The Effects of Trade Diversification on Exchange Rate Risk: Examining U.S. State Oil, Mineral, and Chemical Exports to China, Mexico, Japan, and the United Kingdom

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1 Introduction

The purpose of this paper will be to examine the impacts of exchange rate fluctuations on oil, mineral, and chemical exports from the each state in the United States to China, Japan, Mexico, the United Kingdom, and Canada, and how these fluctuations are impacted by the diversification of trading partners. Four first-differenced, ordinary least squares (OLS) linear regression models will be constructed for this analysis. The first OLS model is the baseline model, where total oil, mineral, and chemical exports are the response variable, and total exports, including all product categories less oil, mineral, and chemical products, and the WTI price of crude oil are included as explanatory variables. The second OLS model includes the change in the trade-weighted real exchange rate, calculated as in (House et al., 2019) for each country's currency relative to the U.S. dollar as an additional explanatory variable. The third OLS model includes the number of trading partners for each state, calculated as the number of unique destination countries for each states' exports, which includes all product categories other than oil, mineral, and chemical products, within a quarter, as yet another explanatory variable. This model also includes an interaction between the number of trading partners and the change in the trade-weighted real exchange rate to determine if the impact of changes in the trade-weighted real exchange rate on oil, mineral, and chemical exports differs depending on the number of trading partners for each state. The last OLS model is one of theoretical importance, in which a different calculation of the real exchange rate similar to (Ellis, 2001) is applied. The results of this analysis show that including the real exchange rate, as calculated in (C. House et al. 2019) improves the predictive ability of the baseline regression model based on a higher adjusted R^2 and a lower residual standard error. However, the trade-weighted real-exchange rate as calculated in (C. House et al. 2019) is not a significant predictor by itself across all states and countries. However, there are state and country specific effects. Additionally, including the number of trading partners results in a slightly more predictive model, based on the same measures. The number of trading partners is itself a significant predictor of quarterly oil, mineral, and chemical exports. Additionally, there are statistically-significant state and country specific effects which will be examined later in the paper. The three main hypotheses that will be tested in this paper are: (1) Changes in the real exchange rate are a predictor of a state's quarterly oil, mineral, and chemical exports, (2) The number of trading partners reduces the number of states in which the change in the real exchange rate is a predictor, and (3) The outcomes of the following proposed models depends on the measure of the exchange rate used. The empirical results show that changes in the real-exchange rate as calculated in (C. House et al, 2019) do not influence the quarterly oil, mineral, and chemical exports for the majority of states. Additionally, including the number of trading partners does not influence how states react to changes in the real exchange rate for the majority of states. However, the measure of exchange rates used does influence the results of the empirical analyses. The "Empirical Analysis" section will examine more state-specific effects.

The paper is outlined as follows: in the next section, I will review the relevant literature regarding the current global exchange rate regime, export predictors, and exchange rate uncertainty and diversification. In the "Models" section, I will present the econometric equations for the four OLS models, a summary of the data used, and a discussion of the panel data methods applied to each of the four models. In the "Empirical Analysis" section, I will present the overall statistical findings of each OLS model, in addition to heat maps of the U.S. to present a geographical representation of the statistical findings in regards to state-level exports to a specific country. In the "Conclusions and Implications" section, I will summarize the results of the empirical analysis and discuss how future research on this topic may be conducted. The "Appendix" section contains more figures of the statistical results in addition to more OLS diagnostic measures on the models included in this paper.

2 Literature Review

In (House et al., 2019), the authors examine state-level export data and trade-weighted exchange rate fluctuations and they find that, when the state-specific trade-weighted exchange rates depreciate, states experience a higher level of exports, lower unemployment, and higher hours worked. Their definition of the state-specific trade-weighted real exchange rate is used in this paper to obtain a real exchange rate measure for each state, and the equation is given in (3). In examining the impact of exchange rate fluctuations on trade more generally, (Dell'Ariccia, 1999) finds that exchange rate volatility is negatively correlated with trade flows when using a panel data set from Western Europe. The authors (Alesssandria and Choi, 2021) find that fluctuations of the real exchange rate tend to impact the U.S. trade balance from 1980 to 2015 to a low degree, while the impact of trade policies tend to account for changes in the U.S. trade balance to a relatively higher degree. As (Akram, 2020) notes, oil price movements arising from changes in economic activity significantly impacted the exchange rates of Norway and Canada relative to the U.S. dollar from the period 2010 to 2018. The author makes the distinction that this relation only holds, however, for price movements related to changes in economic activity. This paper will use the Cushing, OK WTI Crude oil price given by the U.S. Energy Information Administration as a proxy for oil price movements in determining oil, mineral, and chemical exports in the baseline model, though there is not an attempt in this analysis to follow Akram's distinction between the types of oil price movements. In (Reboredo, 2011), the author uses U.S. exchange rate data and crude oil price fluctuations from the period 2000 to 2010 to find that, over this period, oil price and exchange rates moved together, though the strength of this correlation differed among oil-exporting and oil-importing countries. In their paper, (Genec & Artar, 2014) used panel data for a number of developing countries from the period 1985 to 2012 to find that the impact on the real effective exchange rate based on GDP-weighted imports differs between the short and long-term. In modelling the impact of exchange rate uncertainty on U.S. exports, (Arize, 1995) uses a moving average over a five-quarter period of the first differenced exchange rate as a proxy for exchange rate uncertainty. The authors find that uncertain exchange-rate fluctuations are negatively correlated with U.S. exports over the period 1973 to 1991. This paper will use the changes in quarterly oil, mineral, and chemical exports in response to changes in the real exchange rate as a possible measure of the response of state-level U.S. exports to trade-weighted exchange-rate fluctuations. In (De Vita & Abbott, 2004), the authors find that U.S. export volume was impacted by exchange-rate fluctuations over the period 1987 to 2001, though the magnitude of this result depended on the destination of the exports. In (Klein, 1990), the author finds that fluctuations in the real exchange rate impacted the value of U.S. exports in over 60% of the specific bilateral export sectors examined over the period 1978 to 1986. This paper focuses on U.S. oil, chemical, and mineral exports as one case study to examine the impact of exchange rate fluctuations and the diversification of trading partners on trade flows, though future research could extend this analysis to include other export sectors. In looking at oil exports, in (Esfahni et al., 2013) the authors use a weighted average of the different Iranian exchange rates in constructing a model for long-run growth in Iran from 1979 to 2006 using oil revenues as an explanatory variable. In (Shao et al., 2017), the authors find evidence for their hypothesis that China's crude oil imports are positively correlated with the amount of crude oil trade of the exporter. In this case, this paper includes the number of trading partners for each U.S. state as an additional possible explanatory variable for explaining quarterly oil, mineral, and chemical exports. Therefore, based on the hypothesis in (Shao et al., 2017), it will also be determined if China imports more crude oil products from states that have a higher number of trading partners. It will be determined if this result holds for the other countries in this study as well.

3 Data, Model Selection, and Hypotheses

This analysis will utilize three first-differenced, ordinary least squares multiple linear regression models in order to examine differences in quarterly oil, mineral, and chemical exports within each state for different export-country destinations. These models will be fitted using quarterly U.S. data from 2010 to 2021. Data on state-level U.S. exports was obtained from the United States Census Bureau International Trade data set. Quarterly real GDP data for each state was obtained from the U.S. Bureau of Economic Analysis. The crude oil spot price is the Cushing, OK WTI spot price as reported by the U.S. Energy Information Administration. Data on the consumer price index for each country and for each U.S. state, along with nominal exchange rate data, were obtained from the International Monetary Fund International Financial Statistics data set. The baseline model is as follows:

$$\Delta ln(E_{s,c,t}) = \beta_0 + \beta_1 \Delta ln(E^*_{s,c,t}) + \beta_2 \Delta ln(P_{s,c,t}) + \beta_3 \delta_t + \beta_4 SC_t + \epsilon_{s,c,t}, \tag{1}$$

where E represents quarterly oil, mineral, and chemical exports for state s to country c in time period t. Similarly, E^* represents quarterly total exports (less oil, mineral, and chemical products) and P represents the price of crude oil. Additionally, δ represents a control component for the time period, t, and SC represents the state and country combination in time period t. In expanding this model to determine how exchange-rate fluctuations impact oil, mineral, and chemical exports for each state, and how this impact differs by country, the following extension of the baseline model in (1) is proposed:

$$\begin{aligned} \Delta ln(E_{s,c,t}) = \beta_0 + \beta_1 \Delta ln(E^*_{s,c,t}) + \beta_2 \Delta ln(P_{s,c,t}) + \beta_3 \delta_t + \beta_4 SC_t \\ + \beta_5 \Delta ER^*_{s,c,t} + \beta_6 (SC_t \Delta ER^*_{s,c,t}) + \epsilon_{s,c,t}, \end{aligned} \tag{2}$$

where $\Delta ER^*_{s,c,t}$ represents the change in the trade-weighted real exchange rate between state s and country c in time period t based on the formula proposed in (House et al., 2019) where:

$$ER^*_{s,c,t} = \frac{E^*_{s,c,t}}{GDP_{s,t}}\Delta ln(ER_{c,t}) + \frac{E^*_{s,c,t}}{GDP_{s,t}}(ln(CPI_{c,t}) - ln(CPI_{US,t})). \tag{3}$$

