linear estimates to log-linear approximations is 1.32. In contrast, there is a significant re-ranking of the price effects when the cost shocks applied to imports from the other three countries.

Table 6: Shocks to Imports from Four Individual Countries
(Non-linear Estimates, -10% Shocks)

| District | China $\hat{I}_d$ (%) | Germany $\hat{I}_d$ (%) | India $\hat{I}_d$ (%) | UK $\hat{I}_d$ (%) |
|---|---|---|---|---|
| New Orleans, LA | -6.31 | -0.02 | -1.22 | -1.02 |
| Seattle, WA | -4.96 | -0.91 | -0.13 | 0.00 |
| Cleveland, OH | -4.76 | -0.98 | -0.15 | -2.71 |
| Los Angeles, CA | -4.06 | 0.00 | -4.39 | -0.02 |
| Chicago, IL | -3.49 | -1.33 | -0.20 | -1.05 |
| San Francisco, CA | -3.09 | -1.62 | -2.00 | 0.00 |
| Houston-Galveston, TX | -2.43 | -0.40 | -0.21 | -1.04 |
| New York, NY | -1.64 | -0.58 | -3.53 | -0.03 |
| St. Louis, MO | -1.44 | -5.92 | -0.41 | -1.64 |
| Savannah, GA | -1.19 | -0.59 | -1.88 | -0.25 |
| Detroit, MI | -1.17 | -0.26 | -0.04 | -0.01 |
| Charleston, SC | -0.73 | -3.15 | -7.12 | -0.15 |
| Norfolk, VA | -0.60 | -4.82 | -4.44 | -0.94 |
| Minneapolis, MN | -0.36 | -0.47 | -0.19 | -2.05 |
| Miami, FL | -0.06 | -1.48 | -5.03 | 0.00 |

Imports from Germany are relatively concentrated on the East Coast and Midwest. The three districts with the largest price declines are St. Louis, Norfolk, and Charleston. The average price effect is smaller (-1.61%), and the average ratio of the non-linear estimates to log-linear approximations is larger (1.35).

Imports from India, on the other hand, are relatively concentrated on the East Coast. The three districts with the largest price declines are Charleston, Miami, and Norfolk. The average price effect is larger than the average effect for imports from Germany but smaller than the average effect for imports from China (-2.06%), and the average ratio of the non-linear estimates to log-linear approximations is also between the other two (1.33).

Imports from the United Kingdom are relatively concentrated in the Midwest. The three districts with the largest price declines are Cleveland, Minneapolis, and St. Louis. The average price effect for imports from the United Kingdom is smaller than the averages for imports from the other three countries (-0.91%), and the average ratio of the non-linear estimates to log-linear approximations is larger (1.38).

Finally, Table 7 compares the ratio of the non-linear estimate to the log-linear approximation of the price effects of -10% cost shocks for different assumptions about the prevalence of the cost shocks. The first column of estimates assumes that the cost shocks only apply to imports from China. The second column of estimates assumes that they apply more broadly to imports from all four source countries (China, Germany, India, and the UK). The ratio of the non-linear estimate to the log-linear approximation is declining as countries are added, since the share of imports subject to the cost shock increases. In the extreme, if all import source countries were subject to -10% cost shocks, then the non-linear and the log-linear approximation would both be -10%, and the ratio would be equal to one in all districts.

Table 7: Ratios for Imports from China and from All Four Countries
(Ratio of the Non-linear Estimates to the Log-Linear Approximation)

| District | Ratio for China Alone | Ratio for All Four Countries |
|---|---|---|
| New Orleans, LA | 1.15 | 1.09 |
| Seattle, WA | 1.21 | 1.17 |
| Cleveland, OH | 1.21 | 1.10 |
| Los Angeles, CA | 1.24 | 1.10 |
| Chicago, IL | 1.27 | 1.18 |
| San Francisco, CA | 1.29 | 1.16 |
| Houston-Galveston, TX | 1.32 | 1.26 |
| New York, NY | 1.35 | 1.19 |
| St. Louis, MO | 1.36 | 1.07 |
| Savannah, GA | 1.37 | 1.26 |
| Detroit, MI | 1.37 | 1.36 |
| Charleston, SC | 1.39 | 1.02 |
| Norfolk, VA | 1.40 | 1.04 |
| Minneapolis, MN | 1.41 | 1.29 |
| Miami, FL | 1.42 | 1.16 |

# 5 Conclusions

The econometric estimates and model simulations quantify the effects of changes in country-specific import costs on consumer prices and compare them to effects estimated with a simpler log-linear approximation based solely on import value shares. An application of the model to data on U.S. imports of pesticides illustrates that the non-linear estimate is a much better fit than the log-linear approximation when the changes in import costs and the elasticity of substitution between imports from different source countries are large and when the cost shocks are country-specific.

The same methodology can be applied to imports of other commodities from other source countries, and it can be applied in a retrospective analysis of past import cost shocks rather than this prospective analysis of potential future shocks.

# References

Riker, D. (2020). A Trade Cost Approach to Estimating the Elasticity of Substitution. USITC Economics Working Paper 2020-07-D.