IMPORTS AND THE LOCATION OF VEHICLE PRODUCTION WITHIN THE UNITED STATES

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Abstract

Changes in tariffs or foreign production costs can alter the geographic concentration of motor vehicle production within the United States. The magnitude of these economic effects are simulated in a sub-national model of the motor vehicle industry that combines data on vehicle production at the level of individual plants and vehicle models with data on U.S. sales, multi-product ownership, and pricing. A new 25% tariff on U.S. imports from outside of North America would reduce vehicle imports by 73.9%, increase average prices of vehicles in the United States by 5.0%, and increase variable profits from domestic production by 5.2%. The increase in North American vehicle production is unevenly distributed, with the largest percent increases in California, Tennessee, Georgia, and Alabama, moderate percent changes in Mexico and Canada, and the smallest percent increases in Missouri, Michigan, and Texas.

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1 Introduction

The motor vehicle industry, a major contributor to the U.S. economy, is especially open to competition from imports. An increase in the cost of imported vehicles – for example due to a new tariff, dollar depreciation, or other increases in the costs of foreign production – could lead to a reduction in vehicle imports, an increase in prices paid by U.S. consumers, and and increase in sales of domestically produced vehicles.[1] U.S. production of cars and light trucks occurred in 15 states in 2022, with concentrations in the Midwest and Southeast. Changes in domestic production due to a reduction in imports would be unevenly distributed across the country, depending on the location of production of vehicle models that most directly compete with the imports.

This paper builds an industry-specific sub-national model of the motor vehicle industry and then uses the model to simulate the economic effects of changes in trade policy. The simulation analysis starts with a simplified version of the model, with six single-product firms who produce in two different domestic locations and one foreign location but all sell in a common national product market. This simplified model identifies economic factors that determine the geographic distribution of the production effects of a new tariff. If domestic production is initially distributed unevenly across sub-national regions, the reduction in imports leads to a greater percent expansion in the region that is initially smaller, resulting in partial convergence of production levels across domestic regions. The uneven distribution of the percent increases in vehicle production also reflects the variable markups that characterizes the Bertrand oligopoly model. Joint ownership of multiple products and multinational production through FDI is another important factor. Inbound FDI generally magnifies the

[1] For example, in 2019 the U.S. Department of Commerce recommended Section 232 national security tariffs as high as 25% on all vehicle imports from outside of North America and 35% on imports of Sports Utility Vehicles and Crossover Utility Vehicles. See U.S. Department of Commerce (2019) and Congressional Research Service (2020). Despite the recommendation, these tariffs were not ultimately applied by the President.

effects on vehicle production in the domestic locations where there is foreign transplant production.

Next, the simulation analysis employs a much more detailed version of the model that is calibrated to plant- and vehicle model-level data for the light vehicle industry. This full version of the model includes 313 different vehicle models, the complete pattern of multi-product ownership and market concentration, and the location of assembly for each vehicle model. Simulations that us the full model indicate that a new 25% tariff on all U.S. imports from outside of North America would reduce these imports by 73.9%, increase average prices of vehicles in the United States by 5.0%, and increase variable profits from domestic production by 5.2%. The increase in North American production would be unevenly distributed, with the largest percent increases in California, Tennessee, Georgia, and Alabama, moderate percent changes in Mexico and Canada, and the smallest percent increases in Missouri, Michigan, and Texas. Additional simulations that limit the new tariff to imports from a single foreign country show that the segment composition of these imports and of domestic production in each state, as well as the location of foreign transplant production, affect the geographic distribution of the changes in domestic vehicle production.

The rest of the paper is organized in five parts. Section 2 provides a brief overview of related economic literature and recent summary statistics for the U.S. light vehicle industry. Section 3 describes the modeling framework. Section 4 uses a simplified version of the model to illustrate the economic factors that shape how import shocks affect the level and location of domestic vehicle production. Section 5 reports estimated effects from the full version of the simulation model. Section 6 offers caveats, conclusions, and ideas for further research.

2 Overview of the U.S. Motor Vehicle Industry

This section provides an overview of the market for new light vehicles in the United States, with an emphasis on the location of vehicle production. It briefly reviews the related economic literature and then presents recent summary statistics for the industry.