In this case, $CPI_{c,t}$ is the consumer price index of all items in country c in time period t, $CPI_{US,t}$ is the consumer price index of all items in the United States in time period t. The term $GDP_{s,t}$ is the real GDP for state s in time period t, ER is the nominal exchange rate of country c's currency relative to the U.S, and $E^*_{s,c,t}$ represents the total dollar value of exports, including oil, mineral, and chemical products, from state s to country c in time period t. The purpose of this model is to expand prior discussions on the responsiveness of trade flows to exchange rate fluctuations (see section "Literature Review") to state-level trade data. The final expansion of the baseline model includes the number of trading partners, $TP_{s,t}$, for each state in time period t. The number of trading partners is defined as the count of unique export-destinations for all product categories for each state in each quarter. This model is proposed as:

$$\begin{aligned}\Delta ln(E_{s,c,t}) = \beta_0 + \beta_1 \Delta ln(E^*_{s,c,t}) + \beta_2 \Delta ln(P_{s,c,t}) + \beta_3 \delta_t + \beta_4 SC_t \\ + \beta_5 \Delta ER^*_{s,c,t} + \beta_6 \Delta TP_{s,t} + \beta_7 (SC_t \Delta ER^*_{s,c,t} TP_{s,t}) + \epsilon_{s,c,t},\end{aligned} \tag{4}$$

The final model includes another calculation of a trade-weighted real exchange rate, with the real exchange rate formula similar to (Ellis, 2001). The term $ER^{**}_{s,c,t}$ will be used in (4) instead of the real exchange rate measure calculated as in (House et al., 2019) in order to examine the importance of the exchange rate measure used:

$$\begin{aligned}\Delta ln(E_{s,c,t}) = \beta_0 + \beta_1 \Delta ln(E^*_{s,c,t}) + \beta_2 \Delta ln(P_{s,c,t}) + \beta_3 \delta_t + \beta_4 SC_t \\ + \beta_5 \Delta ER^{**}_{s,c,t} + \beta_6 \Delta TP_{s,t} + \beta_7 (SC_t \Delta ER^{**}_{s,c,t} TP_{s,t}) + \epsilon_{s,c,t},\end{aligned} \tag{5}$$

where $ER^{**}_{s,c,t}$ represents the change in the trade-weighted real exchange rate between state s and country c in time period t. The real exchange rate formula is based on the formula proposed in (Ellis , 2001) the real exchange rate is defined as:

$$ER^*_{s,c,t} = \frac{CPI_{c,t} ER_{c,t}}{CPI_{US,t}} \tag{6}$$

and the trade-weight component is the same component from (House et al., 2019). Thus,

$$ER^{**}_{s,c,t} = \frac{CPI_{c,t} ER_{c,t}}{CPI_{US,t}}(\frac{E^*_{s,c,t}}{GDP_{s,t}}), \tag{7}$$

where $CPI_{c,t}$ is the consumer price index of all items in country c in time period t, $CPI_{US,t}$ is the same consumer price index for the United States, and $GDP_{s,t}$ is the real GDP for state s in time period t.

Lastly, a first-differenced panel data methodology is applied in this case in order to examine the differences between exchange rates and export values, two variables in which the units of measure differ. In returning to the proposed hypotheses in the introduction, the first hypothesis follows from the findings cited in the previous literature. If the U.S. experiences changes in its trade flows and trade volumes due to changes in exchange rates, then does this relationship hold when looking at state-level exports, or is this simply a nationwide phenomena? Model (2) aims to answer this question. The second hypothesis, which posits that the diversification of trading partners mitigates exchange rate risk, follows from the idea that states that are diversified in their trading partners may not react to changes in the exchange rate with a particular country. This is similar to the classic theory of diversification when investing in financial markets. This hypothesis will be tested using model (4). If there is a statistically-significant interaction between the number of trading partners and changes in the real exchange rate for a particular state, then this implies that the number of trading partners that a particular state has in a particular quarter impacts how changes in the real exchange rate influence quarterly oil, mineral, and chemical exports. The third hypothesis, which posits that the measure of the real exchange rate used matters to the results of model (4), is a matter pertaining to future research. If the results of this analysis are largely statistically-insignificant, then future research could return to this matter using different export-product categories and different measures of the exchange rate.

4 Empirical Analysis

The results of the baseline model (1) are shown in Table 1. Any results discussed in this section are significant at least at the $\alpha = 0.05$ level.

Table 1:

	Dependent variable:
	Quarterly.Oil.Exports
Quarterly.Total.Exports	0.991***
	(0.012)
Cushing.OK.WTI.Spot.Price.FOB.Dollars.per.Barrel	0.010
	(0.058)
Constant	−0.023
	(0.067)
Observations	9,798
R^2	0.901
Adjusted R^2	0.898
Residual Std. Error	0.356 (df = 9499)
F Statistic	291.244*** (df = 298; 9499)
Note:	*p<0.1; **p<0.05; ***p<0.01

This model refers to equation (1) and covers the period from 2010 to 2021. Note that the coefficient estimates for each time period are omitted for the sake of brevity. country, and the state. $R^2 = 0.9643$. All values rounded to one decimal place. Significance is assumed to be $\alpha = 0.05$.

Refer to the Appendix for further diagnostics on the baseline model. According to Table 1, quarterly total exports are a statistically-significant predictor of the quarterly oil, mineral, and chemical exports overall, as is expected. However, the Cushing WTI spot price of crude oil doesn't appear to be a predictor of oil, mineral, and chemical exports when considering all states and countries overall. There may be a few reasons for the lack of significance when considering the spot price of oil, including the fact that this baseline model is using the spot price of crude oil to not only predict quarterly oil exports, but also quarterly mineral and chemical exports. The next extension of this model is to include the trade-weighted real-exchange rate from (House et al., 2019) as an additional explanatory variable.

Table 2:

	Dependent variable:
	Quarterly.Oil.Exports
Quarterly.Total.Exports	0.990***
	(0.013)
Cushing.OK.WTI.Spot.Price.FOB.Dollars.per.Barrel	0.112*
	(0.060)
REER	1.653
	(14.017)
Constant	−0.018
	(0.058)
Observations	9,549
R^2	0.922
Adjusted R^2	0.917
Residual Std. Error	0.307 (df = 9001)
F Statistic	193.464*** (df = 547; 9001)
Note:	*p<0.1; **p<0.05; ***p<0.01

This model refers to equation (2) and covers the period from 2010 to 2021. Note that the coefficient estimates for each time period are omitted for the sake of brevity.

According to Table 2, quarterly total exports are a statistically-significant predictor of quarterly oil, mineral, and chemical exports. Interesting to note here, however, is that the inclusion of the trade-weighted real-exchange rate in this model causes the spot price of oil to become a significant predictor overall. Additionally, the trade-weighted real exchange rate is not a significant predictor of quarterly oil, mineral, and chemical exports overall. In looking at state specific effects, there is a lack of significance in the interaction coefficients between the trade-weighted real-exchange rate and each state's quarterly oil, mineral, and chemical exports to China. Therefore, using the measure of the real exchange rate in model (2), it doesn't appear that fluctuations in the real-exchange rate impact state-level trade flows to China. In looking at state-level exports to Japan, a 1% increase in the real exchange rate leads to a nearly 200% decrease in quarterly oil, mineral, and chemical exports from Hawaii to Japan. Additionally, a 1% increase in the real exchange rate between Hawaii and Mexico leads to a nearly 100% decrease in quarterly oil, mineral, and chemical exports to Japan. In looking at state-level exports to the United Kingdom, a 1% increase in the real exchange rate between Hawaii and the United Kingdom leads to an approximately 700% decrease in quarterly oil, mineral, and chemical exports to the United Kingdom. Additionally, a 1% increase in the real-exchange rate between Maine and the United Kingdom leads to a nearly 5% increase in quarterly oil, mineral, and chemical exports to the United Kingdom. Looking at state-level exports to Canada, a 1% increase in the real exchange rate leads to an approximately 187% decrease in quarterly oil, mineral, and chemical exports to Canada. Figure 1 shows a geographical heat map of the coefficient estimates for the interaction terms in model (2) for state exports to the United Kingdom, with the states that have a statistically significant result outlined in yellow. Positive correlations between quarterly oil, mineral, and chemical exports and the real-exchange rate are shown in green and negative correlations are shown in red.

