Brands in Motion: How frictions shape multinational production

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Online Appendix

A Constant elasticity of substitution discrete choice

Following Hanemann (1984)'s equation (3.5), let utility of household h be given by

$$U_h = u\left(\sum_m \psi_{mh} c_{mh}, z_h\right),$$

with z the outside good. The model-household parameters ψ_{mh} convert car use into equivalent units of psychological car services.[51]

Unlike the more familiar RUM with unitary demand, we model the c_{mh} as continuous choice variables. There are two interpretations for cars. One involves households with multiple members who share some number of cars. For example with two adults and one teenager in the household $c_h = 1$ if each member has their own car, but would be $c_h = 1/3$ if the three household members shared a single car. Obviously, unless households are very large (car-sharing groups might be an illustration), the continuity assumption is violated by integer issues.

A second interpretation involves endogenous use of a durable good. Suppose that each new car delivers 1 unit of lifetime services. Then $\sum_t c_{ht} = 1$. By driving sparingly or maintaining intensively in a given year, c_{ht} can be reduced, prolonging the duration of use. In this case $c_{ht} = 0.2$ would correspond to using 1/5 of the car's operating life each year. Assuming a steady state and aggregating over all households, the annual demand for new cars of model m in market n is given by $q_{mn} = \sum_h c_{mh}$. Summing across all models, the household's annual consumption is $c_h \equiv \sum_m c_{mh}$. Summing across all households and models, we have $\sum_h \sum_m c_{mh} = Q_n$, where Q_n denotes aggregate number of new cars sold in country n. We have implicitly assumed that in our steady state car replacements are spread evenly over periods, to avoid all consumers buying new cars in the fifth year and no sales at all in between.

Consumers choose c_{mh} for each model of the set of models available in market n and spend the remainder of their income, y_h, on outside good z with price normalized to one. Thus they maximize U_h subject to $\sum_m p_m c_{mh} + z_h = y_h$. Denoting the Lagrange multiplier as λ, and the partial derivatives with respect to $\sum_m \psi_{mh} c_{mh}$ and z_h as u_1 and u_2, the first order conditions are

$$u_1 \psi_{mh} = \lambda p_m \;\; \forall m \text{ with } \; c_{mh} > 0; \quad \text{and} \quad u_2 = \lambda.$$

[51] For example, ψ_{mh} could be the number of driving kilometers expected by the buyer over the lifetime of the model.

Combining we have

$$\frac{u_1}{u_2} = \frac{p_m}{\psi_{mh}} \quad \forall m \text{ with } \ c_{mh} > 0$$

This equation implies a relationship between $\sum_m \psi_{mh} c_{mh}$ and p_m/ψ_{mh} that can only hold for $c_{mh} > 0$ and $c_{mh'} > 0$ under the measure 0 event that $\frac{p_m}{\psi_{mh}} = \frac{p_{m'}}{\psi_{m'h}}$ for $m \neq m'$. Otherwise each household h will select its preferred model m_h^* and consume c_h units while consuming $c_{m'h} = 0$ on all $m' \neq m_h^*$. In other words, the indifference curves between any pair of varieties m and m', holding z constant, are linear, implying a corner solution. Thus c_h is given by

$$\frac{u_1(\psi_{mh} c_h, y - p_m c_h)}{u_2(\psi_{mh} c_h, y - p_m c_h)} = \frac{p_m}{\psi_{mh}} \quad \text{for } \ m = m_h^*$$

The preferred choice, m^*, is given by the argmin of p_m/ψ_{mh} (Hanemann, 1984, p. 548). Since a monotonic transformation of p_m/ψ_{mh} preserves the ranking, this is equivalent to maximizing $\ln \psi_{mh} - \ln p_m$. Parameterizing $\psi_{mh} = \beta_m \exp(\epsilon_{mh})$, the probability a given household chooses model m is

$$\text{Prob}(p_m/\psi_{mh} < p_j/\psi_{hj}) = \text{Prob}(\epsilon_{mh} + \ln \beta_m > \epsilon_{jh} + \ln \beta_j + \ln p_m - \ln p_j), \forall j \neq m.$$

With ϵ distributed according to the CDF $\exp(-\exp(-\eta\epsilon))$ (Gumbel with scale parameter $1/\eta$), the resulting choice probabilities at the level of market n are

$$\mathbb{P}_{mn} = \frac{\beta_m^\eta (p_{mn})^{-\eta}}{\Phi_n}, \quad \text{where} \quad \Phi_n \equiv \sum_{j \in \mathcal{M}_n} \beta_j^\eta (p_{jn})^{-\eta}.$$

The above equation can be re-expressed in the standard conditional logit form by taking logs and then taking the exponential of each term in the numerator and denominator.

Aggregate expected sales of model m in n are

$$\mathbb{E}[q_{mn}] = \sum_h \mathbb{P}_{mn} c_h = \mathbb{P}_{mn} \sum_h c_h = \mathbb{P}_{mn} Q_n.$$

The elasticity of demand with respect to the price of model m is $-\eta(1 - \mathbb{P}_{mn})$, which goes to $-\eta$ as $\mathbb{P}_{mn} \to 0$. Intuitively, demand becomes more responsive to price as η increases because η is *inversely* related to the amount of heterogeneity in consumer preferences.

Expected sales of any model are proportional to the aggregate size of the market expressed in volumes, regardless of $u()$. Furthermore, *income does not affect the choice between models* but, depending on the form of $u()$, the consumption of cars can have any income expansion path. For example, under the Cobb-Douglas case, explored by Anderson et al. (1992), the optimal consumption of the chosen car is $c_{mh} = (\alpha y_h)/p_m$, for $m = m_h^*$. Non-homothetic demand will be obtained from all other assumed $u()$. The quasi-linear case where $U_h = (\sum_m \psi_{mh} c_{mh})^\alpha + z_h$, yields $c_{mh} = \left(\frac{p_m}{\alpha \psi_{mh}^\alpha}\right)^{1/(\alpha-1)}$. The share of expenditure spent on cars will therefore fall with income. An opposite conclusion can be obtained with $U_h = \sum_m \psi_{mh} c_{mh} + z_h^\alpha$, which gives the demand for the chosen car model $c_{mh} = \frac{y_h - \left(\frac{\psi_{mh}}{\alpha p_m}\right)^{1/(\alpha-1)}}{p_m}$. In this case, car expenditure as a share of income is increasing in income.

B Constructing expected profits from estimates

The brand entry estimation requires to empirically measure $\mathbb{E}[\pi_{bnt}]$. Equation (18) shows that we need a number of intermediate estimates for that. In particular, we need to measure $\mathbb{E}[\pi_{mnt}]$ and the model entry fixed costs parameters $\mu^e_{nt} + \beta^e_b + \ln(w^\zeta_{it} w^{1-\zeta}_{nt})$.

The country (nt) fixed effects in equation (22) have structural interpretations given by $\text{FE}^{(2)}_{nt} = \ln \kappa_1 + \eta \ln P_{nt}$. In the model entry equation (23), which involves a constant, the country fixed effects are interpreted as

$$\hat{\sigma}_e \text{FE}^{(3)}_{nt} = \ln Q_{nt} + \eta \ln P_{nt} - \ln(w^{1-\zeta}_{nt}) - \mu^e_{nt} - (\ln Q_{1T} + \eta \ln P_{1T} - \ln(w^{1-\zeta}_{1T}) - \mu^e_{1T}). \tag{B.1}$$

with the model-entry constant given by

$$\hat{\sigma}_e \text{CST}^{(3)} = \ln \kappa_2 - \ln \eta + (\eta - 1)(\ln \varphi_1 - (1-\alpha) \ln w_{i(1)T}) - \beta^e_1 + (\ln Q_{1T} + \eta \ln P_{1T} - \ln(w^{1-\zeta}_{1T}) - \mu^e_{1T}). \tag{B.2}$$

Only relative levels of productivity (φ_b) and headquarter wages ($w_{i(b)}$) matter for market shares. Therefore, we can normalize $\varphi_1 = w_{i(1)T} = 1$, implying

$$(\ln Q_{1T} + \eta \ln P_{1T} - \ln(w^{1-\zeta}_{1T}) - \mu^e_{1T}) = \hat{\sigma}_e \text{CST}^{(3)} - (\ln \kappa_2 - \ln \eta) + \beta^e_1. \tag{B.3}$$

Substituting (B.3) into (B.1), replacing $\eta \ln P_{nt}$ with $\text{FE}^{(2)}_{nt} - \ln \kappa_1$, and isolating the unknown parameters, we obtain

$$\ln(w^{1-\zeta}_{nt}) + \mu^e_{nt} + \beta^e_1 = \ln Q_{nt} + (\text{FE}^{(2)}_{nt} - \ln \kappa_1) - \hat{\sigma}_e(\text{FE}^{(3)}_{nt} + \text{CST}^{(3)}) + (\ln \kappa_2 - \ln \eta). \tag{B.4}$$

We then use the fixed effect of brand b in the entry and market share equations to add the missing β^e_b:

$$\begin{aligned} \hat{\sigma}_e \text{FE}^{(3)}_b &= -(\beta^e_b - \beta^e_1) + (\eta - 1) \ln \varphi_b - (\eta - 1)(1-\alpha) \ln w_{i(b)T}, \quad \text{and} \\ \text{FE}^{(2)}_b &= \eta [\ln \varphi_b - (1-\alpha) \ln w_{i(b)T}]. \end{aligned} \tag{B.5}$$

Multiplying the second line by $\frac{\eta-1}{\eta}$, we isolate β^e_1 as:

$$\beta^e_1 = \beta^e_b - \left(\frac{\eta - 1}{\eta} \text{FE}^{(2)}_b - \hat{\sigma}_e \text{FE}^{(3)}_b \right), \tag{B.6}$$

and rewrite equation (B.4) as

$$\ln(w_{nt}^{1-\zeta}) + \mu_{nt}^{e} + \beta_{b}^{e} = \ln Q_{nt} + (\text{FE}_{nt}^{(2)} - \ln\kappa_1) - \hat{\sigma}_e(\text{FE}_{nt}^{(3)} + \text{CST}^{(3)}) + (\ln\kappa_2 - \ln\eta) + \frac{\eta-1}{\eta}\text{FE}_{b}^{(2)} - \hat{\sigma}_e\text{FE}_{b}^{(3)} \tag{B.7}$$

The model entry fixed cost central parameter is therefore obtained by adding $\ln(w_{i(b)t}^{\zeta})$:

$$\ln(w_{i(b)t}^{\zeta} w_{nt}^{1-\zeta}) + \mu_{nt}^{e} + \beta_{b}^{e} = \ln Q_{nt} + (\text{FE}_{nt}^{(2)} - \ln\kappa_1) - \hat{\sigma}_e(\text{FE}_{nt}^{(3)} + \text{CST}^{(3)}) + (\ln\kappa_2 - \ln\eta) + \frac{\eta-1}{\eta}\text{FE}_{b}^{(2)} - \hat{\sigma}_e\text{FE}_{b}^{(3)} + \left(\frac{\eta-1}{\eta}\boldsymbol{\upsilon}_2 - \hat{\sigma}_e\boldsymbol{\upsilon}_3\right)\mathbf{W}'_{i(b)t}, \tag{B.8}$$

$\mathbf{W}_{i(b)t}$ including the two proxies for $\ln w_{i(b)t}$.

The last step needed for reconstructing $\mathbb{E}[\pi_{bnt}]$ is a measurement of $\mathbb{E}[\pi_{mnt}]$. We obtain it from estimates of the market share and entry equations:

$$\mathbb{E}[\pi_{mnt}] = \frac{\kappa_2}{\eta}Q_n \exp\left(\frac{\eta-1}{\eta}(\text{FE}_{b}^{(2)} - \mathbf{W}'_{i(b)t}\boldsymbol{\upsilon}_2) - (\eta-1)\mathbf{X}'_{int}\mathbf{d} - (\eta-1)\ln C_{bnt} + (\text{FE}_{nt}^{(2)} - \ln\kappa_1)\right) \tag{B.9}$$

In DEV counterfactuals, we also need to reconstruct the price index and brand entry fixed costs parameters. The price index is reconstructed as

$$P_n = \left(\sum_b \kappa_1 M_{bn} \exp\left(\text{FE}_{b}^{(2)} - \mathbf{W}'_{i(b)t}\boldsymbol{\upsilon}_2 - \eta\mathbf{X}'_{int}\mathbf{d} - \eta\ln C_{bnt}\right)\right)^{-1/\eta}, \tag{B.10}$$

The central parameter of the distribution costs is retrieved as

$$\mu_{n}^{d} + \beta_{b}^{d} + \ln(w_{i(b)t}^{\zeta} w_{nt}^{1-\zeta}) = -\hat{\sigma}_d(\text{FE}_{nt}^{(4)} + \text{FE}_{b}^{(4)} - \mathbf{W}'_{i(b)t}\boldsymbol{\upsilon}_4). \tag{B.11}$$

C Exact Hat Algebra (EHA) with the double-CES MP model

EHA solves for an equilibrium in the proportional changes of all variables of interest following a change in frictions. Variables taking a hat symbol are defined as ratios of $\hat{x} = x'/x$, where x is the initial level, and x' is the level attained after the change. The main advantages are that (1) it computes predicted (exact) percentage changes from the actual data, (2) related, it allows for unobservables in the actual decisions (as long as they are unaffected by the counterfactual), (3) it minimizes the data and parameter requirements.

The EHA method used here includes two non-standard features: First, we allow for proportional changes in the fraction of models offered in a market. Second, we incorporate external returns to scale in a multinational production setting. The change in total output located in country k, denoted $\hat{q}_k$, affects outcomes through $\hat{C}_{bn}$. Therefore, the problem can be decomposed in an inner and outer loop, analogous to the structure used in the pure trade model of Kucheryavyy et al. (2016). The first subsection of this appendix presents the details of the inner loop. The second subsection presents the overall solution algorithm.

C.1 EHA with a continuous model-entry margin: the inner loop

Starting with the sourcing decision, equation (6), algebraic manipulations of CES shares yield

$$\hat{C}_{bn} = \left(\sum_k \mathbb{L}_{bk} \text{Prob}(\mathbb{S}_{bkn} = 1)(\hat{\gamma}_{ik}\hat{\tau}_{kn}\hat{q}_k^{\varsigma})^{-\theta} \right)^{-1/\theta}. \tag{C.12}$$

Since all models are the same in expectation, the $\text{Prob}(\mathbb{S}_{bkn} = 1) = s_{bkn} \equiv q_{bkn}/q_{bn}$, i.e. the share of cars brand b sells in n that it sources from country k. This quantity share has the same expected value as the sourcing count share, S_{bkn}/M_{bn}, but it allows for internal consistency in the counterfactuals. The updating function for C_{bn} depends on this sourcing share and on the changes in frictions, both of which we observe.

The price index updating function is

$$\hat{P}_n = \left(\sum_b \mathbb{D}_{bn} \frac{q_{bn}}{Q_n} \hat{M}_{bn} (\hat{\delta}_{in}\hat{C}_{bn})^{-\eta} \right)^{-1/\eta}. \tag{C.13}$$

We observe the initial market share of b in n, q_{bn}/Q_n, and $\hat{C}_{bn}$ is obtained from (C.12). To determine $\hat{M}_{bn}$, we need to investigate how the number of models offered in each market changes in the counterfactual.