2.1 Literature on Imports and the U.S. Motor Vehicle Industry

There is a significant economic literature that estimates oligopoly models of the U.S. motor vehicle industry and uses these models to estimate the economic effects of changes in trade policy. Goldberg (1994) uses an econometric model developed in Goldberg (1995) to estimate the effects of the Voluntary Export Restraints (VERs) on exports from Japan in the 1980s and the North American Trade Agreement (NAFTA) in the 1990s. She finds that the VERs increased average vehicle prices in 1983 and 1984 and shifted demand to the used car market and to large and luxury new cars. She also finds that NAFTA shifted demand away from vehicles imported from Japan and Germany but only had small effects on prices and domestic sales. Berry, Levinsohn and Pakes (1999) uses an econometric model that they develop in Berry, Levinsohn and Pakes (1995) to estimate the economic effects of the same Japanese VERs. They find that the VERs increased market prices in the United States and increased sales and profits from domestic production. The VERs resulted in a significant net decline in domestic consumer welfare because, unlike tariffs, there was no additional government revenue collected by the VERs.

More recently, Grieco, Murry and Yurukoglu (2023) use an econometric model with second choice data, following Berry, Levinsohn and Pakes (2004), to analyze the changes in price-cost margins and market power in the U.S. automotive industry between 1980 and 2018. The authors find that substitutability between vehicle models is significantly higher within vehicle class, and that U.S. prices rose while market concentration fell over the time period, mostly reflecting upgrading of product characteristics. Although Grieco et al. (2023) does not directly analyze the effects of trade policy, they do include a trade-related counterfactual simulation that estimates the economic effects of reassigning the ownership of foreign brands to U.S. "Big 3" manufacturers.

U.S. International Trade Commission (2019) and U.S. International Trade Commission (2023) develop a vehicle model-level simulation framework and estimate the economic effects of the automotive rules of origin in the U.S.-Mexico-Canada Agreement (USMCA). These two reports find that the change in the USMCA rules of origin increased U.S. employment in parts production while slightly reducing U.S. employment in vehicle assembly. The rules led to a small increase in average vehicle prices, a reduction in U.S. vehicle imports from Mexico and Canada, and an increase in U.S. imports from outside of North America.

The simulation model in Section 3 of this paper follows many of the modeling assumptions in Goldberg (1994), Berry et al. (1999), and Grieco et al. (2023) regarding demand, costs, and Bertrand oligopoly in the product market.

2.2 Summary Statistics for the Light Vehicle Industry

According to Ward's Automotive, 21 manufacturers sold light vehicles in the United States in 2022.[2] All but one of the 21 manufacturers sold multiple vehicle models, often under several different makes.[3]

Table 1 reports the number of vehicles, makes, and models in eight distinct segments of the light vehicle market, as well as the segments' expenditure shares on imports from outside of North America. Small Crossover Utility Vehicles (CUVs), Luxury Cars, and Small Cars are the most import-intensive, while Mid and Large Cars and Pickups are the least.

Table 2 reports the distribution of U.S. production of these vehicles across states in

[2] Ward's Intelligence, "U.S. Vehicle Sales by Vehicle Type and Source, 1931-2022."

[3] Examples of makes are Honda's Honda make and Acura make or Ford's Ford make and Lincoln make. Examples of vehicle models include the Ford Escape or the Subaru Outback.

Table 1: Light Vehicle Market Segments in 2022

Segment	Number of Vehicles	Number of Makes	Number of Vehicle Models	Quantity Share of Imports
Small Cars	947,703	11	21	34.6%
Mid and Large Cars	1,191,156	15	24	10.2%
Luxury Cars	738,775	22	68	42.5%
Small CUVs	1,639,542	23	40	46.8%
Mid and Large CUVs	4,372,003	30	82	24.2%
SUVs	1,388,875	14	25	13.9%
Vans	616,048	12	17	10.6%
Pickups	2,652,650	10	17	0.0%

2022. Michigan is at the top of the list, accounting for 19.0% of vehicles produced in North America in 2022, and the Upper Midwest states (Michigan, Indiana, Ohio, and Illinois) together account for 42.2%. Table 2 also reports each state's share of foreign transplant production in the United States.[4] Alabama has the largest share at 22.850%, followed by Indiana, Kentucky, and Ohio. Together, these four states account of approximately one-third of the vehicles produced by foreign transplants in the United States.

Overall, approximately 69% of new light vehicle production in North America was located in the United States in 2022, 23% was located in Mexico, and the rest were located in Canada. In addition, approximately 3 million new light vehicles were imported into the United States from outside of North America.

3 Economic Modeling Framework

This section presents the modeling framework used to simulate changes in equilibrium prices and market shares resulting from a hypothetical new tariff. The model adopts many of the

[4] U.S. transplant production is the subset of total U.S. production that involves foreign-owned companies. For example, all vehicles produced by Subaru in Indiana or by Honda in Ohio are U.S. transplant production. These calculations do not count U.S. production of Stellantis as transplant production, even though Stellantis is a multinational firm.