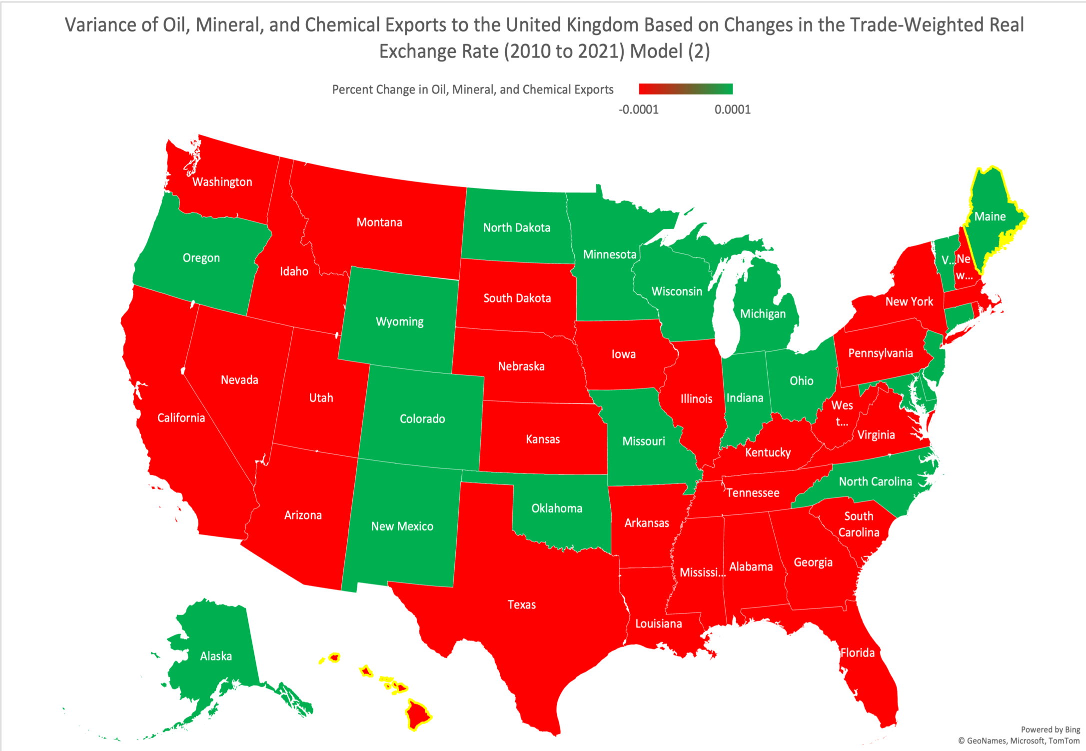

Figure 2: Geographical heat map of the coefficient estimates for interaction terms in model (3) for state-level exports to the United Kingdom. States with statistically significant interaction terms are highlighted in yellow, with significance assumed to be below $\alpha = 0.05$. Green states denote positive correlations, red states denote negative correlations. Generated in Microsoft Excel.

The results of model (2), in which the number of trading partners for each state in each quarter are included as an additional explanatory variable, are shown in Table 3.

Table 3:

	Dependent variable:
	Quarterly.Oil.Exports
Quarterly.Total.Exports	0.958***
	(0.016)
Cushing.OK.WTI.Spot.Price.FOB.Dollars.per.Barrel	0.075
	(0.070)
REER	−13.107
	(21.408)
Trading.Partners	1.012***
	(0.162)
Constant	−0.034
	(0.058)
Observations	9,549
R^2	0.932
Adjusted R^2	0.924
Residual Std. Error	0.294 (df = 8502)
F Statistic	111.364*** (df = 1046; 8502)
Note:	*p<0.1; **p<0.05; ***p<0.01

This model refers to equation (3) and covers the period from 2010 to 2021. Note that the coefficient estimates for each time period are omitted for the sake of brevity.

According to table 3, the quarterly number of trading partners for each state is a significant predictor for the quarterly oil, mineral, and chemical exports when considering all countries and states. The spot price for crude oil and the trade-weighted real exchange rates are not significant predictors in this model. In looking at state-level exports to China, as the number of trading partners for Hawaii increases, the real-exchange rate's impact on quarterly oil, mineral, and chemical exports increases. The same outcome holds for Hawaiian oil, mineral, and chemical exports to Mexico. In looking at state-level exports to the United Kingdom, as the number of trading partners for Colorado, Hawaii, and New Mexico increase, the impact of the real-exchange rate on quarterly oil, mineral, and chemical exports decreases by more than 500% for each state. As the number of trading partners for Maryland increases, the effect of the real exchange rate between Maryland and the U.K. on oil, mineral, and chemical exports increases by nearly 1,200%. Lastly, when the number of trading partners for Hawaii, New Jersey, and New Mexico increases, the effect of the real-exchange rate between each state and Canada increases by over 800% for each state. A geographical heat map for state-level exports to the United Kingdom using the results of model (3) is shown in Figure 3.

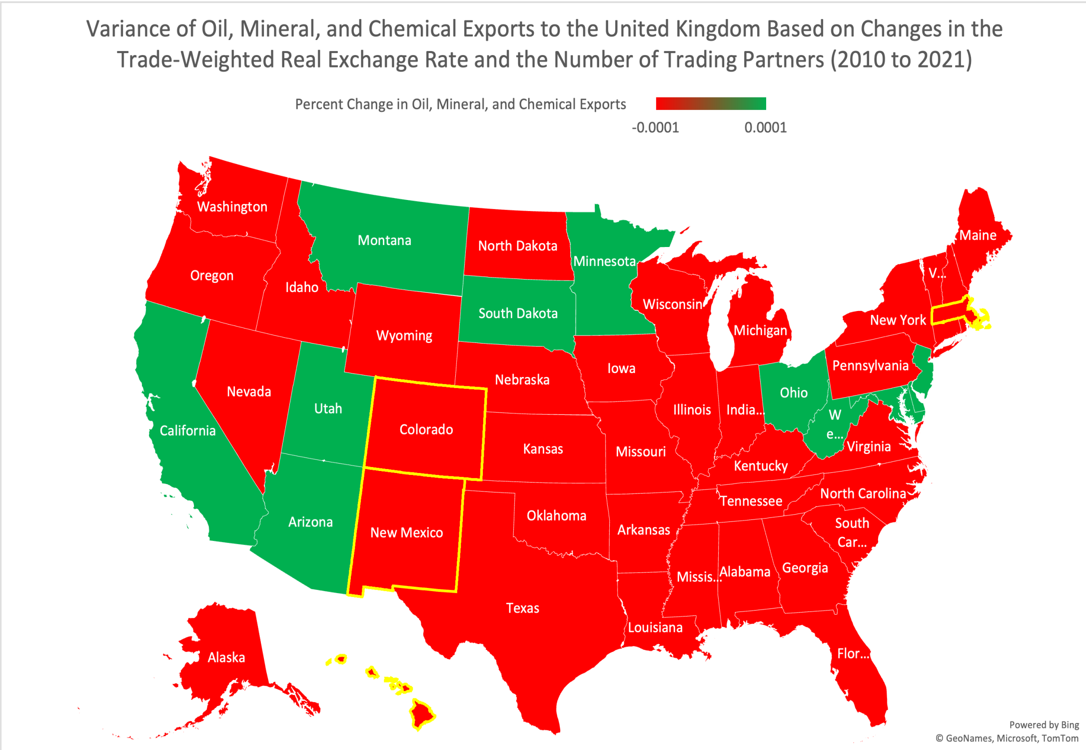

Figure 3: Geographical heat map of the coefficient estimates for interaction terms in model (3) for state-level exports to the United Kingdom. States with statistically significant interaction terms are highlighted in yellow, with significance assumed to be below $\alpha = 0.05$. Green states denote positive correlations, red states denote negative correlations. Generated in Microsoft Excel.

Lastly, the results of model (4), in which the exchange rate calculated similarly to (Ellis, 2001) is used rather than the real exchange rate from (House et al., 2019), are shown in Table 4.

Table 4:

	Dependent variable:
	Quarterly.Oil.Exports
Quarterly.Total.Exports	-1.307^{***}
	(0.054)
Cushing.OK.WTI.Spot.Price.FOB.Dollars.per.Barrel	0.376^{***}
	(0.057)
LOG_RER	2.306^{***}
	(0.147)
Trading.Partners	-0.283
	(0.647)
Constant	-0.064
	(0.086)
Observations	9,549
R^2	0.949
Adjusted R^2	0.943
Residual Std. Error	0.254 (df = 8502)
F Statistic	152.483^{***} (df = 1046; 8502)
Note:	$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

This model refers to equation (4) and covers the period from 2010 to 2021. Note that the coefficient estimates for each time period are omitted for the sake of brevity.

From Table 4, it appears that both the spot price for crude oil and the real-exchange rate are significant predictors of quarterly oil, mineral, and chemical exports. Note that the number of trading partners is no longer a significant predictor. In looking at state-level exports to China, the interaction between Maryland's trading partners and the real-exchange rate is significant, indicating that as the number of trading partners increases, the effect of the real-exchange rate on quarterly oil, mineral, and chemical exports increases. In examining state-level exports to Mexico, as the number of trading partners for Hawaii increases, the effect of the real exchange rate on quarterly oil, mineral, and chemical exports to Mexico decreases. This same result for Hawaii holds for the United Kingdom and Canada. Additionally, as the number of Main's trading partners increases, the effect of the real-exchange rate on oil, mineral, and chemical exports increases. It is interesting to note that Japan experienced the most statistically-significant interaction terms under this model, which are shown in Figure 3.