One of the novel aspects of our EHA approach to counterfactuals is to account for changes in model entry, $\hat{M}_{bn}$. The condition for model entry (12), combined with the definition of fixed model entry costs, F^e_{mn}, determines the probability of model entry. In the EHA method we replace the initial probability of model entry with the initial share of models offered by brand b in market n.

$$\frac{M_{bn}}{M_b} = \text{Prob}(\mathbb{I}_{mn} = 1) = \Phi \left[\frac{\ln \mathbb{E}[\pi_{mn}] - (\mu^e_n + \beta^e_b + \zeta \ln w_i + (1-\zeta)\ln w_n + \ln \delta^e_{in})}{\sigma_e} \right]. \tag{C.14}$$

In the counterfactual, we have the following entry shares:

$$\frac{M'_{bn}}{M_b} = \Phi \left[\frac{\ln \widehat{\mathbb{E}[\pi_{mn}]} + \ln \mathbb{E}[\pi_{mn}] - (\mu^e_n + \beta^e_b + \zeta \ln w_i + (1-\zeta)\ln w_n + \ln \hat{\delta}^e_{in} + \ln \delta^e_{in})}{\sigma_e} \right]. \tag{C.15}$$

Collecting terms, one can rewrite

$$\frac{M'_{bn}}{M_b} = \Phi \left[\frac{\ln \widehat{\mathbb{E}[\pi_{mn}]} - \ln \hat{\delta}^e_{in}}{\sigma_e} + \frac{\ln \mathbb{E}[\pi_{mn}] - (\mu^e_n + \beta^e_b + \zeta \ln w_i + (1-\zeta)\ln w_n + \ln \delta^e_{in})}{\sigma_e} \right]. \tag{C.16}$$

Substituting the second term in brackets with equation (C.14)

$$\frac{M'_{bn}}{M_b} = \Phi\left[\frac{\ln\widehat{\mathbb{E}[\pi_{mn}]} - \ln\hat{\delta}^e_{in}}{\sigma_e} + \Phi^{-1}\left(\frac{M_{bn}}{M_b}\right)\right]. \tag{C.17}$$

Finally, the percent change in number of models offered is

$$\hat{M}_{bn} = \Phi\left[\frac{\ln\widehat{\mathbb{E}[\pi_{mn}]} - \ln\hat{\delta}^e_{in}}{\sigma_e} + \Phi^{-1}\left(\frac{M_{bn}}{M_b}\right)\right]\frac{M_b}{M_{bn}}. \tag{C.18}$$

Equation (C.18) has many known components (M_b and M_{bn} are observed, σ_e is estimated, and $\hat{\delta}^e_{in}$ is part of the counterfactual experiment). The last needed part is to update the expected profits from entry of model m ($\widehat{\mathbb{E}[\pi_{mn}]}$). Using (14), we obtain the last element as $\widehat{\mathbb{E}[\pi_{mn}]} = \hat{\delta}^{1-\eta}_{in}\hat{C}^{1-\eta}_{bn}\hat{P}^{\eta}_{n}$, and therefore

$$\hat{M}_{bn} = \Phi\left[\frac{\ln(\hat{\delta}^{1-\eta}_{in}\hat{C}^{1-\eta}_{bn}\hat{P}^{\eta}_{n}) - \ln\hat{\delta}^e_{in}}{\sigma_e} + \Phi^{-1}\left(\frac{M_{bn}}{M_b}\right)\right]\frac{M_b}{M_{bn}}. \tag{C.19}$$

C.2 The algorithm

The inner/outer loop procedure works as follows:

1. For a given level of $\hat{q}_k$, we have a system of three equations (details in Appendix C.1) determining the three endogenous objects that determine outcomes in the counterfactual: updates of the cost index, the price index, and the number of varieties offered:

$$\hat{C}_{bn} = \left(\sum_k \mathbb{L}_{bk} s_{bkn}(\hat{\gamma}_{ik}\hat{\tau}_{kn}\hat{q}^{\varsigma}_k)^{-\theta}\right)^{-1/\theta}, \tag{C.20}$$

$$\hat{P}_n = \left(\sum_b \mathbb{D}_{bn}\frac{q_{bn}}{Q_n}\hat{M}_{bn}(\hat{\delta}_{in}\hat{C}_{bn})^{-\eta}\right)^{-1/\eta}, \tag{C.21}$$

$$\hat{M}_{bn} = \Phi\left[\frac{\ln(\hat{\delta}^{1-\eta}_{in}\hat{C}^{1-\eta}_{bn}\hat{P}^{\eta}_{n}) - \ln\hat{\delta}^e_{in}}{\sigma_e} + \Phi^{-1}\left(\frac{M_{bn}}{M_b}\right)\right]\frac{M_b}{M_{bn}}, \tag{C.22}$$

   where s_{bkn} is the share of sales in market n sourced from country k. A fixed point iteration with dampening solves for the equilibrium values of the system (C.20), (C.21) and (C.22). In our counterfactual, our main variable of interest is the percentage change in quantities

$$\hat{q}_{b\ell n} = \hat{q}_{bn} \times \hat{s}_{b\ell n}.$$

   Again the EHA approach is very useful here, since it can be used to show that the changes in sourcing probability and brand market share are only functions of changes in frictions (known) and of the three endogenous variables $\hat{C}_{bn}$, $\hat{P}_n$, and $\hat{M}_{bn}$ solved by the fixed point iteration:

$$\hat{s}_{b\ell n} = \left(\frac{\hat{\gamma}_{i\ell}\hat{\tau}_{\ell n}\hat{q}_\ell^{\varsigma}}{\hat{C}_{bn}}\right)^{-\theta}, \text{ and } \hat{q}_{bn} = \hat{M}_{bn}\left(\frac{\hat{\delta}_{in}\hat{C}_{bn}}{\hat{P}_n}\right)^{-\eta} \tag{C.23}$$

2. With the $\hat{q}_{b\ell n}$ generated in the inner loop, country-level output is updated using

$$q'_\ell = \sum_n \sum_b \hat{q}_{b\ell n} q_{b\ell n}, \qquad \text{and therefore} \qquad \hat{q}_\ell = q'_\ell / q_\ell.$$

   Since $\hat{C}_{bn}$ contains $\hat{q}_\ell^{-\theta\varsigma}$, it needs to be updated. The inner loop is then run again, giving a new vector of $\hat{q}_\ell$. This outer loop is run until we reach a fixed point in the vector of country-level output change.

In the segmented market version of our model, each segment can be considered in isolation when updating the market share equation. Start with the identity decomposing the sales of brand b from a plant in ℓ when serving n:

$$q_{b\ell n} = \sum_s q_{b\ell ns} = s_{b\ell n} \times q_{bn} = s_{b\ell n} \times \sum_s q_{bns}.$$

In changes

$$\hat{q}_{b\ell n} = \frac{q'_{b\ell n}}{q_{b\ell n}} = \hat{s}_{b\ell n} \times \frac{\sum_s q'_{bns}}{\sum_s q_{bns}}. \tag{C.24}$$

The expression describing sourcing share $\hat{s}_{b\ell n}$ in equation (C.23) is unchanged, since it is not affected by any segment-level determinant. However, the new level of production at the segment level is

$$q'_{bns} = q_{bns}\hat{q}_{bns} = q_{bns}\hat{M}_{bns}\left(\frac{\hat{\delta}_{ins}\hat{C}_{bn}}{\hat{P}_{ns}}\right)^{-\eta_s}, \tag{C.25}$$

with changes in the price index and number of offered models given by

$$\hat{P}_{ns} = \left(\sum_b \mathbb{D}_{bns}\frac{q_{bns}}{Q_{ns}}\hat{M}_{bns}(\hat{\delta}_{ins}\hat{C}_{bn})^{-\eta_s}\right)^{-1/\eta_s},$$

$$\hat{M}_{bns} = \Phi\left[\frac{\ln(\hat{\delta}_{ins}^{1-\eta_s}\hat{C}_{bn}^{1-\eta_s}\hat{P}_{ns}^{\eta_s}) - \ln\hat{\delta}_{ins}^{e}}{\sigma_e^s} + \Phi^{-1}\left(\frac{M_{bns}}{M_{bs}}\right)\right]\frac{M_{bs}}{M_{bns}}. \tag{C.26}$$

The algorithm is very similar to the unified markets case. The inner loop solves for $\hat{C}_{bn}$, $\hat{P}_{ns}$ and $\hat{M}_{bns}$, using (C.20) and (C.26) which gives $\hat{q}_{b\ell n}$ from (C.25) and (C.24). The outer loop then sums over the new shipments to obtain total output in each country, which enters back $\hat{C}_{bn}$ in the next iteration. The process is repeated until no further change is detected in any of those endogenous variables.

D External returns to scale and amplification

In this appendix, we discuss how our estimates of external IRS generate amplification in the output response to trade policy scenarios. Total output in country ℓ is simply the sum over brands and destinations of expected sales of b in n sourced from ℓ ($q_\ell = \sum_b \sum_n q_{b\ell n}$). Multiplying (9) by (6) and dropping expectations for simplicity, we obtain

$$q_{b\ell n} = \kappa_1(\gamma_{i\ell}\tau_{\ell n})^{-\theta}(w_\ell^\alpha q_\ell^\varsigma)^{-\theta}(\varphi_b/w_i^{1-\alpha})^\eta Q_n P_n^\eta M_{bn}\delta_{in}^{-\eta}C_{bn}^{-\eta-1}. \quad \text{(D.27)}$$

Let $K_{b\ell n}$ denote all the shifters of $q_{b\ell n}$ that do not directly depend on q_ℓ (ignoring for now the indirect effects via M_{bn}, C_{bn} and P_n):

$$K_{b\ell n} \equiv \kappa_1(\gamma_{i\ell}\tau_{\ell n})^{-\theta}(w_\ell^\alpha)^{-\theta}(\varphi_b/w_i^{1-\alpha})^\eta Q_n P_n^\eta M_{bn}\delta_{in}^{-\eta}C_{bn}^{-\eta-1}.$$

Therefore we can write

$$q_{b\ell n} = q_\ell^{-\varsigma\theta}K_{b\ell n}.$$

Aggregate output is therefore $q_\ell = \sum_b \sum_n q_{b\ell n} = q_\ell^{-\varsigma\theta}\sum_b \sum_n K_{b\ell n}$, and

$$q_\ell = \left(\sum_b \sum_n K_{b\ell n}\right)^{\frac{1}{1+\varsigma\theta}}.$$

Let us note at this stage that $K_{b\ell n}$ is also the value taken by $q_{b\ell n}$ under constant returns to scale, that is when $\varsigma = 0$. We can therefore define $q_\ell^{\text{CRS}} = \sum_b \sum_n K_{b\ell n}$ and

$$q_\ell^{\text{IRS}} = \left(q_\ell^{\text{CRS}}\right)^{\frac{1}{1+\varsigma\theta}}.$$

Consider a tariff or a wage shock that shifts national output by a factor $\hat{q}_\ell^{\text{CRS}}$ (the immediate effect). We can therefore express the full proportional change in output under IRS (the sum of immediate and amplification effects) as

$$\hat{q}_\ell^{\text{IRS}} = \left(\hat{q}_\ell^{\text{CRS}}\right)^{\frac{1}{1+\varsigma\theta}}. \quad \text{(D.28)}$$

We refer to the amplification effect as the situation when the elasticity of the IRS output to CRS output ($1/(1+\varsigma\theta)$) is greater than one. With $\varsigma < 0$, we have $\varsigma\theta < 0$ and therefore amplification through external IRS. As $\varsigma\theta$ approaches -1, there will be an infinitely large response to any small initial shock to output in ℓ. Hence, we need $-\varsigma\theta < 1$ which is analogous to the condition establishing uniqueness of equilibrium with external returns in the pure trade model of Kucheryavyy et al. (2016), since θ is the trade elasticity (the coefficient of log sales on log trade costs being $-\theta$ in equation (D.27)) and ς is the scale elasticity.

Taking logs of (D.28) yields a regression that can be used to quantify the amplification effect implied by our estimates of external returns to scale.

$$\ln \hat{q}_\ell^{\text{IRS}} = \frac{1}{1+\varsigma\theta} \ln \hat{q}_\ell^{\text{CRS}} + \epsilon_\ell.$$

The error term ϵ_ℓ is intended as a way to allow for the misspecification due to the fact that in reality our model has three endogenous variables that indirectly depend on q_ℓ. Our estimate of $-\varsigma\theta = 0.27$ implies that we should obtain a coefficient of $1/(1-0.27) = 1.37$. We run the regression on all of our 8 counterfactuals taking the sample to be all 47 assembly countries. Depending on the policy experiment, the coefficient on changes in logs falls between 1.32 and 1.37. The fit is extremely tight, with $R^2 = 0.99$ in every case. The slight under-estimates of amplification in our regressions are not surprising given that we took M_{bn}, C_{bn} and P_n as exogenous in our thought experiment involving K_{bn}. The change in q_ℓ must adjust P_n so as to hold the total number of cars consumed constant in each country. Since we hold world output the same, it seems intuitive that the simple calculations above will tend to *overstate* the amount of IRS output expansion.

E Data Appendix

E.1 Exclusions from the raw IHS data

- In order to restrict attention to vehicles with comparable substitution patterns, we eliminated light commercial vehicles as a car type, to work only with passenger cars. We also dropped pick-up trucks and vans because over 90% of their sales are registered as commercial vehicles.
- We delete shipments of unknown brand or assembly country. There were 62 countries in the IHS data where assembly location was unavailable for all sales and all years (mainly Caribbean and African countries). We also required that at least 90% of the total car sales in a country must come from identified brands, leading us to drop 6 more countries for recent years (Algeria, Bolivia and Peru before 2008, Chile before 2002, Kazakhstan and Belarus before 2005). The remaining 76 markets constituted 98.8% of world automotive sales in the 2016 IHS data. The market-years we lose are also dropped as production sites based on the fact that in most case, their output is essentially meant for domestic consumption.
- Norway is only an option for Think and in those cases it is the only option; therefore a Norway fixed effect cannot be estimated.
- We drop De Tomaso because it is only sold in one market (Kuwait) for two years and the estimations of equation (22) and (23) cannot identify its brand fixed effect. The same is true for Troller, which only sells in Brazil.
- AIL and Pyeonghwa Motors are dropped because the IHS data does not show their production in the headquarters countries (respectively, Israel and North Korea) even though other information reports they do assemble car in those locations during the time frame of our data.
- FSO and TVR are only present in 2000 in our dataset, Moskvich sells in Ukraine until 2001, they are dropped since we consider years starting in 2002 for estimation.
- The Vauxhall brand name is only used in the UK for cars that are elsewhere sold as Opel. Because we want to consider potential relocation from UK to Germany and vice-versa in particular for the Brexit counterfactual, Vauxhall is renamed Opel.
- We eliminated the observations where a brand's total production in a given origin was less than 10 cars a year. Those mostly involved extinct models being sold out of left-over inventories (Mazda selling to Switzerland one unit of the 121 model from a closed factory in the UK several years after production was stopped for instance).
- We drop 43 brands that never had more than one model. They cannot be included in the estimation of the model-entry equation because their brand dummy is a perfect predictor.

Such firms are typically very small, having (collectively) a median share of a market-year of just 0.002%, with the maximum market share of 1.4% in China in 2004.

- We drop two countries from the counterfactuals, that have so few brands that the computation of the equilibrium sometimes failed because of zero brand entry: Pakistan (4 brands in 2016) and Venezuela (6). These markets are retained in the estimation, however.