Table 2: Levels and Shares of Production by State in 2022

States	Number of Vehicles	Share of U.S. Vehicle Production (%)	Share of U.S. Transplant Production (%)
Michigan	1,465,854	19.300	
Indiana	866,775	11.818	20.409
Kentucky	880,854	11.598	12.565
Alabama	731,662	9.914	22.850
Ohio	655,866	8.635	10.000
Texas	388,817	5.119	0.161
California	456,100	6.005	
Tennessee	374,515	4.931	8.314
South Carolina	267,846	3.536	8.150
Missouri	445,498	5.866	
Mississippi	305,322	4.020	9.265
Illinois	289,280	3.809	
Georgia	257,047	3.595	8.286
Kansas	137,241	1.807	
Arizona	3,535	0.047	

assumptions in Goldberg (1994), Berry et al. (1999), and and Grieco et al. (2023), including logit model with many differentiated products. The domestic and foreign producers engage in Bertrand Nash competition in prices. The model focuses on a short run in which the set of producers and the vehicle models that they offer are pre-determined and exogenous. There are constant marginal costs of production. Consumer demand in Berry et al. (1999) and Grieco et al. (2023) includes an outside alternative to new car purchases, while demand in Goldberg (1994) includes a decision about whether to purchase a new car in an earlier step in her sequential logit model.

While there are many similarities between the model in this paper and the models in the literature, there are also important differences. First, the earlier models focused on the national net welfare effects of Voluntary Export Restraints in the 1980s and NAFTA in the 1990s, while the sub-national model in this paper simulates the impact of a new tariff on domestic vehicle production in individual states.[5] Second, the studies in the literature use econometrics to estimate demand parameters at the level of individual consumers, while the model in this paper calibrates its demand parameters to price-cost margins estimated by these earlier studies.

Consumer demand in the model is discrete choice logit. Equation (1) is the quantity market share of vehicle model j, μ_j.

$$\mu_j = \frac{Exp\ (\beta_j\ -\ \alpha\ p_j\ \tau_j)}{1\ +\ \sum_{k=1}^{N} Exp\ (\beta_k\ -\ \alpha\ p_k\ \tau_k)} \tag{1}$$

p_j is the producer price of j. The tariff factor τ_j is equal to one plus the tariff rate if product j is imported from outside of North America. k indexes the N vehicle models sold in the market. The demand parameter β_j captures a combination of product characteristics, including vehicle size, engine power, and appearance. This demand parameter is calibrated to initial quantity shares in the market. The price-sensitivity parameter α is set to 1.275 to fit estimated price-cost margins in the U.S. market in 2018 from Grieco et al. (2023).

If firm j only sells a single product j, then equation (2) is the profits of this oligopolist, π_j.

$$\pi_j = (p_j\ -\ c_j)\ \bar{Q}\ \mu_j\ -\ f_j \tag{2}$$

$\bar{Q}$ is the fixed total number of consumers in the market, including those who chose the outside option of purchasing a used vehicle or not purchasing any vehicle. c_j is the constant marginal cost of product j, and f_j is the fixed cost of production. Equation (3) is firm j's first order condition for its own price, given demand in equation (1).

$$1\ -\ (p_j\ -\ c_j)\ \alpha\ \tau_j\ (1\ -\ \mu_j) = 0 \tag{3}$$

[5] Grieco et al. (2023) does not directly analyze the economic effects of trade policy.

The prices of firm j's competitors enter equation (3) through μ_j.

If the firm that sells product j also sells other products, then the profit function in equation (2) and the first order condition in equation (3) are replaced by the more generalized versions in equations (4) and (5).

$$\pi_j = \sum_{k=1}^{N} \phi_{jk} \; (p_k \; - \; c_k) \; \bar{Q} \; \mu_k \; - \; f_k \tag{4}$$

$$1 \; - \; (p_j \; - \; c_j) \; \alpha \; \tau_j \; + \; \sum_{k=1}^{N} \phi_{jk} \; (p_k \; - \; c_k) \; \alpha \; \tau_j \; \mu_k = 0 \tag{5}$$

Again, k indexes all products in the market, and ϕ_{jk} is an indicator variable that is equal to one if the same firm owns and controls products j and k and is equal zero otherwise.

The model calibrates the set of marginal costs c_j using the N first order conditions. The demand parameter β_j is calibrated according to equation (6).

$$\beta_j = \ln\left(\frac{\mu_j}{\mu_{out}}\right) \; + \; \alpha \; p_j \; \tau_j \tag{6}$$

μ_{out} is the initial share of potential consumers who chose the outside option, either purchasing a used vehicle or no vehicle. Finally, the model translates the changes in market shares into changes in the location of domestic vehicle production using data on the plant where each vehicle model is assembled.[6] The change in vehicle production in each location is the sum of the changes in production of all vehicle models with plants in that location.