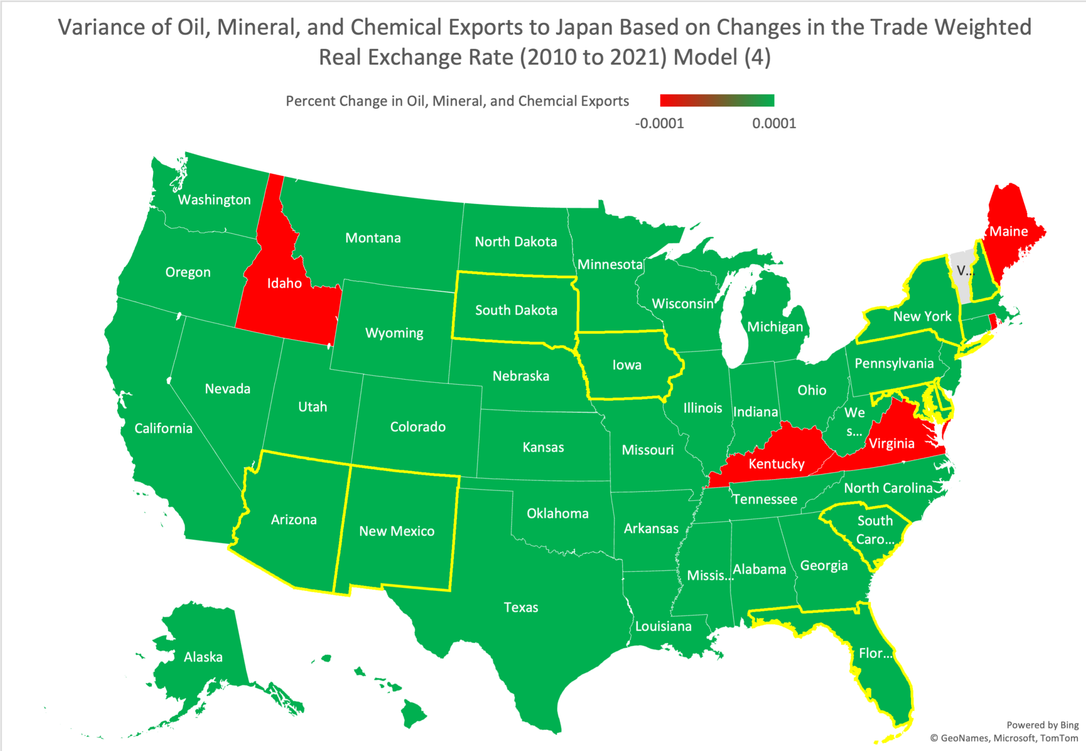

Figure 3: Geographical heat map of the coefficient estimates for interaction terms in model (4) for state-level exports to Japan. States with statistically significant interaction terms are highlighted in yellow, with significance assumed to be below $\alpha = 0.05$. Generated in Microsoft Excel.

In examining the empirical results of models (2) and (5), the third hypothesis that the measure of the real-exchange rate used determines the results of this analysis can be confirmed. Because of this difference in results, the first hypothesis of this paper cannot be definitely confirmed or rejected based solely on the empirical results, as the hypothesis would be rejected considering the results of model (2) and yet confirmed when considering the results of model (5). Similarly, in looking at the second hypothesis of this paper, whether the number of trading partners influences how the real-exchange rate impacts oil, mineral, and chemical exports depends on the measure of the real-exchange rate used. The concluding section has brief remarks on potential disadvantages of each of the exchange rate measures used in this paper.

5 Conclusions and Implications

The results of this analysis fail to definitively confirm the results of prior studies on the effect of exchange rate volatility on the volume of exports at the state-level when considering the majority of states in the absence of trading partners. Each state may experience different levels of exchange rate risk in regards to oil, mineral, and chemical exports, depending on the number of trading partners of each state and the measure of exchange rates used.

In returning to equation (7), notice that the if total exports ($ER_{c,t}$) increase, $ER^*_{s,c,t}$ increases since $CPI_{c,t}$, $ER_{c,t}$, $CPI_{US,t}$, and $GDP_{s,t}$ are all positive. Therefore:

$$\frac{\partial ER^*_{s,c,t}}{\partial E^*_{s,c,t}} = \frac{CPI_{c,t}ER_{c,t}}{CPI_{US,t}GDP_{s,t}} > 0. \tag{8}$$

Since $ER_{c,t}$ includes quarterly oil, mineral, and chemical exports, the positive correlation between ER^{**} and E in model (5) may be simply due to the fact that changes in the real-exchange rate as calculated in (Ellis, 2001) may be driven by changes in total exports, which are directly related to oil, mineral, and chemical exports. This may be one potential downside of using this measure of the real-exchange rate. The (C. House et al. 2019) measure of trade-weighted real-exchange rates weights both the CPI measures and the nominal-exchange rate measure separately, which results in state that have a higher export-share relative to their GDP having a greater pricing adjustment relative to states in which exports make up a lower percentage of GDP. Future research could examine different methods of calculate the real-exchange rate to capture state-specific effects. Additionally, the WTI spot price of crude oil proved to be an insufficient explanatory variable in the baseline model (1). Therefore, a price measure that includes mineral and chemical prices would have been more desirable. Lastly, additional research could utilize different measures of exchanges rates, different product categories, and different export-destination countries to determine how the results in this paper change under these differing conditions.

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Appendix

Figure 1A plots the residuals from the baseline model (1).

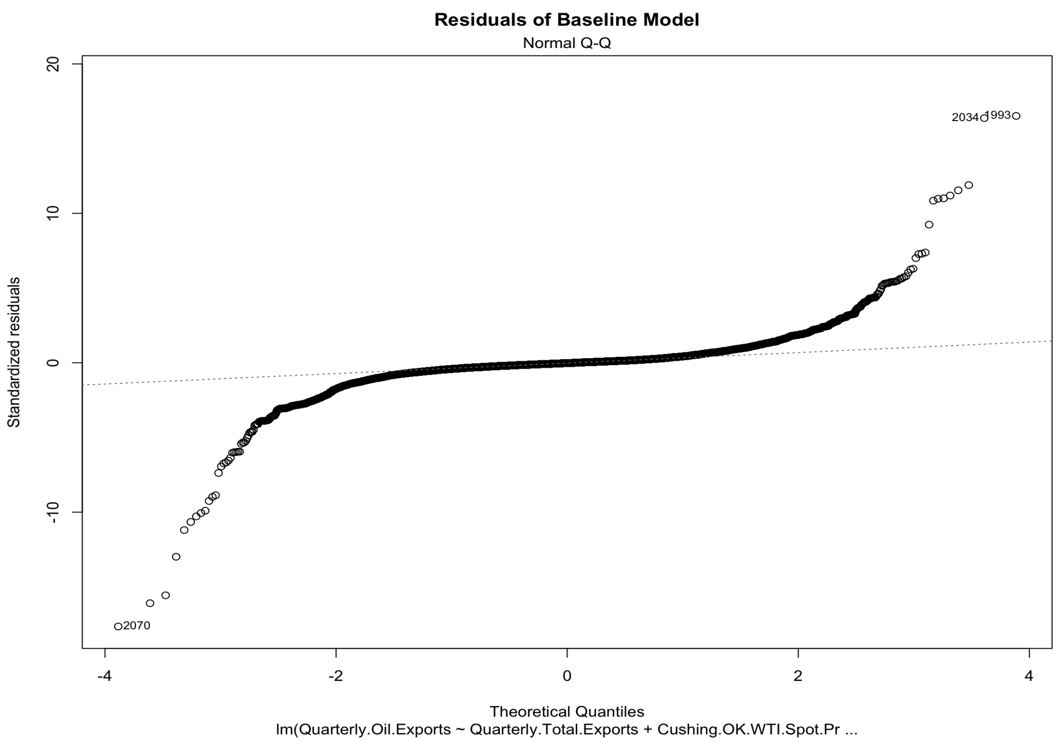

Figure 1A: Plot of the residuals of the baseline model in R.

From figure 1A, there does appear to be a linear pattern in the residuals, though there they are slightly skewed in the negative direction. Figure 2A plots the residuals from model (2).

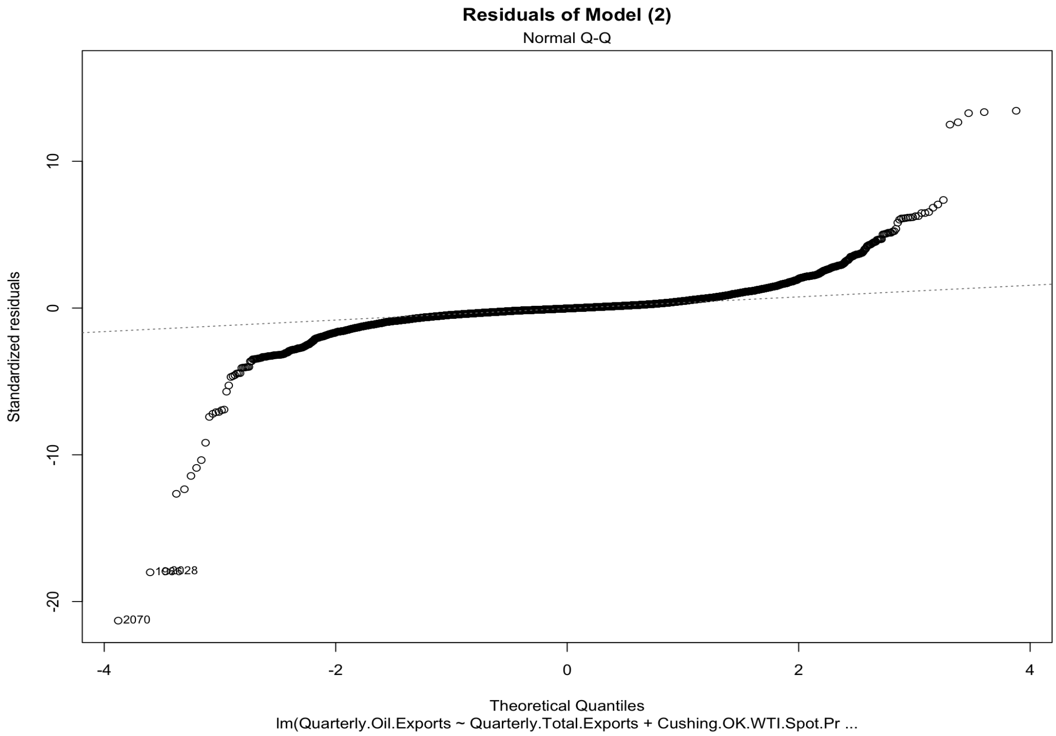

Figure 2A: Plot of the residuals of model (2) in R.

From Figure 2A, the residuals do appear to follow a linear pattern, though they are slightly more skewed in the negative direction as compared to the baseline model. Figure 3A plots the residuals model (3).