E.2 Other data sources: gravity variables, tariffs and RTAs

The time-invariant determinants of frictions (distance, home, contiguity, common language) and GDP per cap variables come from the CEPII gravity database.[52] Tariff information for both assembled cars and parts comes from the WITS database managed by the World Bank. WITS compiles individual country declarations of their applied MFN and preferential *ad valorem* tariffs, as well *ad valorem* equivalents (AVE) of any specific tariffs. The car tariff is the simple average of the tariffs in HS heading 8703. The car parts tariff is the simple average of the three 4-digit HS headings associated with major components (8706, 8707, and 8708), together with the relevant HS6 categories for engines and associated parts (840733, 840734, 840820, 840991, and 840999). There are many holes in the data which we fill via linear interpolation. When the data is missing for the most recent years, we use the last available year. When a preferential rate exists, we use it. For the rest of dyad-years, we use the MFN tariff inclusive of the AVE of specific tariffs. We also corrected a number of issues in available WITS data regarding recent RTAs that are important for our purposes. Korea signed a number of recent agreements (with the EU and USA in 2012, Canada in 2015, Peru in 2012, Turkey in 2013, Australia in 2015, New-Zealand, Vietnam and China in 2016), for which WITS tariff data is either not accurate or not available. Japan signed RTAs with Peru (entered into force in 2012) and Australia (entered into force in 2015), for which the preferential rates were not mentioned in WITS. Colombia also lacked preferential rates for agreements with the USA and Canada (entry into force in 2012) and the EU (entry into force in 2013). For all those cases (and a few other for which it turned out that cars and parts were mostly exempted), we went to individual text and tariff schedules of those agreements to compute the tariff rate relevant for the bilateral pair in the relevant years. This involves in particular to take into account the "Staging" variable specified (usually giving the number of equal cuts in years) applied to the "Base rate" (the MFN rate at the date of entry into force). Sometimes, even that level of detail is not enough. For instance, the Korea-USA agreement finally decided to postpone the negotiated phasing in by five years (`https://www.uskoreacouncil.org/wp-content/uploads/2014/12/Automotive-Provisions.pdf`). We took those into account when mentioned on the countries' relevant website. The correction was done both for assembled cars and parts. Note that the staging of tariff liberalization can be very different across bilateral pairs.[53]

[52] Updated for the purpose of the paper, and available at `http://www.cepii.fr/cepii/en/bdd_modele/presentation.asp?id=8` or `https://sites.google.com/site/hiegravity/data-sources`.

[53] For example, Colombia's 10% MFN car engine tariff went immediately to zero for its FTA with the US but took 8 years to expire in the FTA with the EU. Korea reduced its tariffs on assembled cars from the EU and the USA to 0 in a

Those changes are particularly important for obtaining realistic numbers for our counterfactuals, since Korea and Japan are estimated to be the two top places to produce cars in terms of productive efficiency (lowest estimated costs of production).

The RTA database maintained by the WTO provides the dates, membership and topics covered for each trade agreement.

F Robustness

F.1 Robustness on external returns to scale

Table F.1 reports results of four robustness checks for the magnitude of external returns to scale. Column (1) simply lags the total output variable by one year. Columns (3) and (4) proceed to purge total output from potential simultaneity bias, using two different versions of a Bartik instrument (using a control function approach since our estimation procedure is PPML rather than OLS).

Table F.1: Sourcing decision with alternative output variables

	(1)	(2)	(3)	(4)
ln (1+ car tariff$_{\ell n}$)	-7.688	-7.817	-7.820	-7.815
	(0.890)	(0.916)	(0.914)	(0.914)
log lagged country output	0.243			
	(0.057)			
log current country output		0.278	0.217	0.189
		(0.082)	(0.107)	(0.110)
residual term of Bartik first-stage			0.121	0.137
			(0.127)	(0.104)
Observations	346322	338722	338722	338722
ς	0.032	0.036	0.028	0.024

Standard errors clustered by production country. Fixed effects for brand-destination and production country are included in all columns. Column (1) replaces current output with lagged version. Column (2) replicates our benchmark results for the same sample as the control function in columns (3) and (4), which are two versions of the control function Bartik approach, described in this appendix.

The procedure for constructing the instrument is the following: Start by computing the share of each possible origin country in the sales of each brand-destination combination in a base year (2002 in our case). Then compute the predicted level of sales multiplying this initial share by the level of demand faced by the brand in that destination each subsequent year. This keeps the sourcing shares (our endogenous variable in the final regression) unchanged. Then sum those predicted sales for each origin-year, yielding predicted output of the country-year. This prediction is used in a regression explaining the true level of output ($q_{\ell t}$). Finally use the residual of that

few years, but cars were exempted from any liberalization in the RTA with China (`http://fta.mofcom.gov.cn/korea/annex/fujian2_A_hfgsjr_en.pdf`).

regression in the sourcing decision as a control function, the idea being that the coefficient of $q_{\ell t}$ now reflects the change in output that *comes purely from shifts in demand in destinations where the origin was selling in the base year*. The approach is the same in column (4) but with a more demanding specification, where the shares to be shifted are the market shares of each brand-origin. This means that the only reason why total output is allowed to change is the *overall* demand of each destination country, leaving the market shares and the sourcing decisions of all brands at their base level in 2002.

Our baseline ς is 3.5%. Lagging origin output reduces this value to 3.2%. Using the Bartik instrumentation reduces it more substantially to 2.8 and 2.4% when using the less and more demanding specifications respectively. The Bartik instrumentation loses a moderate number of observations for origin-years that were not assembling cars in 2002 (Bulgaria, Algeria and Morocco are 3 examples of countries that start producing cars later in our sample). Column (2) replicates our baseline estimation on this reduced sample. The coefficient on car tariffs (which is used with the one on $q_{\ell t}$ to reveal ς) is very stable. The coefficients on $q_{\ell t}$ stay positive and statistically significant, but are reduced in an expected way: as mentioned in the main text, our estimated parameter for external returns to scale should be seen as an upper bound, which will tend to give the largest scope for interdependencies across markets in our counterfactuals.

F.2 Estimates using the firm-variety approach

Variety v corresponds to an "underneath the hood" concept of product differentiation—in contrast to models which were "re-badged" versions of cars that were physically very similar. We define distinct varieties using three variables in the IHS database:

Platform "All-new ground up redesign would constitute a new Platform designation." Muffatto (1999) points out that companies vary in terms of how many aspects of the design go into the platform designation. At a minimum, platforms include a common underbody and suspension. Broader definitions include engines, transmissions, and exhaust systems.

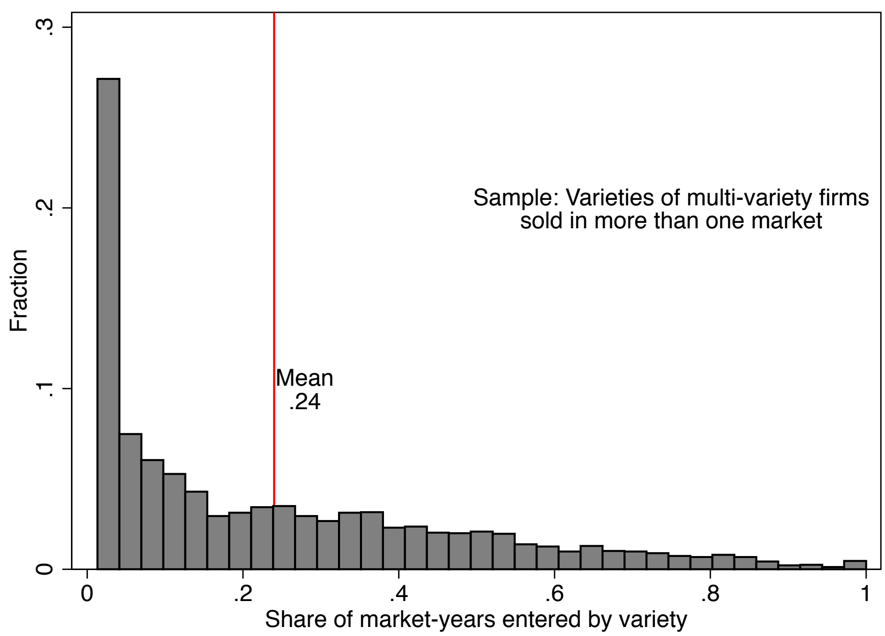
Program "Code is used by OEMs to identify Vehicle throughout design lifecycle." We think of programs as constituting more minor redesigns, or new generations within a given platform.

Body type Distinguishes between sedans, hatchbacks, wagons, etc.

Firm f here corresponds to the IHS variable "Design Parent: The company/OEM responsible for the design of the vehicle platform." Except for a small number of cases that we manually corrected, platforms map many to one to Design Parents. We think of this as the engineering/design approach. While it does not provide a clear ownership criteria, IHS allows for firms to be designated as "parents" even if ownership is less than 50%. For example Kia has Hyundai as a parent even though Hyundai owned about 34% of Kia stock in December 2015.

The biggest problem with the Design Parents (DP) is that IHS only reports it as of 2016. Thus, going back in time, it gives incorrect DPs. For example, it makes no sense to think of Tata as the DP for Jaguar cars before 2008 when the brand was owned by Ford. We are able to track ownership changes for brands over time, as the latter often correspond to distinct, stock-selling corporations (e.g. Audi, Nissan). However, it is more difficult to track ownership of platforms. Brands map many-to-many to Design Parents (they map many-to-one to Sales Parents). The reason is that brands market (and even manufacture) platforms designed by other firms. The IHS Engineering Group identifier is very helpful in a few cases (Chrysler-Fiat, Mazda-Ford). For others the brand-platform mapping seems clean enough.

Figure F.1: Market coverage by multi-variety firms



There were two main concerns about the brand-model approach employed in the main text of the paper. The first concern is that much of the low entry rates observed at the brand-model level could be an artifact of re-badging strategies. Thus while Honda seems to sell the Legend in Japan only, the same variety is in fact available in many markets as the Acura RL.[54] Figure F.1 reproduces Figure 2 using the firm-variety concept. The mean entry rate rises, as expected, but only from 0.23 to 0.24. The whole distributions of entry rates are visually very similar.

The second concern with the brand-model approach is that parent-firm headquarters might be making the critical management and parts supply decisions and that the brand headquarters might be less relevant from the point of view of $\gamma_{i\ell}$ frictions. For example, the top management of Renault-Nissan in Paris might provide all the brands of the group (Renault, Nissan, Dacia and Lada) with designs and production technologies. Using France, Japan, Romania, and Russia,

[54]Another form of re-badging holds the model name constant while changing the brand name. For example the platform B0, program H79 is sold in roughly equal amounts as a "Duster" under the brand Renault and as a Dacia (a Romanian brand acquired by Renault).

respectively, as the brand headquarters might therefore incorrectly specify the relevant frictions.

Table F.2 re-estimates the baseline specification from Table 3. The sample size in the sourcing equation (column 1) falls by 20%. There is a greater number of possible assembly locations when taking account of all the parent firms' production facilities but there are far fewer sourcing shares when grouping by firm instead of brand. The estimates for the $\tau_{\ell n}$ determinants are very similar to those reported in Table 3: The key elasticity of sourcing response, θ, rounds to 7.7 in both regressions. The imprecision of the estimates of the $\gamma_{i\ell}$ determinants in the sourcing equations persists with the new set of headquarter i locations. Distance continues to have the wrong sign. Parts tariffs now enter with a highly significant coefficient but it implies a cost share of HQ-provided intermediates that exceeds one. In sum, using firm headquarters does not markedly improve the γ estimates. In column (2), the firm average market share equation estimates an η of 1.9, considerably lower than the 3.87 obtained for brands. This η implies markups above 100% that are drastically higher than other estimates in the literature. The implausibly low η estimates suggest that the firm-level market share equation suffers from measurement error in the calculation of C_{bn}. Firms aggregate an often highly heterogeneous set of plants producing very distinct sets of cars. Geely-Volvo and Tata-Jaguar are examples of cases where plants from one brand are essentially irrelevant for the other brand's production. Columns (3) and (4) show that deep RTAs promote variety and firm entry but with smaller coefficients and higher standard errors. This corroborates our view that the brand/model concept is more appropriate.

Table F.2: Results with the firm-variety approach

Decision:	Sourcing	Market share	Model entry	Brand entry
Dep. Var:	$S_{b\ell nt}$	$\frac{q_{bnt}}{M_{bnt}Q_{nt}}$	$\frac{M_{bnt}}{M_{bt}}$	$\mathbb{D}_{bnt}$
Method:	PPML	PPML	frac. probit	probit
	(1)	(2)	(3)	(4)
$\text{home}_{\ell n}$	0.891			
	(0.285)			
$\ln \text{dist}_{\ell n}$	-0.251			
	(0.073)			
$\text{language}_{\ell n}$	-0.066			
	(0.112)			
$\ln(1+ \text{car tariff}_{\ell n})$	-7.725			
	(0.905)			
$\text{Deep RTA}_{\ell n}$	0.184			
	(0.131)			
$\text{home}_{i\ell}$	1.447			
	(0.400)			
$\ln \text{dist}_{i\ell}$	0.135			
	(0.106)			
$\text{language}_{i\ell}$	-0.064			
	(0.314)			
$\ln(1+ \text{parts tariff}_{i\ell})$	-11.109			
	(3.024)			
$\text{Deep RTA}_{i\ell}$	-0.577			
	(0.303)			
$\ln q_\ell$	0.227			
	(0.063)			
home_{in}		0.578	0.249	0.597
		(0.283)	(0.082)	(0.520)
$\text{home}_{in} \times \text{LDC}_n$		0.882	1.144	3.689
		(0.461)	(0.113)	(0.609)
$\ln \text{dist}_{in}$		-0.371	-0.079	-0.027
		(0.095)	(0.022)	(0.130)
language_{in}		0.253	0.085	0.006
		(0.198)	(0.055)	(0.198)
Deep RTA_{in}		0.064	0.079	0.095
		(0.113)	(0.034)	(0.155)
$\ln C_{bn}$		-1.913	-0.279	
		(0.995)	(0.244)	
$\ln \mathbb{E}[\pi_{bn}]$				0.932
				(0.127)
Observations	281583	21932	21933	62472
R^2	0.781	0.594	0.761	0.707
Fixed effects:	ℓ, bnt	b, nt	b, nt	b, nt
S.E. cluster:	ℓ	f	f	f

Standard errors in parentheses. r^2 is squared correlation of fitted and true dependent variables except in specification (4) where the pseudo-r^2 is reported. Each regression controls for log per-capita income and price level of the assembly country.

F.3 Sourcing parameter estimates from quantities

We can express the expected sales of a brand to a given market from any of the country ℓ where it is producing by simply multiplying expected sales of b in n (9) by the probability it sources its models from ℓ (6).

$$\mathbb{E}[q_{b\ell n}|\mathbb{D}_{bn}=1,\mathbb{L}_{b\ell}=1]=\kappa_1(\gamma_{i\ell}\tau_{\ell n})^{-\theta}\times(w_\ell^\alpha q_\ell^\varsigma)^{-\theta}\times(\varphi_b/w_i^{1-\alpha})^\eta Q_n P_n^\eta M_{bn}\delta_{in}^{-\eta}C_{bn}^{-\eta-1}. \quad \text{(F.1)}$$

Equation (F.1) can be used to obtain additional sets of estimates of γ frictions, with the difference that they combine the extensive margin of the sourcing equation with the intensive value of sales in each market the brand serves. The regression includes two sets of fixed effects, one for the country of origin, and one for the brand-destination-time combination, which takes into account the third term in (F.1). There are three ways to specify the LHS of the regression. As when estimating total sales of b in n, we can use the unitary coefficient prediction to divide $q_{b\ell n}$ by $M_{bn}Q_n$. Alternatively, we can let fixed effects absorb M_{bn} and Q_n without imposing the constraint, or have an intermediate approach where the dependent variable is market share $q_{b\ell n}/Q_n$.