4 Simplified Illustrative Model

To build an understanding of the economic effects of a new tariff without the complexity of the state- and vehicle model-level data on U.S. vehicle production, this section first presents

[6]The plant or plants where each vehicle model are assembled is exogenous to the model.

a simplified version of the simulation model. In this illustrative model, domestic production occurs in two regions, North and South. Vehicle production in North is always larger or the same size as vehicle production in South. There are two domestic producers of vehicles in each of the two domestic regions and two foreign producers who import into the domestic market. Each producer sells a single vehicle model, so there are six products in this simplified version of the model.

4.1 Non-Nested Logit Model

Consumer demand for the six products has the non-nested logit form in equation (1). The six products are all differentiated, but there is no market segmentation or classes of products in this non-nested model. The illustrative model is calibrated to summary data from the U.S. market in 2022, including total sales of light vehicles (1.35 million vehicles), the import penetration rate in the United States (21.1%), and the average vehicle price ($40,195). The initial share of potential consumers who choose the outside goods μ_{out} is set equal to 0.90, since approximately 90 percent of households do not purchase a new car each year, and either purchase no car or a used car, according to Goldberg (1994). The price-sensitivity parameter α is set equal to 1.275.[7]

The model simulates the expansion in domestic production and other economic effects of a new 25% tariff on imported vehicles. Table 3 reports the simulated increase in the number of vehicles and the corresponding percent changes. To illustrate how asymmetries in the initial distribution of domestic production shape the distribution of changes in production across regions, the rows of the table report simulation results for three alternative assumptions about the initial share of domestic production in North.

In response to the new tariff and the increase in import prices, imports decline and

[7] This is the value of α that fits the median price-cost markup in the full version of the model in Section 5 to the median price-cost markup in 2018 from Grieco et al. (2023).

Table 3: Changes in the Number of Vehicles Produced, Non-Nested Logit

Initial North Share of Domestic Production (%)	Change in North (%)	Change in South (%)	Change in Imports (%)
50	71,604	71,604	-1,810,770
	(1.343)	(1.343)	(-63.510)
60	85,565	57,530	-1,810,760
	(1.338)	(1.349)	(-63.510)
70	99,416	43,336	-1,810,760
	(1.332)	(1.355)	(-63.510)

vehicle production rises in both domestic regions, North and South. The changes in domestic production are unevenly distributed. The simulated increase in the number of vehicles is larger in the North when North initially accounts for more than half of domestic production.[8] The difference between the change in production levels in the two regions is increasing in the initial relative size of North. On the other hand, the *percent changes* are larger in South when North initially accounts for more than half of domestic production, and this difference between the two regions is increasing with the initial relative size of North. Where there is initial asymmetry, South starts to catch up as a result of the overall expansion of the domestic industry, and the production levels in the two regions partially converge.

The asymmetries in the simulation results in Table 3 also reflect the variable markups in the Bertrand oligopoly model. If domestic producers were perfectly competitive and set prices equal to marginal costs with no markups, then producers in North and South would both expand at the same rate in response to the new tariff on imports, since there would be no change in their constant marginal costs and therefore no change in their relative prices.[9]

[8] The estimated changes in the number of vehicles produced assumes that a combined 13,512,553 vehicles are produced in the two regions in the initial equilibrium.

[9] This reflects the Independence of Irrelevant Alternatives (IIA) property of the logit model and the modeling assumption that marginal costs are constant. In a demand system with IIA, an increase in the price of one product will increase demand for a second and a third product at the same rate, so that the demand for the second relative to the third remains the same. Constant elasticity of substitution demand also has the IIA property.

Table 4 reports simulations using a more restricted version of the illustrative model without the variable markups. In this case, the percent change in domestic production is the same in North and South, regardless of the initial relative size of the two regions. The estimates in Table 4 demonstrate that the variable markups in the oligopoly model are responsible for the asymmetric growth rates across regions in Table 3.

Table 4: Changes in Vehicles Produced Without Variable Markups, Non-Nested Logit

Initial North Share of Domestic Production (%)	Change in North (%)	Change in South (%)	Change in Imports (%)
50	82,500 (1.548)	82,500 (1.548)	-2,047,130 (-71.800)
60	99,000 (1.548)	66,000 (1.548)	-2,047,130 (-71.800)
70	115,500 (1.548)	49,500 (1.548)	-2,047,130 (-71.800)

The simulations reported in Table 5 extend the model to focus on the implications of multi-product firms, and specifically the impact of joint ownership of foreign and domestic production within the same firm through foreign direct investment (FDI). In this case, the first order conditions for the multi-product firms are based on equation (5) rather than equation (3). This extension of the simplified model specifically assumes that two of the firms manufacture one product in South and import one product. In other words, there is foreign transplant production in the South owned by foreign firms that also import.