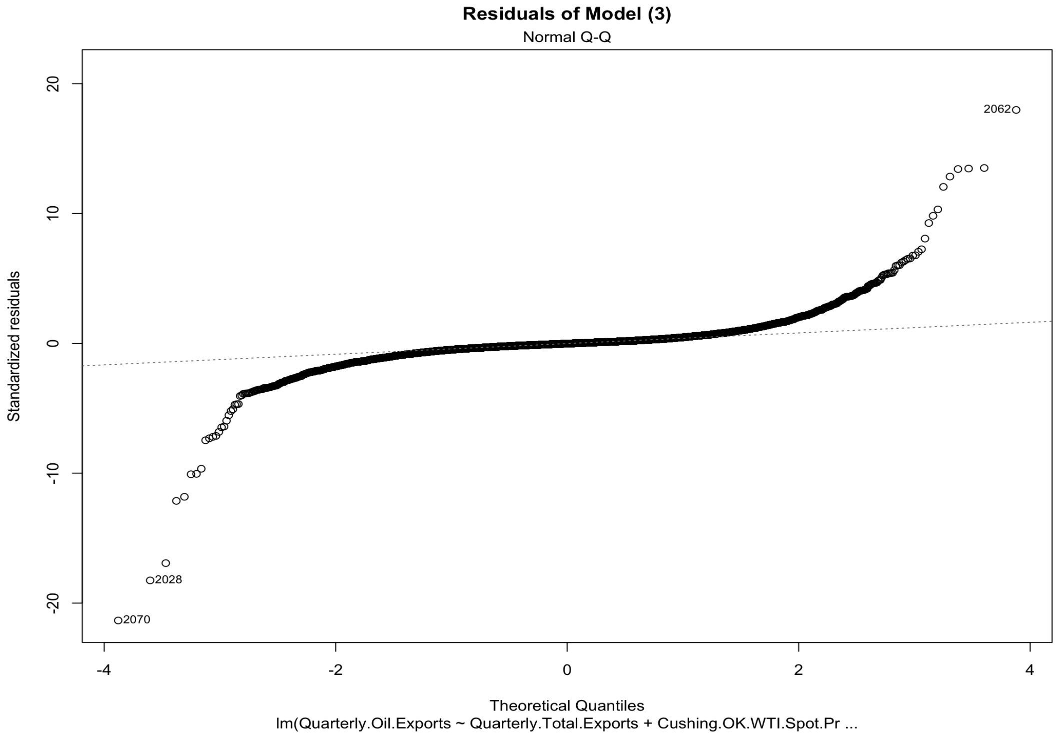

Figure 3A: Plot of the residuals of model (3) in R.

The residual plot for model (3) appears fairly similar to the residual plot for model (2). There appears to be a linear relationship among the residuals for model (3). Figure 4A plots the residuals of the final model, model (4).

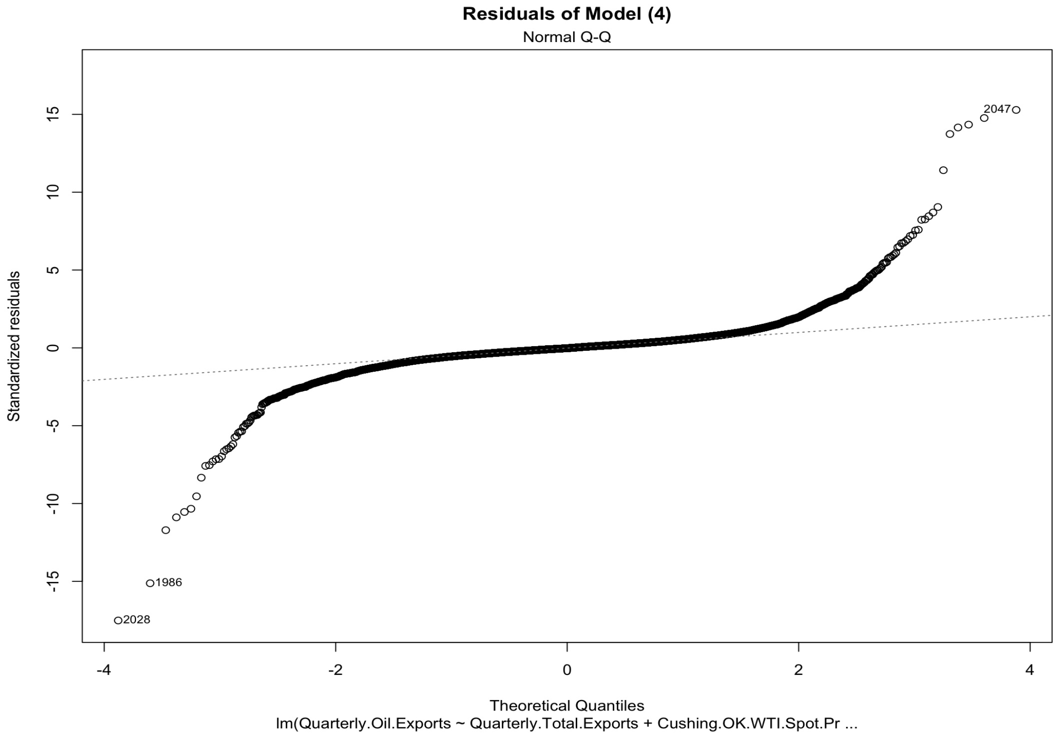

Figure 4A: Plot of the residuals of model (4) in R.

From Figure 4A, it appears that there is again a linear pattern among the residuals. Tables 5, 6, and 3A include all statistical results for models (2), (4), and (5). Figures 5A through 8A show the geographical heat maps for the destination-countries not discussed in the "Empirical Results" section using model (2).

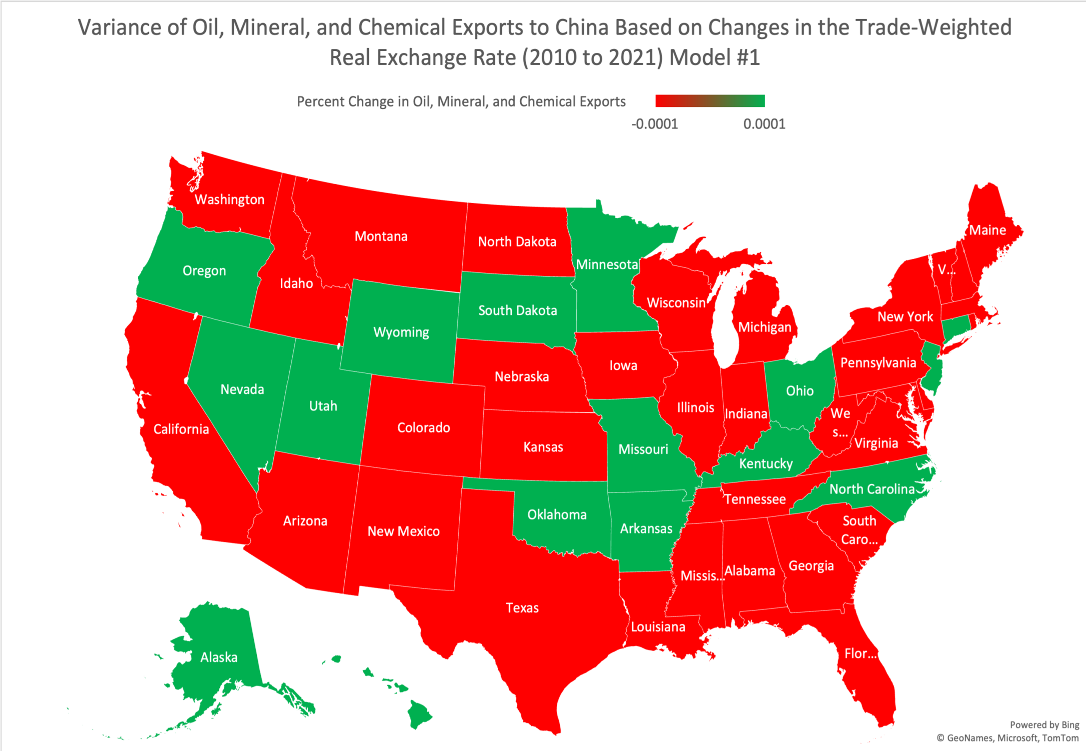

Figure 5A: Heat map of state-level exports to China under model (2).