We also evaluate the robustness of estimates regarding whether (first 3 columns) or not (last 3 columns) external economies of scale are considered. The main takeaway from Table F.3 is that the coefficients on Deep RTA$_{i\ell}$ and on tariffs on car parts are stronger and more significant than in our baseline results. However, since the estimates of θ are also larger, the AVE of deep RTA remain very similar to the baseline. The ratio of coefficients between car and parts tariffs also provides comparable alternative estimates of $1-\alpha$ ranging between 29% and 50%.

G Fit of the DEV simulation

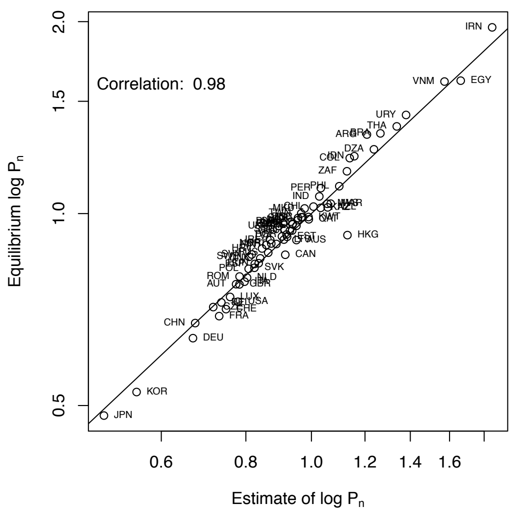
Figure G.1 shows the fit of one run of the DEV simulation under the factual set of tariffs and RTA policies. The equilibrium price index is a key element of the model, (inversely) summarizing the degree of competition on each destination, once all actors have solved for the optimal sourcing, model entry and brand entry choices. Its fit with estimated one shown in panel (a) is quite remarkable: Japan, Korea, Germany, China and the US are among the most competitive markets, while Iran, Vietnam and Egypt are at the other end of the spectrum. Producers present in those latter markets are still protected by very high tariffs, which lowers entry and overall competition for local consumers. Panel (b) graphs true brand-origin-destination sales against simulation-predicted sales with both expressed on a log scale. The data cluster around the 45-degree line, obtaining a correlation (in logs) of 0.63. Panel (c) aggregates flows at the country-pair level, and the fit is even more impressive, at 0.74. Part of the high explanatory power stems from the presence of Q_n in the prediction in both graphs. Nevertheless, the figure does show that the estimated model captures the main variation in the data, whereas failure to do so would have raised concerns about its suitability for conducting counterfactuals. Panel (d) further aggregates and shows the equilibrium output of each producing country against the true one in 2016. Black hollow circles simply

Table F.3: Bilateral brand sales regression provide alternative estimates of γ

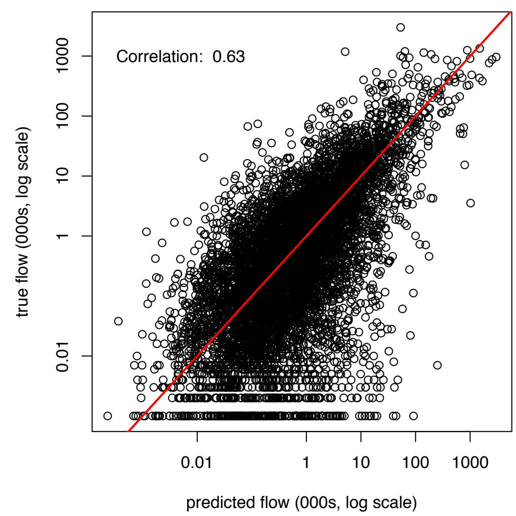
Dep. Var:	$\frac{q_{b\ell n}}{M_{bn}Q_n}$ (1)	$q_{b\ell n}$ (2)	$\frac{q_{b\ell n}}{Q_n}$ (3)	$\frac{q_{b\ell n}}{M_{bn}Q_n}$ (4)	$q_{b\ell n}$ (5)	$\frac{q_{b\ell n}}{Q_n}$ (6)
Trade costs						
$\text{home}_{\ell n}$	1.497	1.738	1.392	1.506	1.746	1.397
	(0.277)	(0.309)	(0.264)	(0.276)	(0.315)	(0.264)
$\ln \text{dist}_{\ell n}$	-0.742	-0.609	-0.687	-0.746	-0.606	-0.688
	(0.079)	(0.105)	(0.074)	(0.079)	(0.106)	(0.074)
$\text{language}_{\ell n}$	0.031	0.145	-0.044	0.025	0.155	-0.047
	(0.180)	(0.175)	(0.146)	(0.181)	(0.176)	(0.146)
ln (1+ car $\text{tariff}_{\ell n}$)	-10.878	-12.999	-11.722	-10.882	-12.943	-11.730
	(0.803)	(1.821)	(0.960)	(0.798)	(1.839)	(0.965)
Deep $\text{RTA}_{\ell n}$	0.535	1.039	0.523	0.535	1.038	0.520
	(0.158)	(0.211)	(0.168)	(0.157)	(0.213)	(0.167)
MP frictions						
$\text{home}_{i\ell}$	2.530	1.399	2.194	2.540	1.373	2.206
	(0.526)	(0.409)	(0.566)	(0.532)	(0.425)	(0.570)
$\ln \text{dist}_{i\ell}$	0.229	-0.088	0.210	0.219	-0.109	0.201
	(0.139)	(0.101)	(0.126)	(0.139)	(0.104)	(0.126)
$\text{language}_{i\ell}$	0.034	0.156	-0.040	0.021	0.132	-0.049
	(0.330)	(0.267)	(0.282)	(0.328)	(0.274)	(0.279)
ln (1+ parts $\text{tariff}_{i\ell}$)	-4.225	-6.548	-4.898	-3.242	-5.082	-3.913
	(2.153)	(2.219)	(2.364)	(2.146)	(2.291)	(2.349)
Deep $\text{RTA}_{i\ell}$	0.652	0.604	0.641	0.667	0.609	0.656
	(0.291)	(0.286)	(0.335)	(0.294)	(0.295)	(0.338)
log current country output				0.268	0.652	0.292
				(0.078)	(0.054)	(0.076)
Observations	375473	375473	375473	375473	375473	375473
rsq	0.927	0.943	0.832	0.926	0.944	0.833

Estimation with PPML. Standard errors in parentheses, clustered by origin country. All regressions have origin and brand-market-year fixed effects. r^2 is squared correlation of fitted and true dependent variables except in specification (4) where the pseudo-r^2 is reported. Each regression controls for log per-capita income and price level of the assembly country.

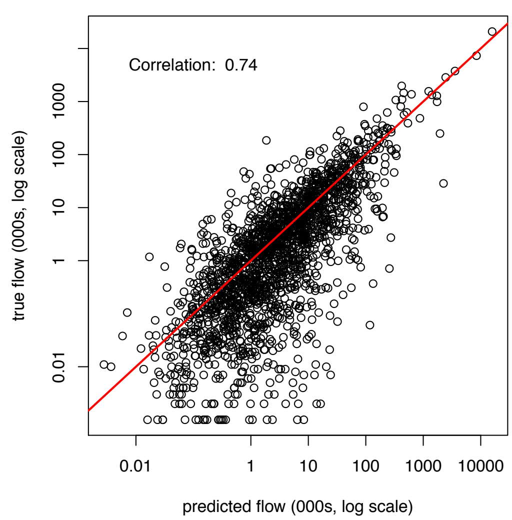
Figure G.1: Fit of the DEV simulation: predictions vs data



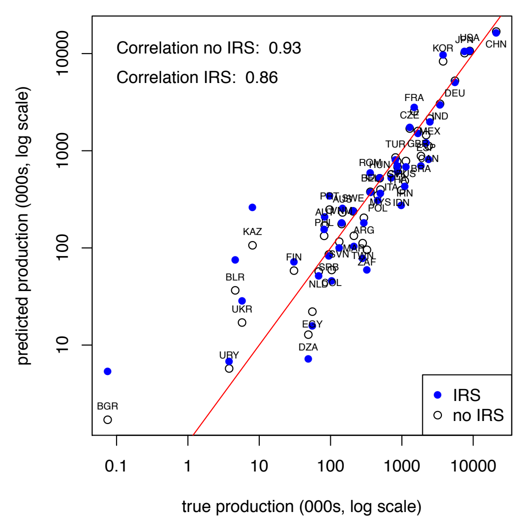
(a) Price indices (P_n)



(b) Brand flows ($q_{b\ell n}$)



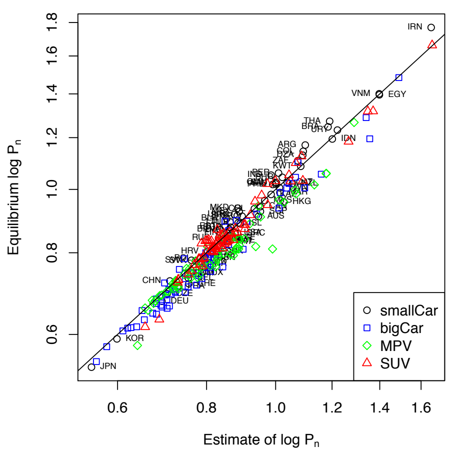
(c) Trade flows ($q_{\ell n}$)



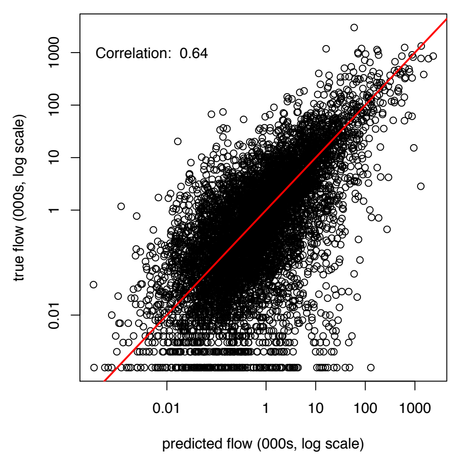
(d) National output (q_ℓ)

re-iterate the global ability of our model to explain global patterns of the data. The blue ones show equilibrium in the IRS situation, where the output of a country feeds back into lower production costs, and requiring an outer loop to solve for the vector of production. The difference between the two scenarios is very clear: when the model predicts that a country should produce more than its actual production (which serves as an initializing guess), this difference is amplified by the scenario with endogenous external economies of scale. Conversely, initial negative deviations are worsened.

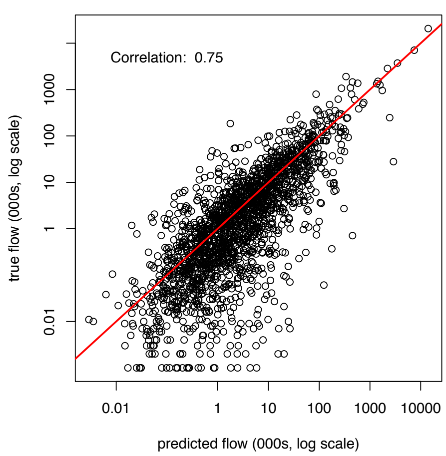
Figure G.2: Fit of the DEV simulation: predictions vs data



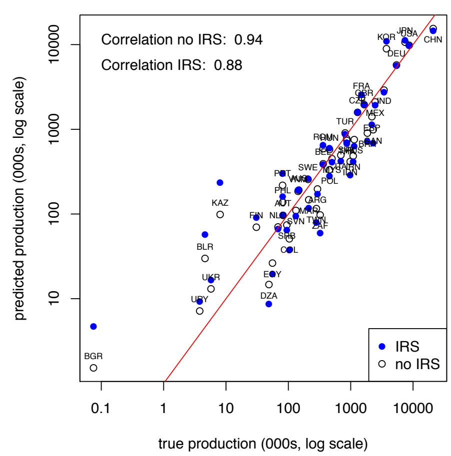
(a) Price indices



(b) micro sales ($q_{b\ell n}$)



(c) trade flows ($q_{\ell n}$)



(d) output (q_ℓ)

Figure G.2 shows the fit of the segmented market version of DEV. The correlations between the true flows and the flows predicted by the model are very similar and even slightly higher than in the unified market case.

H Evidence on capacity constraints in the medium-run

Our model does not have rising marginal costs due to plant-level capacity constraints. This assumption underlies our discrete choice formulation of the sourcing decision. If rising marginal costs were indeed a key feature of the data, the sourcing decision would require equating marginal costs across plants and the firm would often use multiple plants to serve the same market. In our data we observe 98% single-country sourcing. Thus it is very rare for firms to source the same car from two different countries. This fact is in line with the assumption of constant (or decreasing) marginal costs.

Our model allows for non-constant returns to scale that are external to the firm. Our estimates imply *increasing* returns, which we interpret as arising from Marshallian effects such as labor market pooling and, especially endogenous numbers of input suppliers. These effects would work to offset the short-run tendency of marginal costs at the plant-level to rise following a demand shock. Whether the industry-level increasing returns or plant-level decreasing returns dominate in the aggregate should depend on the time frame of the counterfactual.

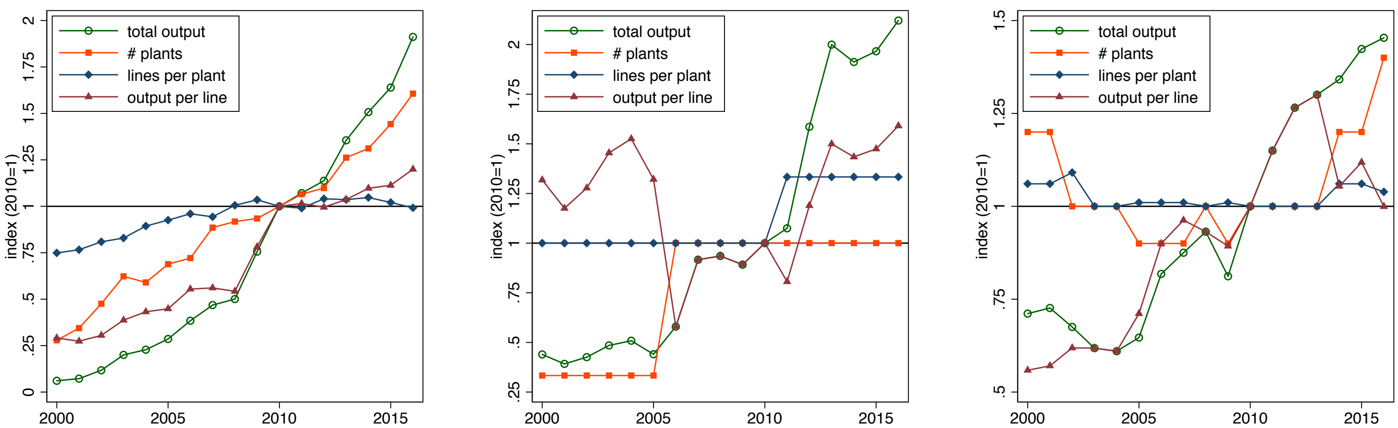
Our notion of the "medium run" is the period in which the brand can adjust all four of the margins we estimate (The short run would involve only intensive margin choices and the long run would allow for adding or dropping countries in the production choice set). Medium-run does not correspond to a specific amount of calendar time. However, we have observed that most changes in the sourcing decision tend to happen when the brand introduces a new model generation. The modal duration of a program is six years and only one third of the models last longer than that. We therefore think of the medium run as approximately six years.