Table 5 reports simulation results for this model with FDI, again for the same 25% tariff on imports. In this case, since production in South is owned and controlled by a foreign producer, there is a larger percent increase in production in South than in North *even if* production levels in the two regions are initially equal. Foreign-owned domestic producers increase their prices less in response to the increase in import prices, to offset some of their loss of import sales. There are much larger increases in vehicle production in South compared to North in Table 5. The increases in production in South in the FDI extension of the model (Table 5) are also much larger than the increases in South in the basic model that does not have multi-product firms (Table 3).

Table 5: Changes in Vehicles Produced with FDI, Non-Nested Logit

Initial North Share of Domestic Production (%)	Change in North (%)	Change in South (%)	Change in Imports (%)
50	69,973 (1.313)	111,732 (2.096)	-1,811,270 (-63.528)
60	84,011 (1.313)	89,781 (2.105)	-1,811,160 (-63.524)
70	98,067 (1.314)	67,637 (2.115)	-1,811,060 (-63.520)

4.2 Nested Logit Model

The independence of irrelevant alternatives (IIA) property of logit models is a limitation that is often criticized and usually addressed in the literature. For example, Goldberg (1994) and Goldberg (1995) develop a sequential nested logit framework to allow for more complex patterns of substitution among pairs of vehicle models.[10] In the same spirit, this section considers a nested logit extension of the illustrative model. There are two market segments, and two corresponding nests in the logit demands. One product from each segment is produced in each of the three locations, so there are still six differentiated products. Equation (7) is the share equation for the nested logit model, with a nesting parameter θ that ranges from zero to one and is lower if the products are more similar.[11]

[10] Berry et al. (1995) and Berry et al. (1999) develop a random coefficients logit model that also avoids the IIA property.

[11] The nesting parameter θ is sometimes called the dissimilarity index.

$$\mu_j = \left(\frac{Exp\ (\theta\ \gamma_c)}{1\ +\ \sum_d Exp\ (\theta\ \gamma_d)} \right) \left(\frac{Exp\ \left(\frac{\beta_j\ -\ \alpha\ p_j\ \tau_j}{\theta}\right)}{1\ +\ \sum_{k \in c} Exp\ \left(\frac{\beta_k\ -\ \alpha\ p_k\ \tau_k}{\theta}\right)} \right) \tag{7}$$

Segment c is the nest that includes product j, and d indexes both of the segments. γ_c is defined in equation (8).

$$\gamma_c = Log\ \left(\sum_{j \in c} Exp\ \left(\frac{\beta_j\ -\ \alpha\ p_j\ \tau_j}{\theta} \right) \right) \tag{8}$$

The first order condition for single-product firms in equation (3) still applies, though μ_j is defined differently, according to equations (7) and (8).

Table 6 illustrates the importance of nesting by varying the nesting parameter θ across the rows of the table.[12] All three simulations assume that domestic production is initially distributed unevenly, with 60% in North and 40% in South, and that each firm produces a single product. When θ is equal to one, the model is equivalent to the non-nested logit simulation results in Table 3. Lowering θ significantly increases the magnitude of the estimated effects on domestic production and imports, though this nesting does not change the signs of these effects.

Table 6: Changes in Vehicles Produced, Nested Logit

Nesting Parameter θ	Change in North (%)	Change in South (%)	Change in Imports (%)
1.00	85,565	57,530	-1,810,760
	(1.338)	(1.349)	(-63.510)
0.75	350,894	236,683	-2,078,600
	(5.485)	(5.550)	(-72.904)
0.50	720,465	495,289	-2,435,310
	(11.404)	(11.614)	(-85.415)

[12]The estimates with $\theta = 1$ are the same as the first run in the non-nested simulations reported in Table 3.

4.3 Market-Wide Effects

The four versions of the illustrative model also provide estimates of market-wide effects. Table 7 reports the percent changes in total market demand, the quantity of imports, average vehicle prices in the market, and variable profits from domestic production for the four variants of the illustrative model. These market-wide effects are not especially sensitive to the initial share of North in domestic production, so all of the simulations reported in Table 7 assume that this share is equal to 60%. (The simulations also all set μ_{out} equal to 0.90, the new tariff equal to 25%, and α equal to 1.275.)

Table 7: Percent Changes in Market-wide Aggregates

Estimated Effect	Non-Nested Model	Non-Nested Model without Markups	Non-Nested Model with FDI	Nested with $\theta = 0.75$
Total Market Demand	-12.342	-13.929	-12.117	-11.034
Imports	-63.510	-71.800	-63.524	-72.904
Average Prices	4.212	5.275	4.153	4.222
Variable Profits from Domestic Production	1.371	n/a	1.353	5.633

In all four simulations, the hypothetical new tariff reduces total quantity demanded in the market and reduces the number of imported vehicles, while it increases the average price in the market and the variable profits from domestic production. The changes in market-wide aggregates are generally magnified when the simulations do not include the Bertrand variable markups or when there is nested logit demand.