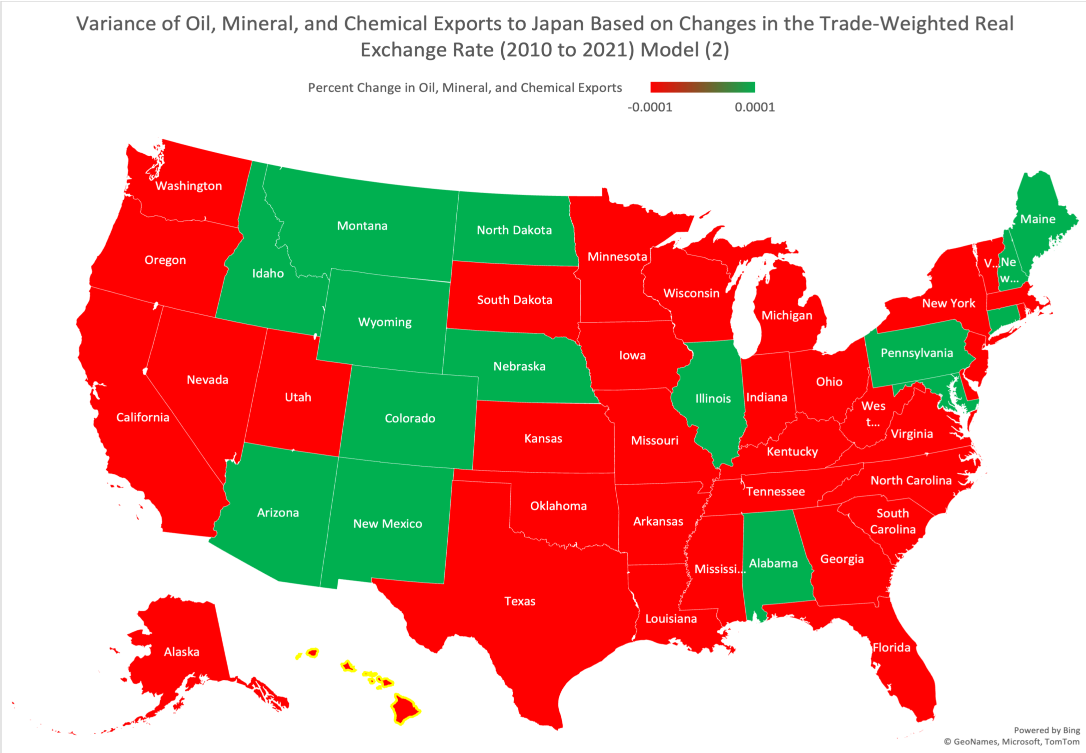

Figure 6A: Heat map of state-level exports to Japan under model (2).

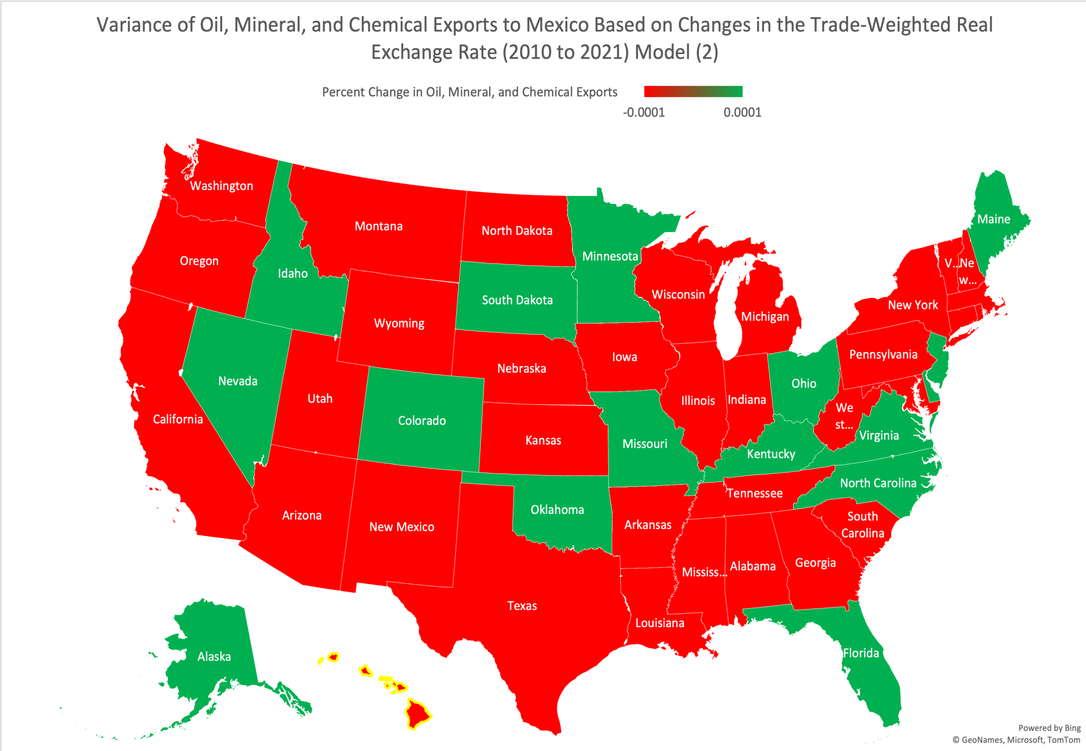

Figure 7A: Heat map of state-level exports to Mexico under model (2).

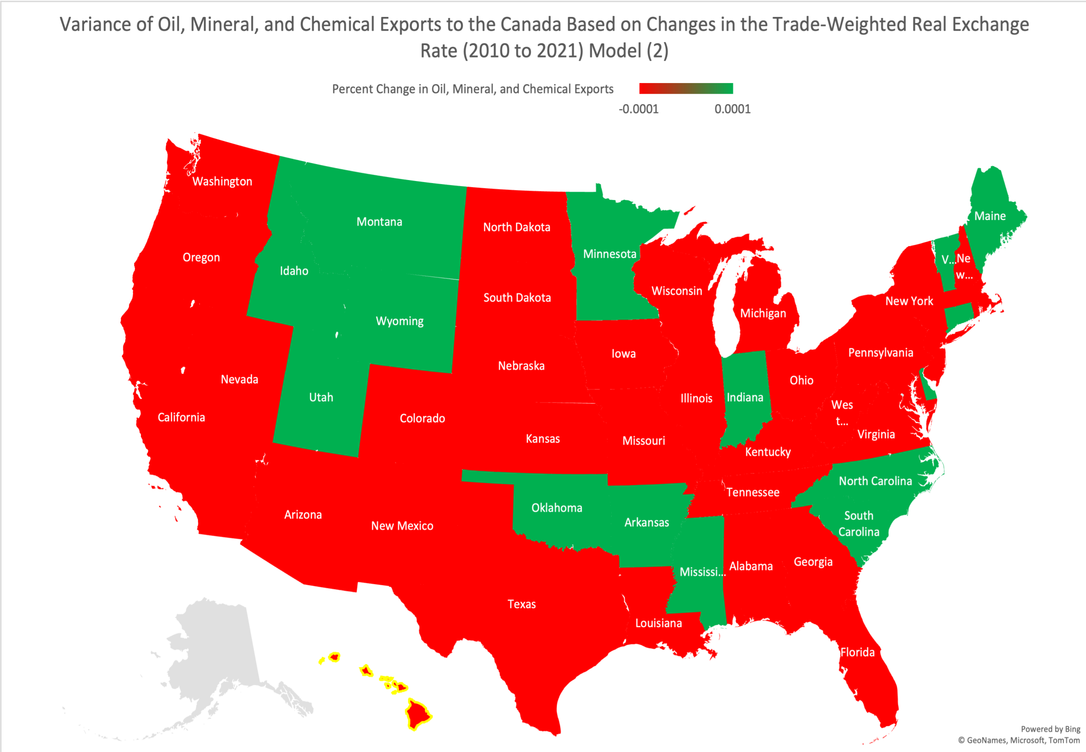

Figure 8A: Heat map of state-level exports to Canada under model (2).

Figures 9A through 12A show the geographical heat maps for the destination-countries not discussed in the "Empirical Results" section using model (3).

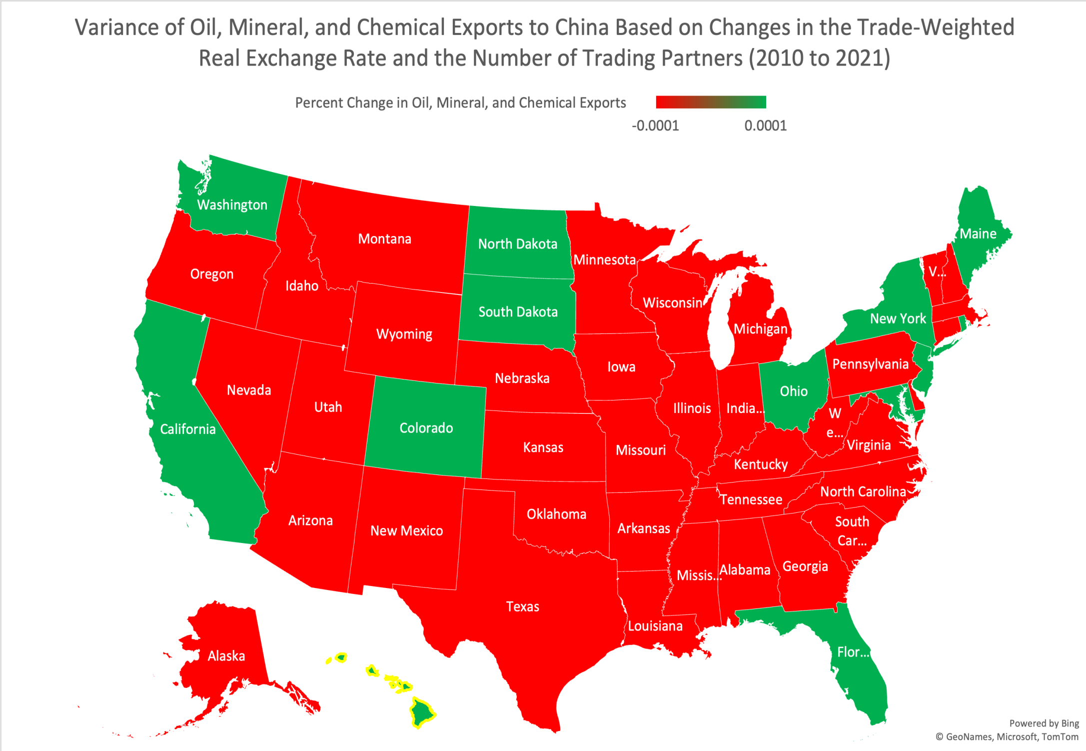

Figure 9A: Heat map of state-level exports to China under model (4).