We do not have direct evidence on the shape of the marginal cost curve over this medium-run scenario. However, to the extent that capacity constraints are binding and marginal costs sharply increasing in output, we would expect not to see any large increases in national car output over 5–7 year time frames.

There are two relevant cases for evaluating the potential for large output increases. The first is where the country's factories already have substantial excess capacity. While we do not observe capacity in our data, we use the maximum past production level as a proxy. This definition was inspired by Bresnahan and Ramey (1993) which used the maximum historical number of production shifts. Their approach does not allow for increases in line speed which Bresnahan and Ramey (1994) observe to "have a sizable impact on the variance of output at quarterly frequencies." At annual frequencies we would expect even greater scope for line speed increases since Bresnahan and Ramey (1994) report that line speed increases are mainly obtained by adding workers to the line.

Using the past-peak measure of capacity, we find that many countries in our study have substantial excess capacity in 2016. Poland's 2016 production was just 58% of its 2010 maximum and Belgium in 2016 had fallen to 41% of its 2007 peak. France and Italy are in a similar situation at with current quantities 44% and 51% of past peaks. Hence, for these countries we would not anticipate any significant limits to responding to higher demand from either Trans-Atlantic integration or Brexit. Another important country in our counterfactuals with current production under capacity is Japan (84%).

Figure H.1: Output increases on 3 margins in China, Slovakia, and Mexico



(a) China (b) Slovakia (c) Mexico

The second case of interest are countries producing quantities near their historical maxima. Important examples include China, Korea, Germany, Slovakia, the US, Canada, and Mexico. For these countries to expand output by large amounts they would have to construct new plants, add production lines to existing plants, or increase production per line (either by adding workers to increase line speed or adding extra shifts). To judge how feasible this might be, Figure H.1 decomposes output growth for three countries that have dramatically expanded their car industries in the last 17 years: China, Mexico, and Slovakia. These countries exhibit substantial growth from each of these sources, depending on the time range. In the case of China, rising incomes led to an astounding 32-fold increase in car production between 2000 and 2016, an annual rate of increase of over 23%. While the rate of growth has abated, Chinese car output still managed to grow by 91% from 2010 to 2016, roughly corresponding to our medium-run scenario. It did so mainly by increasing the number of plants (37 were opened in the 7-year period) but output per production line also grew by 20%. In the early 2000s growth was more evenly divided between new plants, new production lines, and expand output per line.

China is undoubtedly an extreme case, but even countries serving mature markets such as Slovakia and Mexico can be used to illustrate the potential of countries to increase production rapidly in the medium run. Slovakia experienced a boom in new car investments following accession to the European Union in 2004. From 2004 to 2010, output doubled. By 2016, car production had doubled again. Over the longer time frame, all the production increase can be attributed to new plants and production lines as output per line did not increase. However, since 2011 production has increased entirely on the intensive margin with a 97% increase in output per production line. The Mexican car industry traces its success back to NAFTA in 1993 but it increased production by a factor of 2.4 since 2004. For the first 9 years, all the increases were on the intensive margin but since 2013 four new plants were opened in Mexico along with one extra production line.

To summarize, there are three aspects of the data suggesting that capacity issues are unlikely to pose binding constraints in the medium-run ($\approx$ 6 year) time frame relevant for our policy counterfactuals. First, single-country sourcing is almost universal. Second, our estimates support downward sloping industry cost curves. Third, large output increases, featuring increases in plants, production lines, and output per line, have been observed in multiple countries over 6-year time frames.

I EHA version of counterfactual scenario results

In this section of the appendix, we report results using the Exact Hat Algebra (EHA) approach described in the text, and in more details in appendix C. We also highlight the differences between EHA and DEV approaches to counterfactual analysis.

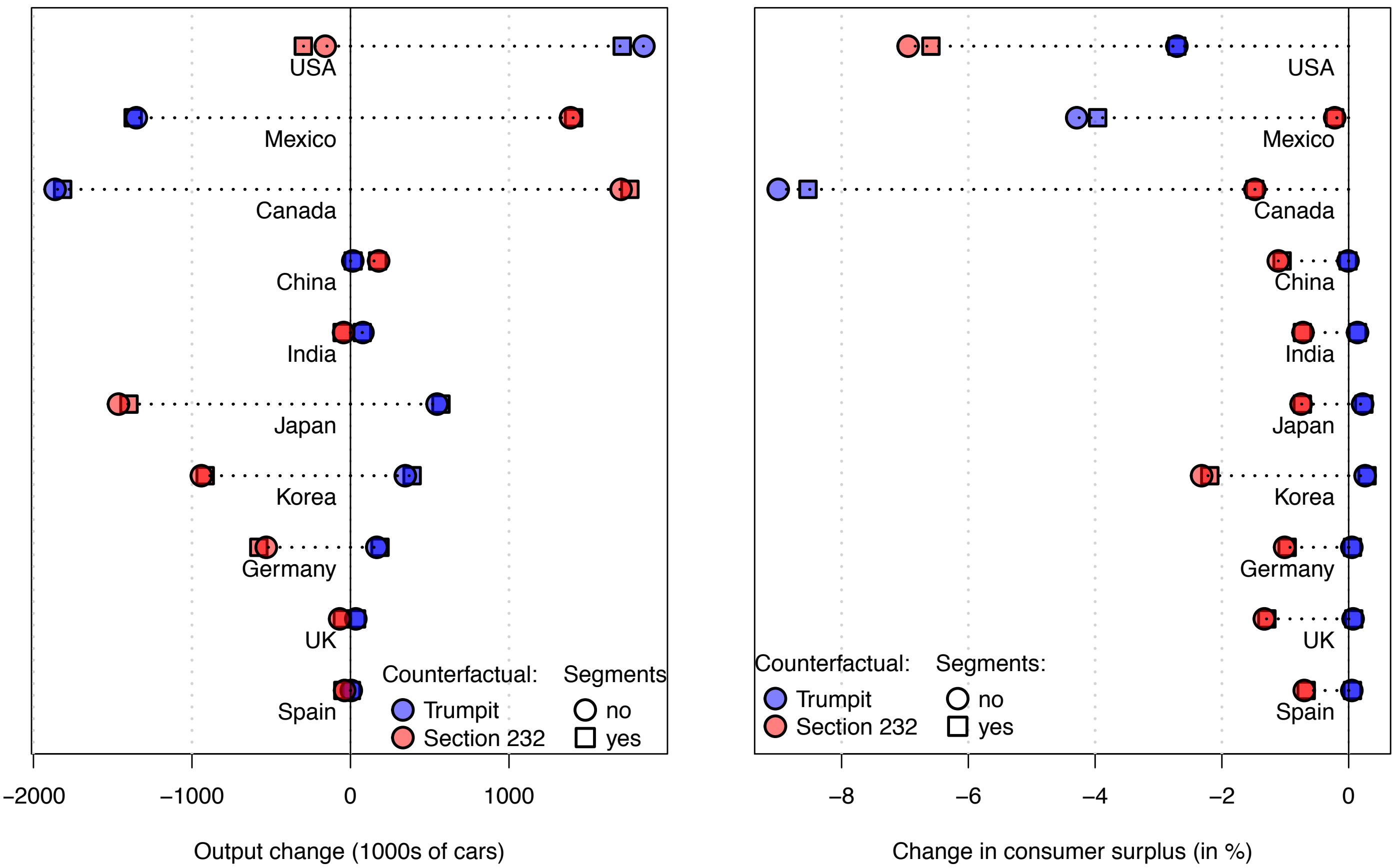
A key pattern is that the source of quantitative differences between EHA and DEV almost always arises from the different ways the two methods deal with a zero realized flow. EHA is rightly praised for its lower informational requirements. It also allows the counterfactual to implicitly hold constant deviations from expected values that might arise from unobservable frictions. To obtain bilateral zero flows, EHA implicitly assumes infinite frictions. As a result, any country ℓ that fails to be chosen by brand b to supply any models to market n, in the actual data will also remain a zero flow in under any counterfactual policy. In DEV, on the other hand, the computed flows (both factual and counterfactual) are expected values (and therefore greater than zero so long as the brand enters the market).

I.1 Trumpit and Section 232

The Trumpit counterfactual is an interesting case to study the role of zero flows and how the two methods deal with them. For example, Ford does not actually send cars from its Spanish or Polish factories to the North American market. The large British plants of Toyota and Nissan did not send a single car in 2016 to any of the three NAFTA members. In EHA, this is interpreted as a huge and persistent friction. As a consequence, the US market carries out zero substitution from Nissan's Mexico factory to its UK factory in response to Trumpit. However, Ford, Toyota and Nissan (among many others) have positive *expected* flows from their European plants to North America in DEV. Trumpit leads them to source substantially more from those EU-based operations to serve North-American markets. For Poland, Spain, and the UK, the EHA counterfactual shows a much weaker response compared to DEV as expected, reflecting the fact that the latter method accounts for the possibility of UK-made Nissans to be sold in the US. The most extreme case is Poland for which DEV increases exceeds those of EHA by up to seven percentage points.

India's Trumpit outcomes reveals the way EHA implicitly takes into account model "residuals," i.e. deviations from expected values. Since India is a high-cost producer and faces near 34% MFN tariffs on exports to Mexico, we would not expect it to be much of an exporter to Mexico.

Figure I.1: Trumpit and Section 232 (Exact Hat Algebra method)



But in fact Chevrolet, Ford, Volkswagen, Hyundai, and Suzuki all export large amounts. Trumpit implies that US-made cars face 25% tariffs on its exports to Mexico. This creates an expansion in Indian auto manufacturing of around 4% (74 th. cars). DEV does not build this unexplained ability of India to export cars to Mexico into the counterfactual (or factual). As a consequence, it only predicts an increase of 0.65% for India. The case for Spain is simply the reverse of India. Spain is a low-cost maker with zero-tariff access to Mexico. It would be expected to be a major exporter to Mexico before NAFTA but in fact it only exports about 25 thousand cars (implying a bad "residual" under EHA). Hence the average increase is almost ten times as large under DEV (+3.84%) than under EHA (+0.3%).

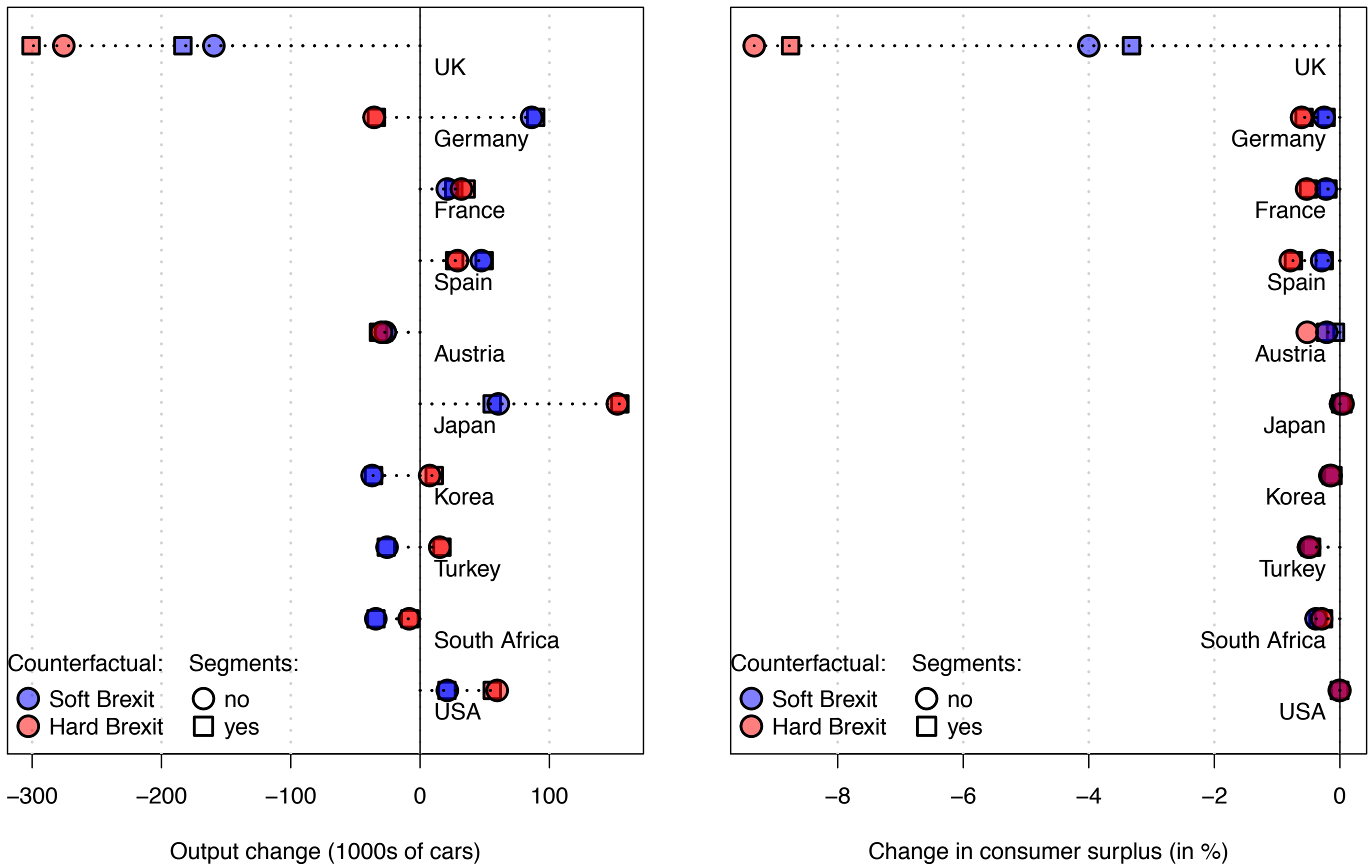
The net effect of cases like that of Spain is adding to the US output gains under EHA. This is because EHA rules out re-sourcing to a number of countries in Europe where US-owned plants do not currently send positive amounts of cars to the US. Therefore, under EHA, US factories do not have to share the gains from reduced access to Canadian and Mexican plants with their EU counterparts. Under DEV, the EU plants gains are large enough to generate a small net loss in US production under Trumpit. For the same reason, DEV dampens losses to US car buyers, who benefit from the option of importing EU-made cars. It seems plausible to us that the DEV outcomes for the US are the more likely ones to prevail in the medium-run as multinationals increase sourcing from their European factories to reflect the loss of preferential access of Mexican and Canadian plants to the US market.

The principal winners and losers in terms of output changes in the Section 232 scenario are the same under EHA and DEV. Mexico and Canada gain even more under EHA, 57% and 77% (as compared to 30% and 40% with DEV). On the flip side, Japanese, Korea, and Germany all lose more. The exception to the rule is the US, where car production is predicted to *fall* by 3.5% under EHA, whereas DEV had predicted a 26% increase. The first-order explanation for these differences is that DEV understates the shares of the US market served by Mexican and Canadian plants. In 2016 data those shares are 10% and 14%, much higher than DEV predictions of 4.3% and 2.9%, respectively. The emphasis EHA puts on initial flows as proxies for persistent unobserved frictions accounts for why factories in Canada and Mexico expand so much when Section 232 raises the costs of serving the US from other locations. While this might seem like a point in favor of EHA, these large expansions are not as plausible given features of the revised NAFTA that our simulations do not consider, namely tighter rules of origin and quotas on the amount of cars exported to the US that would escape Section 232 tariffs.

I.2 United Kingdom exits the European Union (Brexit)

Figure I.2 points to outcomes for both the UK car industry and the British car buyer that are much worse under EHA than under DEV. The industry contracts by 18% under hard Brexit, and still by 11% for Soft Brexit. In absolute terms, losses for the UK would be 183 thousand cars under Soft Brexit and more than 300 thousands under Hard Brexit. Consumer losses also rise slightly under EHA.