The illustrative model demonstrates the effects of several different modeling assumptions, one at a time, including the initial location of domestic vehicle production, variable markups from Bertrand competition in prices, and joint ownership and control over multiple vehicle models. In fact, the light vehicle industry is a complex mix of these factors. The full version of the model in the next section combines all of these factors.

5 Simulations Using the Full Version of the Model

The full version of the model incorporates detailed data on plant- and vehicle model-level production and sales in 2022 from Ward's Intelligence.[13] It includes 313 different vehicle models in the eight distinct market segments listed in Table 1. These segments are represented by eight nests in the logit model of demand. Vehicle production occurs in 18 distinct production locations (15 states, Canada, Mexico, and the Outside of North America).[14] Like in the illustrative model, the full version of the model sets μ_{out} equal to 0.90, the new tariff equal to 25%, and α equal to 1.275. It uses prices from the Kelley Blue Book at the level of individual vehicle models.[15] These price inputs are based on the most popular trim of each vehicle model in 2022.

5.1 A New Tariff on All Imports from Outside North America

Table 8 reports the market-wide effects for alternative assumptions about the nesting parameter θ. The first column of estimates, with $\theta = 1.00$, is non-nested logit. In every column, the new tariff results in reductions in total demand and imports and in increases in average prices and the profits from domestic production. In the case with moderate segmentation of teh market ($\theta = 0.75$), the new 25% tariff on all U.S. imports from outside of North America would reduce these imports by 73.9%, increase average prices of vehicles in the United States by 5.0%, and increase the variable profit from domestic production by 5.2%. As θ is reduced, the changes in total demand and average prices are dampened or the same, while

[13] Ward's Intelligence, "North America Vehicle Production by State and Plant, 2017–2021" and "U.S. Vehicle Sales by Vehicle Type and Source, 1931-2022."

[14] The 15 states are Alabama, Arizona, California, Georgia, Illinois, Indiana, Kansas, Kentucky, Michigan, Mississippi, Missouri, Ohio, South Carolina, Tennessee, and Texas.

[15] `https://www.kbb.com/car-prices/`.

the changes in imports and the profits of domestic producers are amplified.

Table 8: Simulated Market-Wide Effects – All Countries

Estimated Effects	$\theta = 1.00$	$\theta = 0.75$	$\theta = 0.50$
Total Market Demand	-12.669	-11.195	-8.941
Imports	-66.017	-73.863	-84.616
Average Prices	4.954	4.954	4.954
Variable Profits from Domestic Production	1.408	5.157	10.436

Table 9 indicates that the new tariff also results in an overall shift in U.S. light vehicle sales toward Pickups, Mid and Large Cars, Vans, and SUVs. These are the four segments with the lowest import penetration rates in 2022 (Table 1).

Table 9: Shifts in Segment Shares and Average Prices ($\theta = 0.75$)

Market Segment	Initial Share (%)	New Share (%)
Small Cars	7.014	6.694
Mid and Large Cars	8.815	9.501
Luxury Cars	5.214	4.051
Small CUVs	12.134	10.354
Mid and Large CUVs	32.355	31.508
SUVs	10.278	10.627
Vans	4.559	4.876
Pickups	19.631	22.389

Table 10 reports the simulated changes in the total number of vehicles produced for the U.S. market by location (state or country in North America). With moderate segmentation of the market ($\theta = 0.75$), the largest percent increases in vehicle production are in California, followed by Tennessee, Georgia, and Alabama.[16] This ranking reflects many factors. These

[16]It is important to keep in mind that the model is estimating the expansion of production at existing plants in specific states and not the addition in new plants or new states.

states generally focus on production of Luxury Cars and Mid and Large CUVs, and they also have significant foreign transplant production.

Alternatively, the production effects can be ranked by the share of the total increase in North American vehicle production contributed by each state and country in North America. According to this second ranking, Mexico accounts for 21.403% of the total increase in North American production, while Canada accounts for 9.901%. The largest contributing state is Alabama (accounting for 9.616%), followed by Michigan (8.467%), California (8.411%), and Indiana (8.054%).[17] This ranking clearly reflects the large initial production levels in Mexico, Canada, Michigan, and Indiana.

A comparison of the estimates for the different columns in Table 10 demonstrates the impact of nesting on the geographic heterogeneity of the simulated. In the first column ($\theta = 1$), there is no nesting and there is much less heterogeneity in the percent changes across states and countries in North America. In this case, the coefficient of variation of the percent changes for the 13 states in the table is 0.04. In contrast, when $\theta = 0.50$, the coefficient of variation of the percent changes is 0.50.