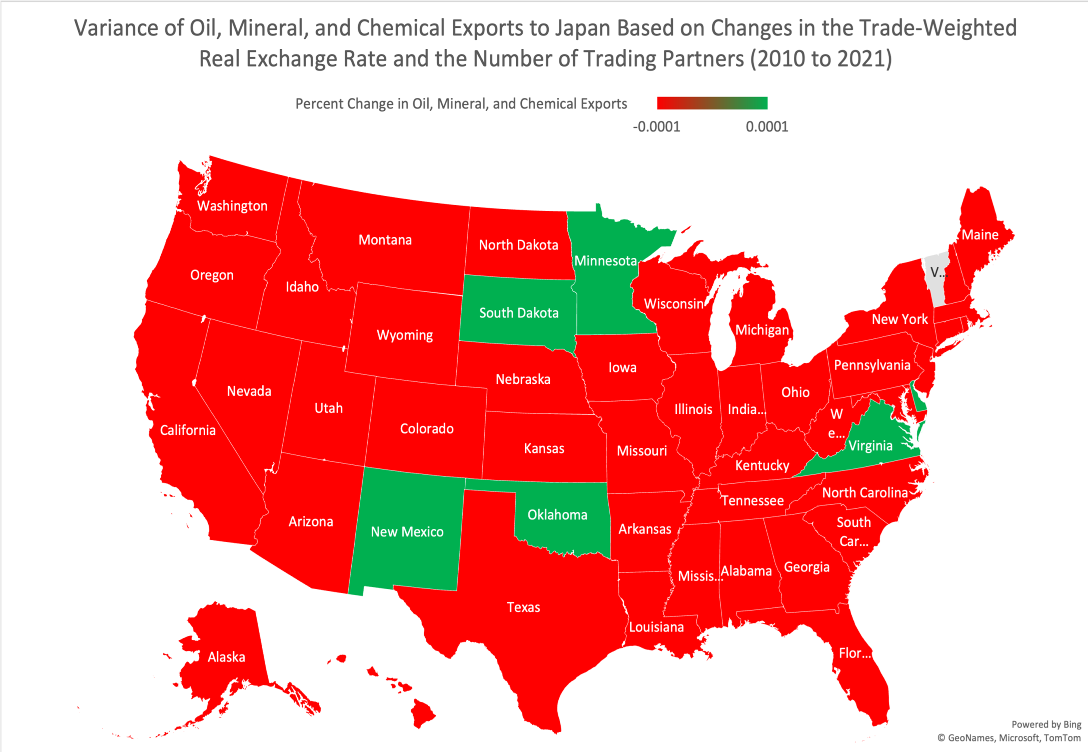

Figure 10A: Heat map of state-level exports to Japan under model (4).

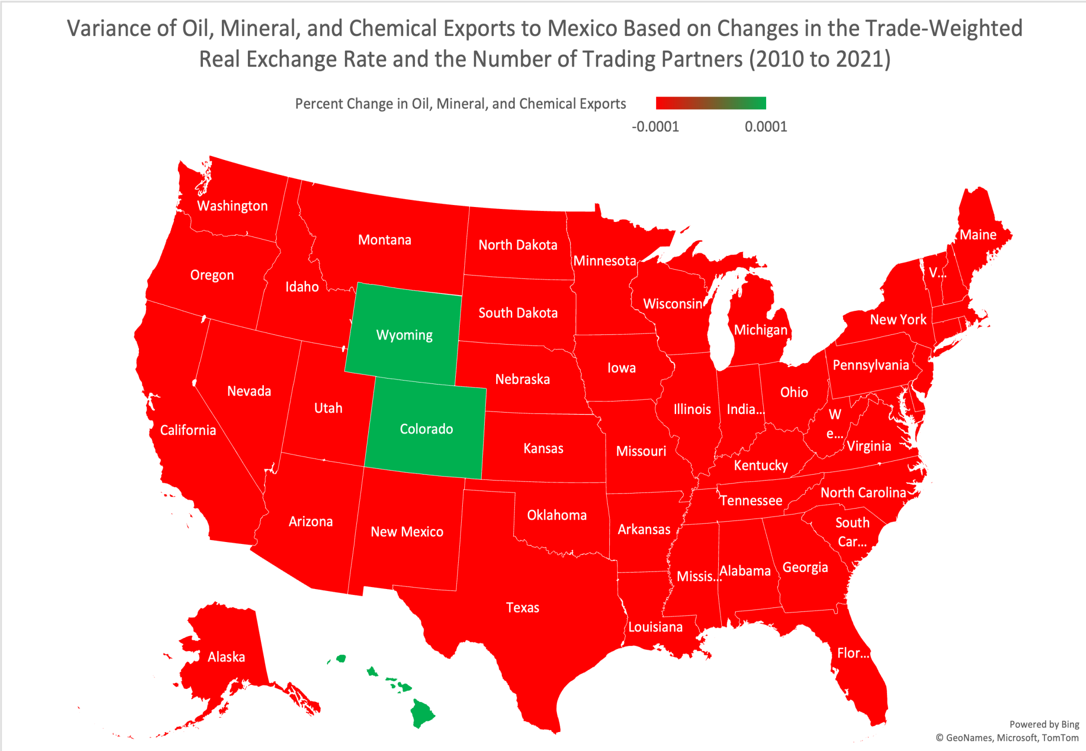

Figure 11A: Heat map of state-level exports to Mexico under model (4).

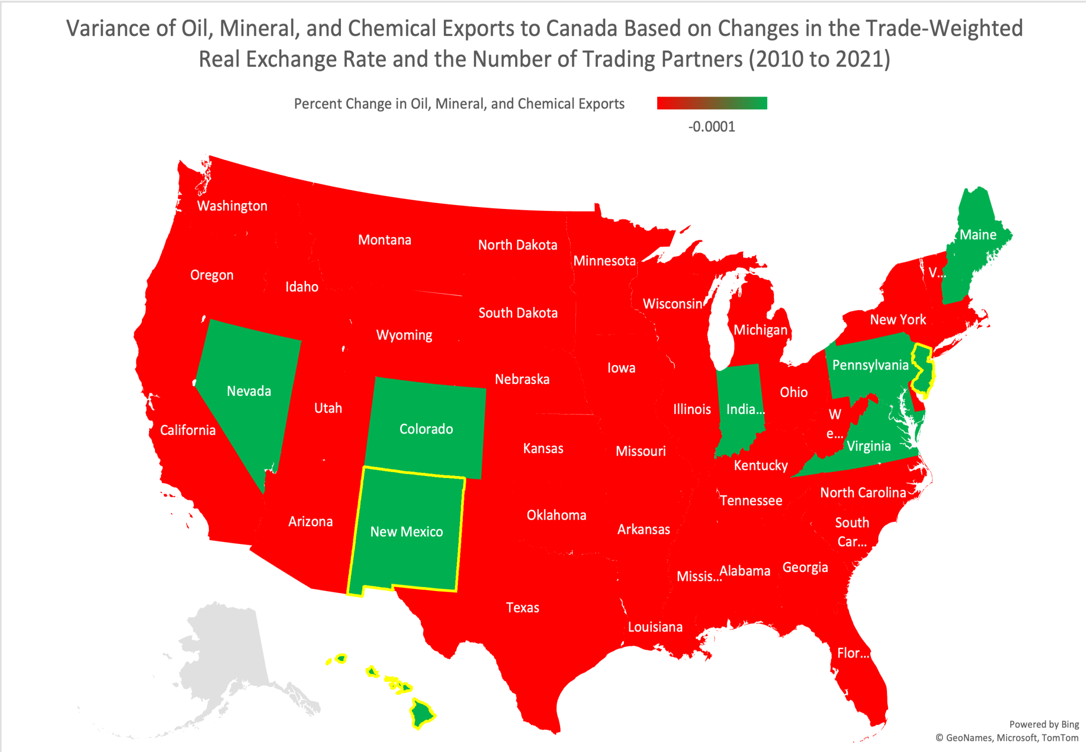

Figure 12A: Heat map of state-level exports to Canada under model (4).

Figures 13A through 16A show the geographical heat maps for the destination-countries not discussed in the "Empirical Results" section using model (4).