Figure I.2: Brexit



The structure of multinational production and British consumer tastes both contribute to make Brexit even more detrimental to the UK production in the EHA case than under DEV. Major German brands such as VW, BMW and Mercedes-Benz lack UK factories. This limits the scope for re-orienting the supply for UK demand to UK production locations (BMW and Mercedes-Benz for instance re-optimize their sourcing strategy to increase the share of models imported from their US plants). Because of the positive residual in the German brands' markets shares in the UK, this effect is magnified under EHA.

Aside from the UK, the big losers from Soft Brexit are South Korea, Turkey, and South Africa. All three countries suffer from the loss of tariff-free access to the UK that they obtained through trade agreements with the EU. South Africa is especially hard hit in the EHA setting (around -11%) because it has a surprisingly high sourcing share in the data (18 times higher than South Africa's exports to France for example). South Africa's production losses under EHA are large enough to trigger add-on costs from lower scale economies. Turkey's situation reverses the EHA/DEV differences (Turkey's share in UK purchases are only a third of their share in France).

The Brexit counter-factual is also valuable to illustrate how scale economies lead to market interdependencies. In a constant returns world, Honda's sourcing decision for sales in the US would be unaffected by Brexit. This is because there would be no tariff changes and, as a non-EU brand, no γ changes. With increasing returns, the smaller scale of the UK car industry raises Honda's UK plant's relative costs. The simulation predicts that US will lower its UK sourcing probability for the Honda Civic by 5%. Bigger effects arise when friction changes are combined with scale economies. The US probability of sourcing Mini hatchbacks and convertibles from the Netherlands falls by 32% when Brexit raises the costs of assembling the Mini in a no longer deeply integrated RTA by an estimated 6%. Increasing returns would magnify the reduction to 37%.

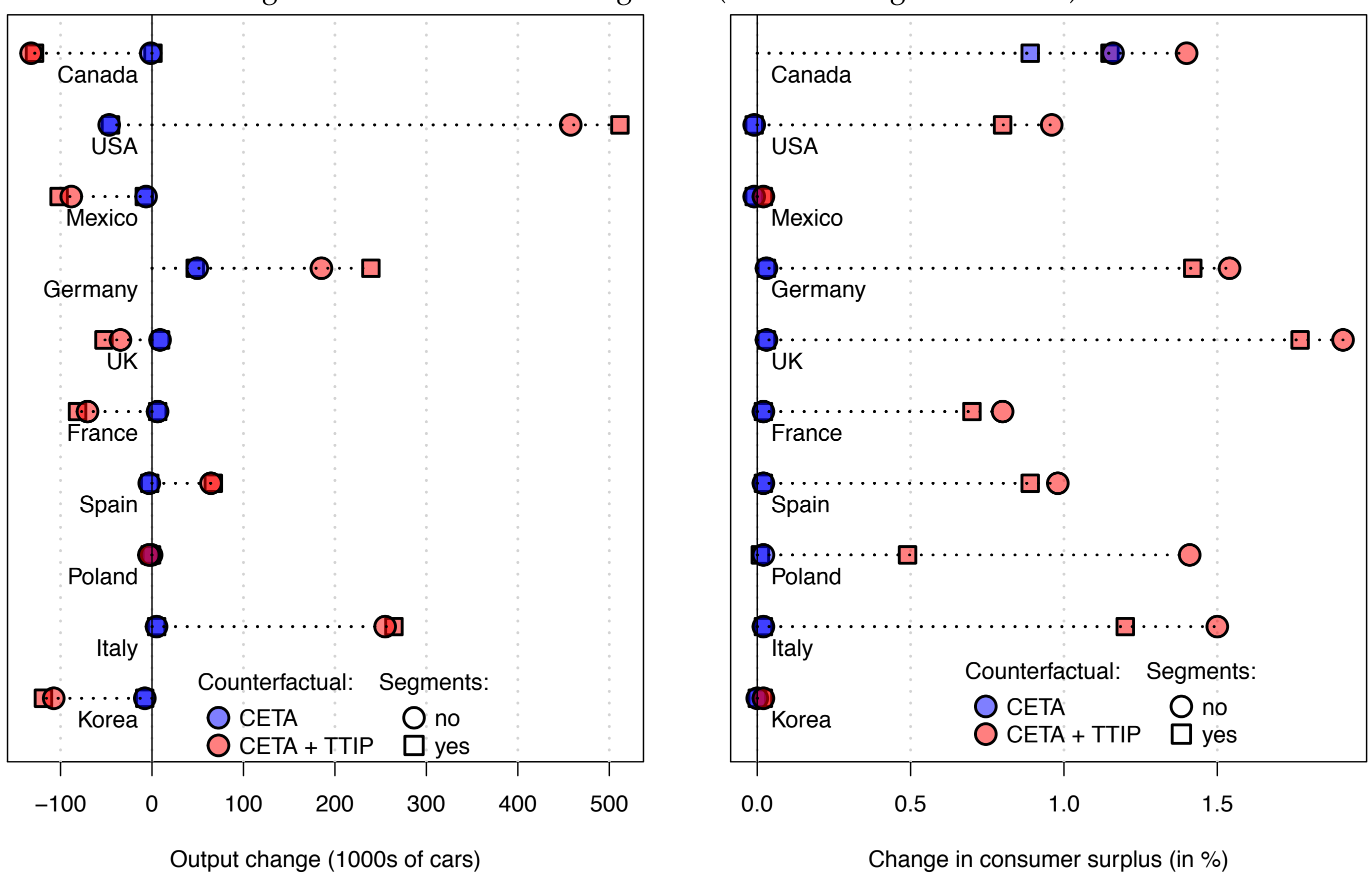
I.3 Trans-Atlantic Integration

Figure I.3 shows the effect of a deep trade agreement between the European Union (all current 28 members) and Canada (CETA) as well as an extension including the US (CETA+TTIP). Our counterfactuals point to very different outcomes from CETA for Canada under EHA and DEV. The DEV method predicts an 8% production increase, while under EHA, Canadian production is essentially unchanged. The reason EHA predicts such small effects is that Canada has negligible exports to the EU. Our estimates predict it should export about one percent of cars to the UK, for example. The share in actual data is one tenth that. Similar ratios apply to other EU destinations. Canada does not import large shares from the EU either, so under EHA only Germany and Italy experience sizable output changes.

Not surprisingly, including the US in trans-Atlantic integration leads to much bigger impacts, just as it did in the DEV method reported in the main text. As with DEV, consumers on both sides of the Atlantic benefit by about one percent, on average. Also in common with DEV, the Asian exporters Korea and Japan (not shown) lose from the changes in preferential market access.

The most dramatic difference between DEV and EHA is that in the latter, auto production in

Figure I.3: Trans-Atlantic Integration (Exact Hat Algebra method)



the US *increases* when it is included in trans-Atlantic integration. Once again, the explanation comes from the fact that in the 2016 data many brands that manufacture in Europe have zero exports to United States. Important examples include Ford in Poland and VW in Spain. EHA implicitly assumes prohibitively large frictions and does not allow these brands to respond to the export opportunities created by TTIP. Without this added competition, there is negligible offsetting of the roughly 400 ths. cars in exports to Europe which the US gains under both EHA and DEV.

Under CETA+TTIP, Italy stands out as a major gainer (45%) for EHA and this comes entirely from one interesting fact about 2016 car flows. Fiat factories in Italy successfully export Jeeps to the US. EHA allows this to expand massively. In contrast, Ford's factories in Poland *should* be exporting already to the US and therefore rapidly expand through a mix of τ and γ effects. In practice, Ford uses this plant exclusively to serve EU car buyers.

I.4 Trans-Pacific Integration

Figure I.4: Trans-Pacific Integration (Exact Hat Algebra method)

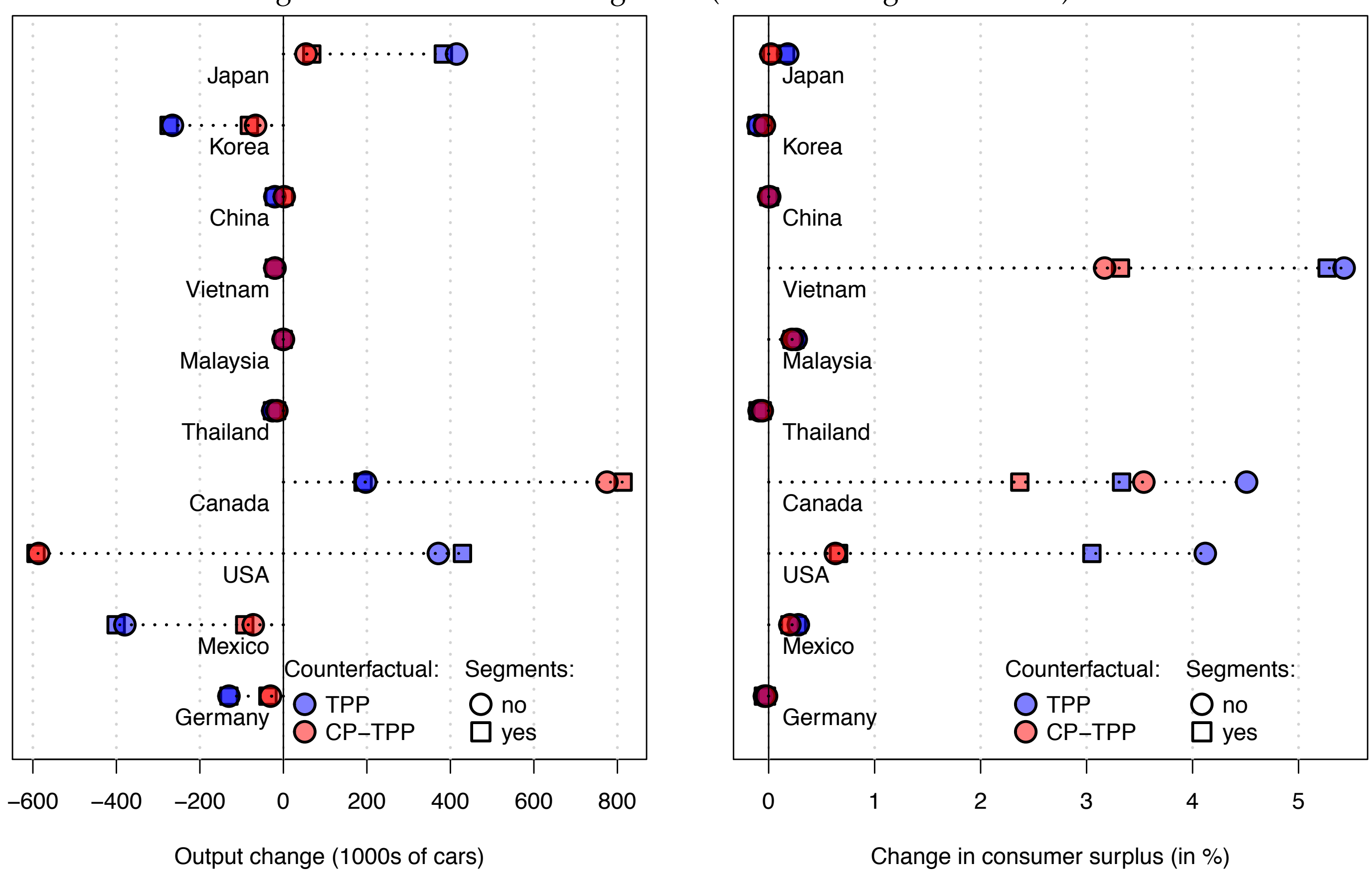


Figure I.4 shows the EHA outcomes for trans-Pacific integration, again with and without the US on board. The most striking outcome of either a TPP or CPTPP is the large predicted gain in Canadian car production. It would be tempting to attribute those gains to the elimination of high tariffs protecting Vietnamese and Malaysian markets and non-tariff barriers on the large Japanese market. Under CPTPP, Canadian car plants would certainly gain preferential access to those markets relative to the US, although in practice these plants would have to find a way to attain the 45% CPTPP rule of origin when denied the ability to count US inputs as part of the regional content. These considerations turn out to be irrelevant under the EHA method because Canada's actual exports to Vietnam and Malaysia are zero and Canada's entire exports to Japan amount to just 288 cars (a mix of Cadillacs and Chryslers).

Vietnam under TPP or CPTPP is a showcase for how different EHA and DEV solutions can be. Under DEV, Vietnam increases production with the TPP scenario, through a combination of improved access to the US market and γ effects boosting the expected sales of US brands with operations in Vietnam. In reality, Vietnam production is 100% oriented towards the local market. This implies no gains in exports to the US under EHA. However, the Japanese makers present in Vietnam will radically increase their sourcing from Japan, leading to the production losses we see for Vietnam under EHA.

I.5 Summary of EHA differences from DEV

An important overall conclusion of the EHA result is that the choice between solution methods is not innocuous. It often has serious quantitative effects and sometimes changes the sign of the output changes. Fortunately, the direction of the consumer surplus changes caused by our policy experiments are the same whenever they are non-negligible (over 0.5% in absolute value in either method). Even their magnitudes tend to be fairly robust across methods: the median absolute difference among the non-negligible changes in 0.6%. The output differences come in large part from the way brand-market zero flows are handled under EHA. We see these discrepancies as motivating the search for empirical evidence on whether EHA or DEV counterfactuals are more accurate in practice.

J Tables detailing counterfactual scenario results

In this section, we provide four tables in which the counterfactual results are detailed for a wider range of countries than in Figures 6 to 9 in the text for DEV and Figures I.1 to I.4 for EHA in the appendix. For each set of counterfactual scenarios (Trumpit/Brexit/Transatlantic Integration/Transpacific Integration), we give the unified and segmented versions for each of the DEV and EHA methods.

Table J.1: Trumpit DEV (unified)

Country	Change in shipments (ths. cars) to: *Domestic*	*RTA*	*ROW*	*Total*	% Chg.	CS % Chg.
25% duties and loss of deep RTA						
MEX	-10	-569	-228	-806	-40.65	-4.77
CAN	-47	-412	-87	-546	-67.74	-6.22
JPN	11	343	60	415	3.93	0.09
KOR	2	268	52	322	3.32	0.10
DEU	5	117	24	146	2.88	0.05
ESP	2	36	10	48	4.01	0.01
GBR	3	35	6	45	2.95	-0.00
BRA	28	12	4	44	6.41	-0.55
USA	568	-634	24	-42	-0.39	-0.84
FRA	1	34	5	39	1.40	0.02
CZE	0	29	7	36	2.04	0.03
BEL	0	25	8	33	8.90	0.03
POL	0	21	7	28	9.06	0.01
TUR	0	17	5	22	2.74	0.04
IND	5	15	2	21	0.72	-0.00
25% tariffs applied on major countries exc. Canada & Mexico						
USA	2707	-11	-629	2067	19.34	-4.48
KOR	14	-1320	-170	-1476	-15.23	-0.75
MEX	23	431	140	594	29.95	-0.30
JPN	37	-744	120	-587	-5.57	-0.36
CAN	21	228	42	290	35.98	-0.66
DEU	14	-325	24	-287	-5.66	-0.46
BEL	-3	-80	-40	-122	-32.83	-0.60
POL	-2	-65	-31	-98	-31.95	-0.64
ESP	0	-85	-8	-92	-7.77	-0.68
CHN	122	-50	18	90	0.55	-0.19
AUS	-2	-66	-17	-85	-34.46	-1.39
FRA	21	-26	76	70	2.51	-0.36
GBR	17	-87	22	-49	-3.21	-0.74
BRA	-9	-41	4	-46	-6.59	-0.35
KAZ	0	-33	-5	-38	-14.56	-1.10

The RTA column sums USA, Canada, and Mexico (excluding domestic shipments).