Table 11 examines the sensitivity of the simulation model to incorporating the pattern of joint ownership across individual vehicle models.[18] The additional simulation in the last column removes joint ownership by setting ϕ_{jk} equal to one if j is the same as k and setting it equal to zero otherwise. This restriction eliminates multi-product profit maximization. The restriction has only a small effect on the percent changes in vehicle production due to the new tariff. Indiana, Alabama, Kentucky, Georgia, Mississippi, and Texas have the largest reductions in the percent changes when the pattern of joint ownership is removed from the model. They are some of the top states for transplant production according to Table 2.

[17]For brevity, the table does not report the small effects on vehicle production in Kansas (5,149 vehicles, 0.892% of the North American total increase) or Arizona (532 vehicles, 0.092%).

[18]All of the simulations in Table 11 assume that θ is equal to 0.75.

Table 10: Simulated Changes – Imports from All Countries Outside North America

States and Countries	$\theta = 1.00$	$\theta = 0.75$	$\theta = 0.50$
Alabama	11,476 1.524%	55,487 7.369%	123,395 16.387%
California	6,321 1.386%	48,533 10.641%	106,215 23.288%
Canada	15,160 1.489%	57,134 5.612%	116,150 11.409%
Georgia	4,142 1.517%	20,728 7.591%	46,456 17.013%
Illinois	4,021 1.390%	14,080 4.867%	26,731 9.240%
Indiana	13,701 1.523%	46,474 5.166%	92,304 10.260%
Kentucky	13,272 1.510%	45,058 5.128%	88,262 10.045%
Mexico	30,158 1.456%	123,503 5.963%	271,112 13.089%
Michigan	20,589 1.404%	48,860 3.333%	86,261 5.884%
Mississippi	4,597 1.504%	13,327 4.360%	27,214 8.902%
Missouri	6,205 1.395%	8,597 1.933%	11,653 2.619%
Ohio	9,096 1.389%	28,327 4.326%	53,639 8.191%
South Carolina	4,018 1.496%	16,869 6.281%	34,353 12.790%
Tennessee	5,335 1.424%	29,601 7.904%	65,686 17.539%
Texas	5,753 1.480%	14,784 3.802%	25,681 6.605%
Imports from the Rest of the World	-1,867,790 -66.017%	-2,089,770 -73.863%	-2,394,010 -84.616%

Table 11: Sensitivity Analysis – Simulated Changes without Joint Ownership

States and Countries	With Joint Ownership	Without Joint Ownership
Alabama	55,487 7.369%	54,481 7.235%
California	48,533 10.641%	48,769 10.693%
Canada	57,134 5.612%	56,245 5.525%
Georgia	20,728 7.591%	20,398 7.470%
Illinois	14,080 4.867%	14,161 4.895%
Indiana	46,474 5.166%	45,258 5.030%
Kentucky	45,058 5.128%	43,998 5.007%
Mexico	123,503 5.963%	122,574 5.918%
Michigan	48,860 3.333%	49,005 3.343%
Mississippi	13,327 4.360%	13,012 4.257%
Missouri	8,597 1.933%	8,686 1.953%
Ohio	28,327 4.326%	28,578 4.364%
South Carolina	16,869 6.281%	16,630 6.192%
Tennessee	29,601 7.904%	29,606 7.905%
Texas	14,784 3.802%	14,404 3.705%
Imports from the Rest of the World	-2,089,770 -73.863%	-2,090,660 -73.894%

5.2 Country-Specific Import Cost Shocks

The final set of simulations consider the effects of a new tariff on imports from a single country outside of North America, either Japan, Korea, or Germany. The estimated percent increases in production vary across the states depending on the segment concentration of imports from the country, the segment concentration of each state's production, and the location of the transplant domestic production of Japanese, Korean, or German manufacturers.

Table 12 indicates that vehicle imports from Japan were relatively concentrated in the Mid and Large CUV sales in 2022. In contrast, vehicle imports from Korea were relatively concentrated in the Small CUVs, while imports from Germany were relatively concentrated in Luxury Cars.

Table 12: Segment Shares by Country of Origin

Market Segment	All (%)	Japan (%)	Korea (%)	Germany (%)
Small Cars	11.608	13.451	16.651	
Mid and Large Cars	4.308	4.799	5.246	6.062
Luxury Cars	11.148	3.195	3.188	58.491
Small CUVs	27.146	21.227	45.036	5.876
Mid and Large CUVs	36.627	42.526	27.460	29.374
SUVs	6.849	14.912		
Vans	2.314		2.420	0.197
Pickups				

Table 13 indicates the location of North American foreign transplant production owned by Japanese, Korean, and German manufacturers. For Japan, the top states and countries in North America are Indiana, Canada, Mexico, and Kentucky. For Korea, they are Alabama, Georgia, and Mexico. For Germany, they are Mexico, South Carolina, and Alabama.