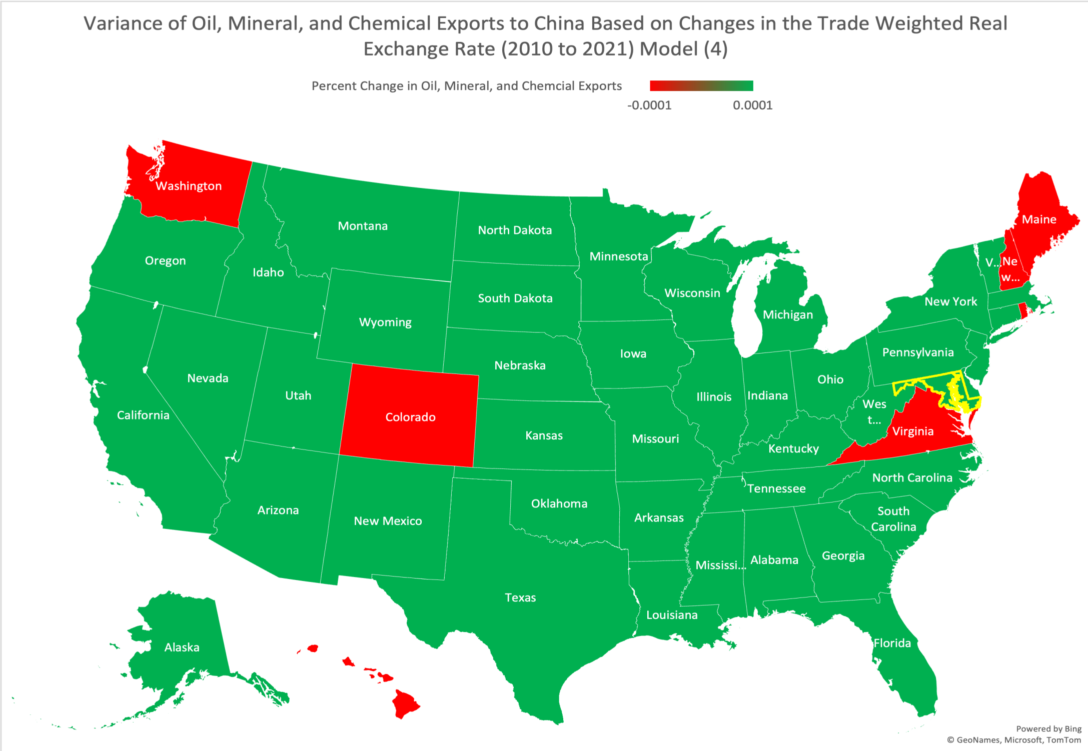

Figure 13A: Heat map of state-level exports to China under model (5).

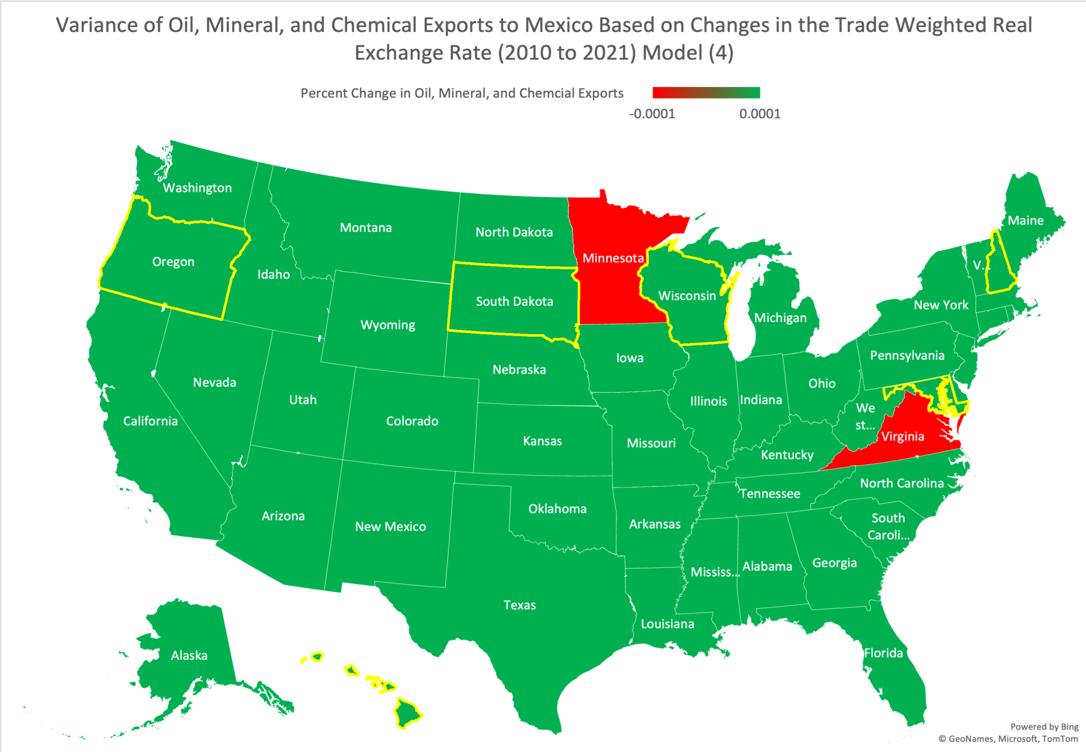

Figure 14A: Heat map of state-level exports to Mexico under model (5).

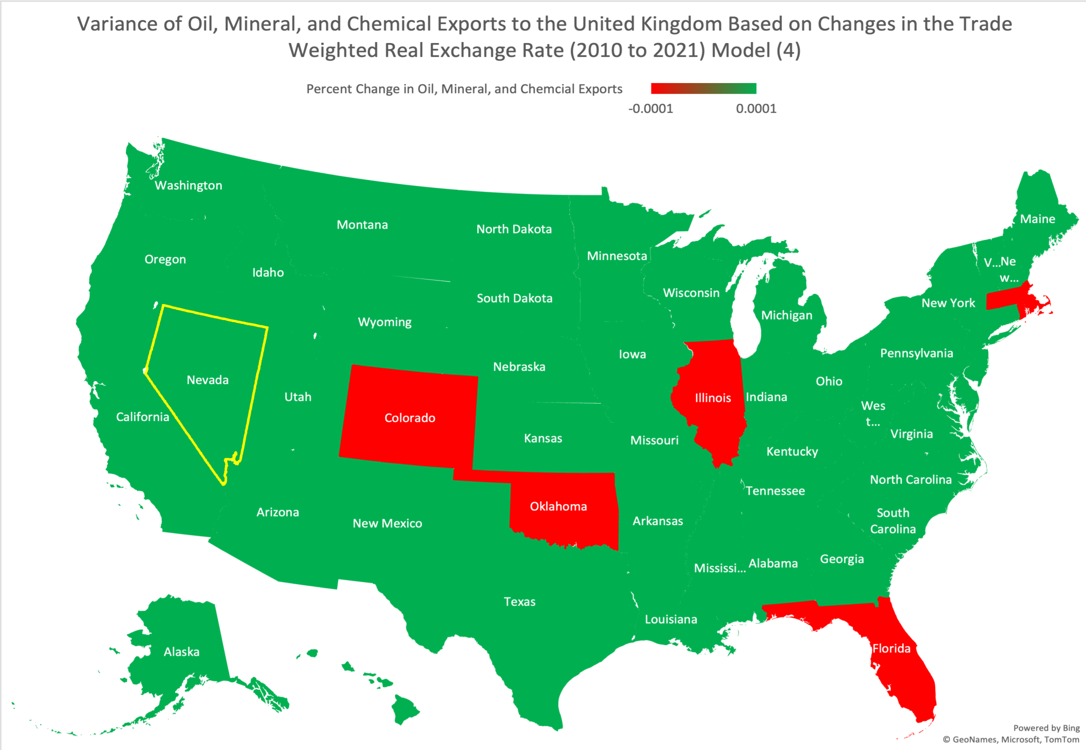

Figure 15A: Heat map of state-level exports to the United Kingdom under model (5).

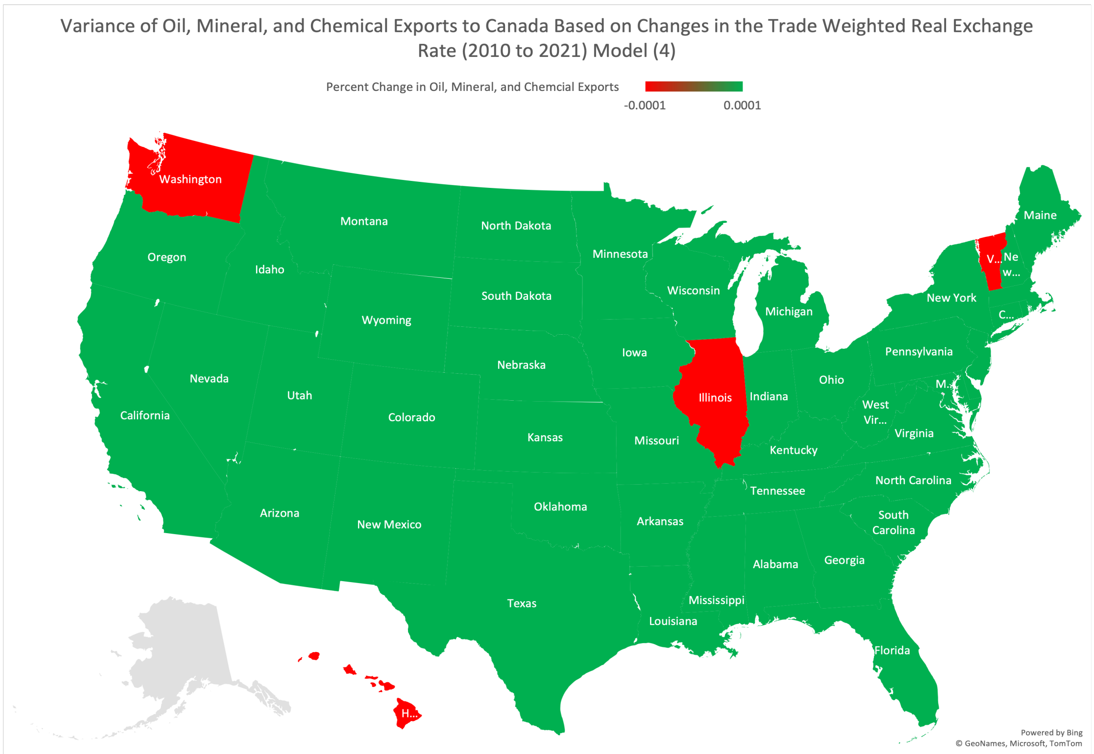

Figure 16A: Heat map of state-level exports to Canada under model (5).