Table J.2: Trumpit DEV (segmented)

Country	Change in shipments (ths. cars) to:				% Chg.	CS % Chg.
	Domestic	*RTA*	*ROW*	*Total*		
25% duties and loss of deep RTA						
MEX	-8	-512	-212	-733	-38.43	-4.08
CAN	-49	-343	-82	-474	-67.41	-5.26
JPN	11	350	62	423	3.72	0.08
KOR	2	286	62	350	3.24	0.09
USA	415	-644	6	-223	-2.31	-0.79
DEU	5	127	22	155	2.76	0.05
GBR	3	49	8	59	3.06	0.03
FRA	2	45	8	55	2.13	0.03
ESP	1	34	9	44	3.84	0.02
BRA	26	12	4	42	5.96	-0.51
CZE	0	31	8	39	2.39	0.03
BEL	0	20	5	26	6.67	0.05
TUR	0	18	5	23	2.64	0.03
SVK	0	16	4	20	2.83	0.02
POL	0	15	4	20	6.99	0.01
25% tariffs applied on major countries exc. Canada & Mexico						
USA	3205	-5	-639	2561	26.48	-5.18
KOR	17	-1312	-172	-1467	-13.55	-0.74
JPN	38	-965	122	-805	-7.09	-0.43
MEX	23	416	128	567	29.73	-0.30
DEU	8	-501	14	-478	-8.53	-0.54
CAN	18	230	33	282	40.02	-0.59
GBR	11	-181	23	-147	-7.56	-0.57
CHN	168	-54	20	134	0.92	-0.24
BEL	-3	-82	-44	-129	-33.70	-0.62
ESP	-0	-83	-10	-93	-8.20	-0.69
POL	-2	-54	-34	-89	-31.76	-0.14
FRA	24	-21	83	86	3.35	-0.43
AUS	-2	-43	-15	-60	-30.86	-1.14
TUR	2	-68	15	-52	-5.98	-0.43
BRA	-8	-44	3	-49	-6.90	-0.37

The RTA column sums USA, Canada, and Mexico (excluding domestic shipments).

Table J.3: Trumpit EHA (unified)

Country	Change in shipments (ths. cars) to:				% Chg.	CS % Chg.
	Domestic	*RTA*	*ROW*	*Total*		
25% duties and loss of deep RTA						
CAN	6	-1836	-34	-1864	-78.80	-9.00
USA	2304	-498	45	1851	20.90	-2.71
MEX	-80	-1170	-101	-1351	-54.60	-4.29
JPN	2	521	23	546	7.20	0.22
KOR	2	322	21	346	9.20	0.26
DEU	4	154	8	166	3.00	0.05
IND	-0	76	3	79	4.50	0.14
BRA	15	16	10	42	2.30	-0.06
GBR	0	32	2	33	2.00	0.07
ITA	2	26	1	28	4.80	0.07
THA	-0	20	-1	19	2.20	0.07
HUN	0	16	1	17	3.40	0.04
SVK	-0	16	0	17	1.90	0.05
CHN	9	4	1	15	0.10	-0.01
COL	7	5	0	12	11.40	-0.76
25% tariffs applied on major countries exc. Canada & Mexico						
CAN	76	1601	30	1707	72.10	-1.48
JPN	4	-1533	66	-1463	-19.40	-0.75
MEX	83	1219	86	1388	56.10	-0.22
KOR	21	-962	0	-941	-25.10	-2.32
DEU	14	-532	-13	-531	-9.60	-1.01
CHN	192	-20	6	178	0.90	-1.11
USA	855	-190	-825	-159	-1.80	-6.95
ITA	-14	-120	-14	-147	-25.00	-1.07
CZE	4	1	66	71	5.50	-0.73
GBR	23	-137	46	-68	-4.10	-1.33
FRA	15	-15	52	52	3.50	-0.51
SWE	-1	-44	-1	-46	-22.30	-0.73
IND	0	-44	0	-43	-2.50	-0.72
TUR	6	-1	37	43	5.20	-0.46
ESP	1	-18	-20	-37	-1.70	-0.70

The RTA column sums USA, Canada, and Mexico (excluding domestic shipments).

Table J.4: Trumpit EHA (segmented)

Country	Change in shipments (ths. cars) to: *Domestic*	*RTA*	*ROW*	*Total*	% Chg.	CS % Chg.
25% duties and loss of deep RTA						
CAN	-1	-1780	-35	-1816	-79.10	-8.53
USA	2174	-499	39	1714	19.90	-2.71
MEX	-86	-1181	-105	-1371	-55.40	-3.96
JPN	3	542	26	571	7.70	0.24
KOR	4	359	26	389	10.50	0.29
DEU	4	172	10	186	3.40	0.06
IND	-0	72	3	74	4.20	0.14
BRA	15	18	10	43	2.30	-0.05
GBR	0	37	2	39	2.30	0.08
ITA	2	28	1	32	5.40	0.07
HUN	0	19	2	21	4.60	0.05
THA	-0	21	-1	19	2.20	0.08
SVK	0	18	1	19	2.20	0.05
CHN	11	5	1	17	0.10	-0.01
COL	7	6	0	13	12.80	-0.73
25% tariffs applied on major countries exc. Canada & Mexico						
CAN	81	1659	23	1763	76.80	-1.48
MEX	85	1241	82	1408	56.90	-0.22
JPN	5	-1484	82	-1397	-18.80	-0.73
KOR	22	-939	1	-917	-24.70	-2.19
DEU	5	-510	-73	-578	-10.70	-0.97
USA	683	-192	-789	-297	-3.50	-6.59
CHN	187	-21	5	171	0.90	-1.05
ITA	-18	-120	-24	-162	-27.40	-1.01
CZE	5	1	79	84	6.50	-0.67
FRA	18	-15	64	67	4.50	-0.47
IND	-0	-45	-8	-53	-3.00	-0.73
TUR	8	-1	45	52	6.40	-0.38
GBR	26	-137	60	-51	-3.10	-1.29
ESP	1	-19	-30	-48	-2.20	-0.67
SWE	-1	-46	0	-47	-22.60	-0.43

The RTA column sums USA, Canada, and Mexico (excluding domestic shipments).

Table J.5: Brexit DEV (unified)

Country	Change in shipments (ths. cars) to:				% Chg.	CS % Chg.
	Domestic	*RTA*	*ROW*	*Total*		
Soft Brexit: shallow FTA (0 tariffs, no deep integration measures)						
KOR	2	-143	-16	-157	-1.61	-0.10
JPN	2	54	35	91	0.86	0.02
USA	9	31	12	53	0.49	-0.00
GBR	116	-78	-85	-46	-3.04	-4.34
DEU	11	19	10	40	0.80	-0.08
TUR	1	-32	-9	-40	-4.96	-0.34
FRA	6	13	7	26	0.91	-0.09
MEX	5	-26	-3	-24	-1.21	-0.33
CZE	1	11	6	17	0.99	-0.07
AUT	-0	-8	-6	-15	-7.17	-0.13
ESP	2	6	4	11	0.96	-0.13
ROM	0	7	3	10	1.74	-0.08
NLD	-0	-5	-4	-10	-18.51	-0.20
MAR	0	-8	-0	-8	-7.89	-0.28
CAN	0	4	3	7	0.86	-0.01
Hard (“no deal”) Brexit: 10% tariffs in both directions						
JPN	2	125	41	169	1.60	0.04
USA	9	72	14	95	0.89	0.01
KOR	2	-66	-5	-69	-0.71	-0.06
FRA	10	-60	2	-47	-1.68	-0.29
DEU	21	-73	4	-47	-0.93	-0.26
GBR	255	-201	-84	-29	-1.93	-8.16
CZE	1	-30	2	-27	-1.55	-0.25
AUT	-0	-13	-8	-21	-10.01	-0.34
TUR	1	-14	-6	-19	-2.29	-0.36
ESP	4	-21	1	-16	-1.33	-0.37
RUS	1	11	2	14	2.06	-0.00
IND	1	11	2	13	0.46	0.01
NLD	-0	-7	-5	-13	-24.24	-0.52
CAN	0	9	3	12	1.54	0.01
SVK	0	-12	0	-12	-1.66	-0.33

The RTA column sums the UK and the EU27 (excluding domestic shipments).

Table J.6: Brexit DEV (segmented)

Country	Change in shipments (ths. cars) to: *Domestic*	*RTA*	*ROW*	*Total*	% Chg.	CS % Chg.
Soft Brexit: shallow FTA (0 tariffs, no deep integration measures)						
KOR	4	-139	-14	-150	-1.38	-0.09
JPN	2	51	40	93	0.82	0.02
GBR	112	-92	-103	-83	-4.25	-3.37
TUR	-0	-37	-25	-63	-7.20	-0.33
DEU	12	28	14	55	0.97	-0.09
USA	13	18	16	47	0.50	-0.00
FRA	7	20	9	35	1.38	-0.09
CZE	1	12	8	20	1.23	-0.09
MEX	6	-22	-1	-17	-0.90	-0.35
ROM	0	11	4	15	2.52	-0.09
ESP	2	8	5	14	1.26	-0.13
AUT	-0	-6	-6	-13	-13.47	-0.05
NLD	-1	-5	-5	-11	-16.07	-0.15
CHN	7	1	2	10	0.10	-0.00
SVK	0	5	3	8	1.18	-0.10
Hard (“no deal”) Brexit: 10% tariffs in both directions						
JPN	3	129	49	180	1.59	0.04
USA	15	51	17	82	0.85	0.01
GBR	290	-259	-103	-73	-3.75	-7.42
KOR	4	-50	-0	-46	-0.42	-0.06
DEU	26	-74	5	-42	-0.75	-0.29
TUR	1	-18	-22	-40	-4.55	-0.35
FRA	14	-53	4	-36	-1.39	-0.33
CZE	1	-27	3	-23	-1.41	-0.33
AUT	-0	-8	-8	-16	-16.75	-0.16
RUS	1	11	2	15	2.35	-0.01
IND	1	11	2	14	0.50	0.00
NLD	-0	-7	-6	-14	-20.99	-0.46
ESP	4	-19	2	-14	-1.18	-0.40
CHN	1	8	2	11	0.10	-0.00
CAN	0	6	3	10	1.40	-0.01

The RTA column sums the UK and the EU27 (excluding domestic shipments).

Table J.7: Brexit EHA (unified)

Country	Change in shipments (ths. cars) to: *Domestic*	*RTA*	*ROW*	*Total*	% Chg.	CS % Chg.
Soft Brexit: shallow FTA (0 tariffs, no deep integration measures)						
GBR	68	-162	-65	-159	-9.60	-4.00
DEU	21	50	16	86	1.60	-0.25
JPN	2	46	12	61	0.80	0.01
ESP	5	36	6	47	2.20	-0.29
KOR	8	-45	-0	-37	-1.00	-0.16
ZAF	-0	-31	-3	-34	-10.60	-0.38
NLD	-0	-17	-11	-28	-40.60	-0.29
AUT	-0	-14	-13	-27	-32.40	-0.21
TUR	6	-32	1	-26	-3.10	-0.50
USA	5	13	3	21	0.20	-0.01
FRA	7	12	3	21	1.40	-0.22
CZE	1	13	3	17	1.30	-0.14
IND	0	6	5	11	0.60	0.02
POL	1	7	1	9	2.00	-0.33
ROM	0	5	2	8	2.10	-0.15
Hard (“no deal”) Brexit: 10% tariffs in both directions						
GBR	211	-416	-71	-276	-16.50	-9.33
JPN	4	130	18	153	2.00	0.05
USA	7	49	4	60	0.70	0.00
IND	0	36	6	43	2.40	0.08
DEU	39	-80	6	-36	-0.60	-0.61
FRA	16	13	3	32	2.10	-0.53
AUT	-0	-15	-15	-30	-36.00	-0.52
ESP	11	12	6	29	1.30	-0.79
NLD	-0	-16	-12	-29	-42.00	-0.69
TUR	7	6	2	15	1.90	-0.48
THA	0	10	2	13	1.40	0.04
ZAF	1	-9	-0	-8	-2.60	-0.29
SVK	0	-9	0	-8	-1.00	-0.49
KOR	9	-5	3	7	0.20	-0.14
MEX	2	4	2	7	0.30	-0.05

The RTA column sums the UK and the EU27 (excluding domestic shipments).

Table J.8: Brexit EHA (segmented)

Country	Change in shipments (ths. cars) to: *Domestic*	*RTA*	*ROW*	*Total*	% Chg.	CS % Chg.
Soft Brexit: shallow FTA (0 tariffs, no deep integration measures)						
GBR	51	-164	-70	-183	-11.10	-3.32
DEU	21	53	16	89	1.60	-0.22
JPN	3	40	13	56	0.70	0.01
ESP	5	39	6	50	2.30	-0.25
KOR	8	-45	1	-36	-1.00	-0.14
ZAF	-1	-31	-3	-34	-10.50	-0.35
NLD	-1	-18	-11	-29	-43.00	-0.23
AUT	-0	-14	-14	-28	-34.30	-0.07
TUR	5	-31	1	-26	-3.20	-0.48
FRA	7	16	3	26	1.70	-0.19
CZE	1	18	3	22	1.70	-0.12
USA	6	11	3	21	0.20	-0.01
SVK	0	12	2	14	1.60	-0.16
POL	1	8	1	10	2.30	-0.16
ROM	0	7	3	10	2.60	-0.10
Hard ("no deal") Brexit: 10% tariffs in both directions						
GBR	210	-432	-78	-301	-18.30	-8.75
JPN	5	129	21	155	2.10	0.05
USA	8	44	4	56	0.60	0.00
IND	0	31	6	37	2.10	0.07
FRA	17	16	3	36	2.40	-0.50
DEU	40	-79	5	-34	-0.60	-0.57
AUT	-0	-16	-16	-32	-39.20	-0.23
NLD	-0	-19	-13	-32	-46.90	-0.57
ESP	11	11	5	27	1.20	-0.74
TUR	6	9	2	17	2.10	-0.45
THA	0	12	2	15	1.70	0.05
ROM	1	8	3	11	3.10	-0.36
KOR	10	-3	5	11	0.30	-0.11
CHN	7	0	0	8	0.00	0.00
ZAF	1	-8	-0	-8	-2.40	-0.26

The RTA column sums the UK and the EU27 (excluding domestic shipments).