Table 13: Production Location by Foreign Nationality

Location in North America	Japan (%)	Korea (%)	Germany (%)
Canada	16.194		
Mexico	14.790	21.988	42.806
Alabama	9.069	51.829	11.628
Georgia		26.183	
Indiana	19.724		
Kentucky	12.144		
Mississippi	8.954		
Ohio	9.665		
South Carolina			36.972
Tennessee	6.246		8.594
Texas	3.213		

These segment and state shares of the three specific countries help to explain the simulation results for country-specific tariff changes in Table 14.[19] In the simulation with the new tariff applied only to imports from Japan, the largest percent increase in North American vehicle production are in Illinois, followed by Tennessee, Texas, Georgia, and Alabama. For the simulations that focus on a tariff on imports from Korea, the largest percent increase in North American vehicle production are in Georgia, followed by Alabama, Tennessee, and Mexico. Finally, for the simulations that focus on imports from Germany, the largest percent increase in North American vehicle production are in California, followed by Kentucky, South Carolina, and Tennessee.

[19]The first column of estimates repeats the $\theta = 0.75$ column from Table 10.

6 Conclusions

A hypothetical new tariff on all U.S. light vehicle imports from outside of North America would reduce these imports, increase average prices of vehicles in the United States, and increase the variable profit from domestic production. The increase in domestic production would be unevenly distributed, with the largest percent increases in California, Tennessee, Georgia, and Alabama, moderate percent changes in Mexico and Canada, and especially small percent increases in Missouri, Michigan, and Texas. This distribution of economic effects reflects the segment composition of imports and vehicle production in each state, as well as the location of foreign transplant production.

There are important caveats and limitations of the model worth noting. First, the model estimates changes in vehicle production levels, but not changes in employment levels, due to data limitations. However, direct employment effects will likely be closely linked to production effects if there is constant returns to labor and wages are determined on a broader economy-wide labor market. There may be substantial indirect employment effects as well, as the shifts in labor demand spill over to the supply chains, including engines, transmissions, brakes, electronics, steel, and aluminum producers, though these effects are also not included in the model due to data limitations. Second, as noted by Goldberg (1994) and Berry et al. (1999), it would be very useful to extend the analysis into a dynamic framework, but it will be very difficult to do so given the complexity of the capital-intensive motor vehicle industry.[20]

[20] Hashmi and van Biesebroek (2016) is an interesting example of a dynamic model of the motor vehicle industry; however, their dynamic model is at the firm level rather than the vehicle model level, and it focuses on how market structure affects incentives to innovate rather than trade policy.

Table 14: Simulated Changes in Vehicles Produced – Specific Countries

States and Countries	All	Japan	Korea	Germany
Alabama	55,487 7.369%	18,883 2.508%	16,976 2.254%	4,202 0.558%
California	48,533 10.641%	10,003 2.193%	5,724 1.255%	21,484 4.710%
Canada	57,134 5.612%	23,160 2.275%	13,276 1.304%	5,868 0.576%
Georgia	20,728 7.591%	6,898 2.526%	6,639 2.431%	1,696 0.621%
Illinois	14,080 4.867%	8,855 3.061%	1,577 0.545%	905 0.313%
Indiana	46,474 5.166%	19,106 2.124%	10,461 1.163%	4,709 0.523%
Kentucky	45,058 5.128%	16,326 1.858%	7,681 0.874%	11,928 1.358%
Mexico	123,503 5.963%	42,146 2.035%	37,759 1.823%	10,781 0.520%
Michigan	48,860 3.333%	24,360 1.662%	8,378 0.571%	6,109 0.417%
Mississippi	13,327 4.360%	6,007 1.965%	4,147 1.357%	1,112 0.364%
Missouri	8,597 1.933%	1,986 0.446%	2,389 0.537%	863 0.194%
Ohio	28,327 4.326%	13,076 1.997%	5,188 0.792%	3,794 0.579%
South Carolina	16,869 6.281%	5,852 2.179%	3,447 1.284%	2,517 0.937%
Tennessee	29,601 7.904%	10,396 2.776%	7,821 2.088%	3,167 0.846%
Texas	14,784 3.802%	10,453 2.688%	1,396 0.359%	704 0.181%
Imports from the Rest of the World	-2,089,770 -73.863%	-804,261 -28.427%	-523,249 -18.494%	-316,464 -11.185%

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