Table J.9: CETA (unified)

Country	Change in shipments (ths. cars) to:				% Chg.	CS % Chg.
	Domestic	*RTA*	*ROW*	*Total*		
CETA						
USA	-10	-56	-2	-68	-0.64	-0.01
CAN	-12	63	13	65	8.03	1.62
DEU	-2	43	3	43	0.85	0.06
KOR	-0	-32	-3	-35	-0.36	-0.01
JPN	-0	-29	-4	-33	-0.32	-0.01
MEX	-1	-14	-3	-18	-0.89	0.00
GBR	-2	16	1	15	1.01	0.08
ESP	-1	9	1	9	0.77	0.09
BEL	-0	7	1	8	2.03	0.07
POL	-0	6	1	7	2.14	0.08
ITA	-1	5	0	5	0.99	0.08
TUR	-0	-4	-1	-5	-0.63	0.01
CZE	-0	4	1	5	0.28	0.06
SVK	-0	4	1	5	0.65	0.07
PRT	-0	4	0	4	1.31	0.11
CETA + TTIP						
DEU	-37	407	69	438	8.65	0.89
KOR	-3	-256	-45	-303	-3.13	-0.08
BEL	5	213	53	271	72.67	1.11
POL	3	178	45	226	73.68	1.21
JPN	-3	-171	-40	-214	-2.03	-0.05
ESP	0	155	40	195	16.35	1.31
USA	-618	416	15	-188	-1.76	1.13
MEX	-11	-102	-22	-136	-6.84	0.37
FRA	-31	-42	-12	-85	-3.02	0.66
TUR	-2	-31	-5	-38	-4.69	0.29
ROM	-1	23	11	33	5.67	0.89
CZE	-4	-20	-8	-32	-1.84	0.71
ITA	-8	32	6	29	5.46	1.04
CHN	-12	-13	-4	-29	-0.18	0.01
RUS	-4	-15	-3	-23	-3.30	0.15
GBR	-33	54	-1	19	1.26	1.33
CAN	-21	19	-5	-7	-0.89	2.13

RTA is EU28 plus Canada in top panel (CETA) and also includes US in the lower panel.

Table J.10: CETA (segmented)

Country	Change in shipments (ths. cars) to: *Domestic*	*RTA*	*ROW*	*Total*	% Chg.	CS % Chg.
CETA						
USA	-11	-61	-3	-75	-0.77	-0.01
CAN	-12	56	12	56	7.89	1.77
DEU	-3	41	4	43	0.76	0.06
KOR	-0	-36	-6	-42	-0.39	-0.01
JPN	-0	-29	-3	-32	-0.29	-0.01
GBR	-1	23	3	25	1.27	0.07
MEX	-1	-13	-2	-16	-0.82	0.00
ESP	-1	10	1	11	0.92	0.08
CZE	-0	7	1	8	0.49	0.07
BEL	-0	7	1	8	2.03	0.06
POL	-0	5	1	6	2.11	0.02
TUR	-0	-5	-1	-5	-0.61	0.00
SVK	-0	5	1	5	0.76	0.06
FRA	-2	7	0	5	0.19	0.05
HUN	-0	3	0	3	0.54	0.06
CETA + TTIP						
DEU	-31	361	74	404	7.21	0.81
KOR	-6	-285	-62	-353	-3.26	-0.06
JPN	-5	-220	-63	-288	-2.54	-0.05
BEL	6	188	53	246	64.22	1.01
POL	3	158	48	210	74.56	0.29
ESP	2	140	40	182	15.95	1.14
MEX	-11	-103	-21	-135	-7.10	0.44
FRA	-32	-29	-13	-73	-2.83	0.72
GBR	-33	85	-1	50	2.61	1.06
USA	-499	405	44	-50	-0.52	1.28
TUR	-2	-38	-7	-47	-5.45	0.22
CHN	-14	-16	-4	-34	-0.22	0.03
ITA	-4	30	7	32	7.74	1.00
ROM	-1	14	10	23	3.87	0.68
RUS	-4	-15	-4	-23	-3.60	0.22
CAN	-20	17	-3	-6	-0.80	2.32

RTA is EU28 plus Canada in top panel (CETA) and also includes US in the lower panel.

Table J.11: CETA EHA (unified)

Country	Change in shipments (ths. cars) to:				% Chg.	CS % Chg.
	Domestic	*RTA*	*ROW*	*Total*		
CETA						
DEU	-1	47	3	49	0.90	0.03
USA	-4	-41	-1	-47	-0.50	-0.01
JPN	-0	-10	0	-10	-0.10	0.00
GBR	-0	8	1	9	0.50	0.03
KOR	-0	-8	-0	-8	-0.20	0.00
MEX	-0	-6	-0	-6	-0.30	-0.01
FRA	0	6	0	6	0.40	0.02
ITA	0	4	0	5	0.80	0.02
HUN	0	4	0	5	1.00	0.01
ESP	-0	-2	-0	-3	-0.10	0.02
SVK	0	3	0	3	0.30	0.01
SWE	0	2	0	2	1.20	0.03
CZE	-0	-1	-0	-2	-0.10	0.01
CAN	-17	14	1	-1	-0.10	1.16
BEL	-0	1	0	1	0.30	0.02
CETA + TTIP						
USA	-155	439	174	458	5.20	0.96
ITA	19	226	11	255	43.20	1.50
DEU	-68	244	9	185	3.30	1.54
JPN	-6	-128	-17	-150	-2.00	-0.04
CAN	-24	-107	-2	-132	-5.60	1.40
KOR	-7	-90	-10	-107	-2.90	0.02
CHN	-90	-2	-1	-93	-0.50	0.05
MEX	-6	-80	-3	-88	-3.60	0.02
CZE	-6	-73	-5	-84	-6.50	1.19
FRA	-21	-46	-3	-71	-4.70	0.80
ESP	-0	49	16	64	2.90	0.98
TUR	-6	-39	-2	-48	-5.80	0.41
GBR	-34	4	-5	-35	-2.10	1.91
SVK	-0	-32	-2	-34	-4.00	1.15
ZAF	-6	-24	-4	-33	-10.30	0.58

RTA is EU28 plus Canada in top panel (CETA) and also includes US in the lower panel.

Table J.12: CETA EHA (segmented)

Country	Change in shipments (ths. cars) to:				% Chg.	CS % Chg.
	Domestic	*RTA*	*ROW*	*Total*		
CETA						
DEU	-1	44	4	47	0.90	0.03
USA	-5	-40	-1	-45	-0.50	-0.01
JPN	-0	-10	0	-10	-0.10	0.00
GBR	-0	9	1	9	0.60	0.03
MEX	-0	-8	-0	-8	-0.30	-0.01
KOR	-0	-8	-0	-8	-0.20	0.00
FRA	-0	6	0	6	0.40	0.02
ITA	0	4	0	5	0.90	0.02
HUN	0	4	0	5	1.00	0.01
SVK	0	3	0	3	0.30	0.01
ESP	-0	-2	-0	-2	-0.10	0.02
SWE	0	2	0	2	1.10	0.01
CZE	-0	-2	-0	-2	-0.20	0.01
CAN	-15	14	2	1	0.00	0.89
BEL	-0	1	0	1	0.30	0.02
CETA + TTIP						
USA	-125	449	187	512	5.90	0.80
ITA	18	235	12	265	44.80	1.20
DEU	-59	272	27	239	4.40	1.42
JPN	-7	-137	-24	-169	-2.30	-0.04
CAN	-23	-104	-2	-128	-5.60	1.15
KOR	-10	-96	-13	-119	-3.20	0.02
MEX	-6	-92	-4	-102	-4.10	0.02
CHN	-97	-2	-1	-100	-0.50	0.05
CZE	-7	-83	-6	-97	-7.50	1.13
FRA	-24	-52	-5	-81	-5.50	0.70
ESP	-0	50	17	67	3.10	0.89
TUR	-8	-44	-3	-55	-6.80	0.39
GBR	-35	-10	-7	-53	-3.20	1.77
SVK	-0	-41	-3	-45	-5.20	0.89
ZAF	-6	-25	-4	-35	-10.70	0.60

RTA is EU28 plus Canada in top panel (CETA) and also includes US in the lower panel.

Table J.13: TPP (unified)

Country	Change in shipments (ths. cars) to:				% Chg.	CS % Chg.
	Domestic	*RTA*	*ROW*	*Total*		
TPP with USA						
JPN	-52	700	-12	636	6.03	0.39
KOR	-5	-253	-54	-312	-3.22	-0.05
CAN	19	136	95	250	31.02	3.16
USA	-303	80	136	-88	-0.82	1.49
DEU	-2	-56	-12	-70	-1.38	-0.01
CHN	-50	-14	-3	-67	-0.41	0.05
MEX	-10	-33	-9	-51	-2.56	0.50
VNM	-32	41	41	50	27.66	28.06
GBR	-4	-26	-12	-42	-2.79	0.00
THA	-4	-16	-8	-28	-4.53	0.11
TUR	-1	-16	-9	-26	-3.16	0.04
FRA	-1	-14	-8	-23	-0.83	-0.00
CZE	-0	-12	-9	-21	-1.21	-0.00
IND	-2	-14	-4	-20	-0.67	-0.01
ESP	-1	-14	-5	-19	-1.62	0.03
CP-TPP (without USA)						
CAN	25	68	221	313	38.87	2.93
JPN	-20	235	-29	186	1.77	0.12
USA	-74	-96	-9	-178	-1.67	0.08
KOR	-2	-99	-33	-134	-1.38	-0.01
CHN	-20	-7	-2	-28	-0.17	0.02
MEX	-3	24	6	27	1.37	0.28
DEU	-1	-19	-6	-27	-0.53	-0.01
GBR	-2	-10	-8	-20	-1.31	0.00
THA	-2	-9	-5	-15	-2.48	0.04
FRA	-1	-7	-5	-13	-0.47	-0.00
TUR	-0	-6	-6	-12	-1.53	0.01
CZE	-0	-6	-5	-12	-0.65	-0.00
MYS	-16	7	-2	-11	-2.96	2.00
IND	-1	-6	-3	-9	-0.30	-0.01
AUS	-4	9	3	9	3.63	0.77
VNM	-32	8	16	-8	-4.61	24.62

The RTA column includes TPP12 (including US) in top panel and excludes US in lower panel.

Table J.14: TPP (segmented)

Country	Change in shipments (ths. cars) to:				% Chg.	CS % Chg.
	Domestic	*RTA*	*ROW*	*Total*		
TPP with USA						
JPN	-41	773	24	756	6.66	0.37
KOR	-8	-292	-82	-382	-3.52	-0.04
CAN	14	122	95	232	32.93	2.28
DEU	-4	-85	-21	-111	-1.98	-0.02
CHN	-65	-15	-3	-83	-0.57	0.07
GBR	-4	-43	-13	-60	-3.08	-0.01
MEX	-10	-38	-7	-56	-2.91	0.47
VNM	-32	34	42	44	23.09	29.12
USA	-252	68	152	-32	-0.33	1.21
THA	-4	-16	-7	-27	-4.04	0.10
TUR	-1	-17	-8	-26	-3.04	0.03
ESP	-1	-16	-6	-23	-2.04	0.03
FRA	-1	-14	-8	-23	-0.87	-0.00
CZE	-0	-12	-7	-19	-1.19	-0.00
IND	1	-15	-4	-18	-0.64	-0.03
CPTPP (without USA)						
CAN	20	60	218	298	42.36	2.07
JPN	-16	250	-6	228	2.01	0.12
USA	-77	-92	-9	-178	-1.85	0.07
KOR	-3	-110	-49	-162	-1.50	-0.02
DEU	-1	-21	-12	-34	-0.61	-0.01
CHN	-22	-6	-2	-30	-0.20	0.03
MEX	-3	23	10	30	1.57	0.25
GBR	-2	-12	-8	-21	-1.11	0.00
THA	-2	-8	-4	-14	-2.09	0.04
MYS	-18	8	-3	-13	-3.20	2.31
FRA	-1	-6	-4	-11	-0.43	-0.00
TUR	-0	-5	-5	-11	-1.22	0.01
CZE	-0	-5	-5	-10	-0.61	0.00
AUS	-2	8	3	9	4.72	0.63
ESP	-0	-4	-3	-7	-0.65	0.01
VNM	-33	8	19	-6	-2.98	26.31

The RTA column includes TPP12 (including US) in top panel and excludes US in lower panel.

Table J.15: TPP EHA (unified)

Country	Change in shipments (ths. cars) to: *Domestic*	*RTA*	*ROW*	*Total*	% Chg.	CS % Chg.
TPP with USA						
JPN	-0	411	4	415	5.50	0.18
MEX	-30	-340	-10	-380	-15.30	0.28
USA	259	48	64	371	4.20	4.12
KOR	-9	-239	-18	-266	-7.10	-0.10
CAN	36	159	3	197	8.30	4.51
DEU	-3	-117	-10	-130	-2.40	-0.04
GBR	-1	-33	-4	-38	-2.30	-0.05
ITA	-2	-23	-2	-26	-4.40	-0.05
THA	-0	-23	-3	-26	-2.90	-0.09
CHN	-13	-5	-1	-20	-0.10	0.01
VNM	-20	0	0	-20	-14.00	5.43
HUN	-0	-13	-2	-15	-3.10	-0.03
SWE	-0	-10	-1	-11	-5.30	-0.05
ZAF	-0	-8	-1	-9	-2.70	-0.05
IND	0	-6	-1	-7	-0.40	-0.01
CP-TPP (without USA)						
CAN	83	20	673	775	32.80	3.54
USA	-461	-113	-12	-586	-6.60	0.63
MEX	-6	-16	-50	-72	-2.90	0.20
KOR	-1	-32	-34	-67	-1.80	-0.04
JPN	1	144	-91	54	0.70	0.02
DEU	0	-17	-14	-31	-0.60	-0.02
VNM	-21	0	0	-21	-14.40	3.17
THA	-0	-14	-2	-16	-1.80	-0.06
GBR	-0	-6	-6	-11	-0.70	-0.02
HUN	-0	-3	-2	-5	-1.00	-0.01
IND	0	-4	0	-4	-0.20	-0.01
ITA	-0	-1	-3	-4	-0.60	-0.01
FRA	0	-2	-1	-3	-0.20	-0.01
SWE	-0	-1	-2	-2	-1.20	-0.02
CHN	4	-1	-0	2	0.00	0.00

The RTA column includes TPP12 (including US) in top panel and excludes US in lower panel.

Table J.16: TPP EHA (segmented)

Country	Change in shipments (ths. cars) to: *Domestic*	*RTA*	*ROW*	*Total*	% Chg.	CS % Chg.
TPP with USA						
USA	306	53	69	429	5.00	3.05
MEX	-31	-359	-11	-401	-16.20	0.27
JPN	2	375	6	383	5.20	0.16
KOR	-12	-240	-22	-274	-7.40	-0.11
CAN	35	153	3	191	8.30	3.33
DEU	-3	-115	-12	-130	-2.40	-0.05
GBR	-1	-29	-3	-33	-2.00	-0.05
THA	-0	-23	-3	-26	-3.00	-0.10
CHN	-15	-5	-1	-22	-0.10	0.01
VNM	-21	0	0	-21	-15.00	5.27
ITA	-1	-16	-1	-18	-3.10	-0.04
HUN	-0	-13	-2	-15	-3.30	-0.03
ZAF	-0	-9	-1	-10	-2.90	-0.06
SWE	-0	-8	-1	-9	-4.50	-0.03
IND	0	-7	-1	-8	-0.40	-0.01
CP-TPP (without USA)						
CAN	82	20	711	814	35.50	2.37
USA	-471	-109	-12	-593	-6.90	0.66
MEX	-7	-18	-67	-92	-3.70	0.20
KOR	-2	-32	-48	-81	-2.20	-0.05
JPN	1	145	-78	68	0.90	0.03
DEU	-0	-16	-21	-37	-0.70	-0.02
VNM	-22	0	0	-22	-15.30	3.32
THA	-0	-14	-2	-16	-1.80	-0.06
GBR	-0	-5	-6	-12	-0.70	-0.02
HUN	-0	-3	-3	-5	-1.20	-0.01
IND	0	-5	0	-5	-0.30	-0.01
ITA	-0	-1	-4	-4	-0.70	-0.01
FRA	0	-2	-1	-3	-0.20	-0.01
ZAF	0	-1	-2	-3	-0.80	-0.03
SWE	-0	-1	-2	-3	-1.30	-0.01

The RTA column includes TPP12 (including US) in top panel and excludes US in lower panel.